Corrosion Control/Coupon Study

Dennis Thurston
Russ Teders

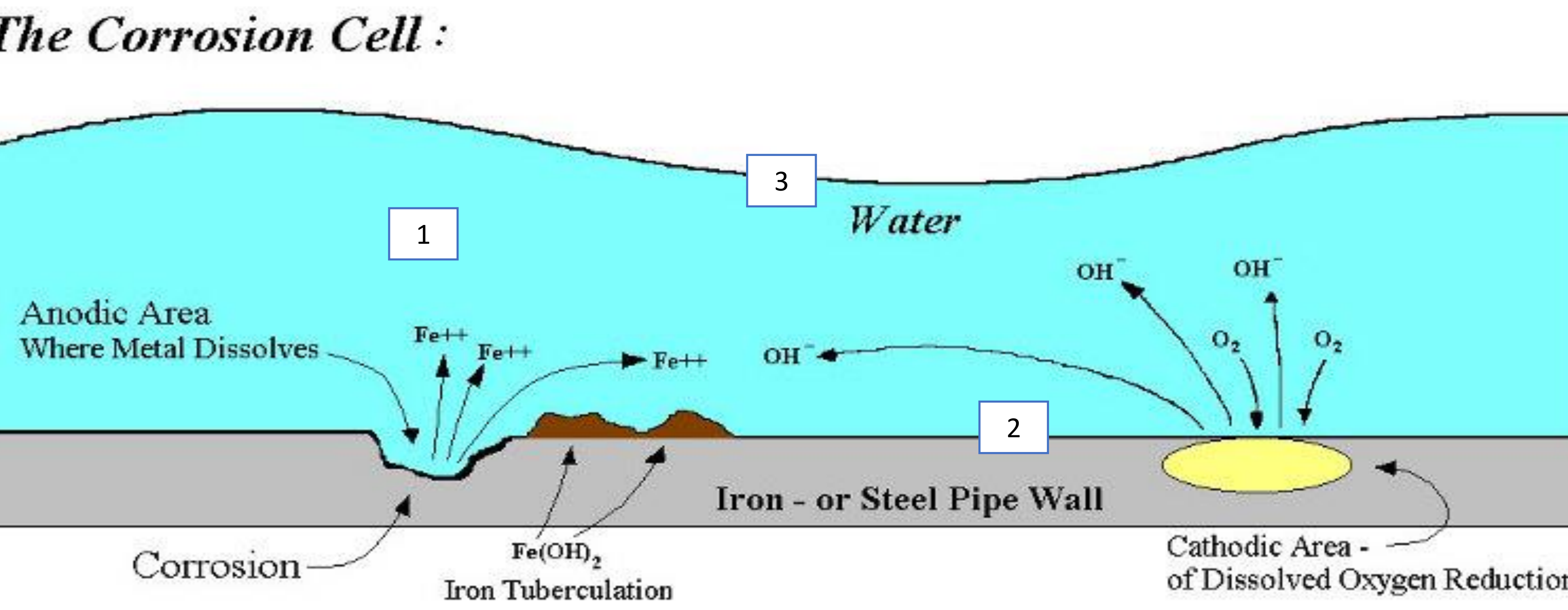
Corrosion Control …

Before

After

ELECTROCHEMICAL REACTION

3 PARTS REQUIRED FOR REACTION TO TAKE PLACE



If any of the steps of Corrosion can be prevented, the corrosion will stop

Corroding and Depositing

More on the Building Blocks

pH

- <7 – Acidic
- >7 – Basic
- High pH, less likely to corrode
- Can influence ORP and phosphate effectiveness

Alkalinity

- Capacity of Water to neutralize acid
- Mg/L as Calcium Carbonate
- High alkalinity waters tend to resist changes in pH
- Low alkalinity waters less resistant to pH changes

TDS

- High TDS – lots of ions
- More ions increase ability to complete circuit
- Low TDS can want to steal back ions

More on the Building Blocks

DIC

- Sum of all dissolved inorganic carbon species
- Similar to alkalinity
- DIC increases, so does buffer capacity
- When low 3-6 mg C/L pH adjustments help
- When over 30 mg C/L pH adjustments not effective

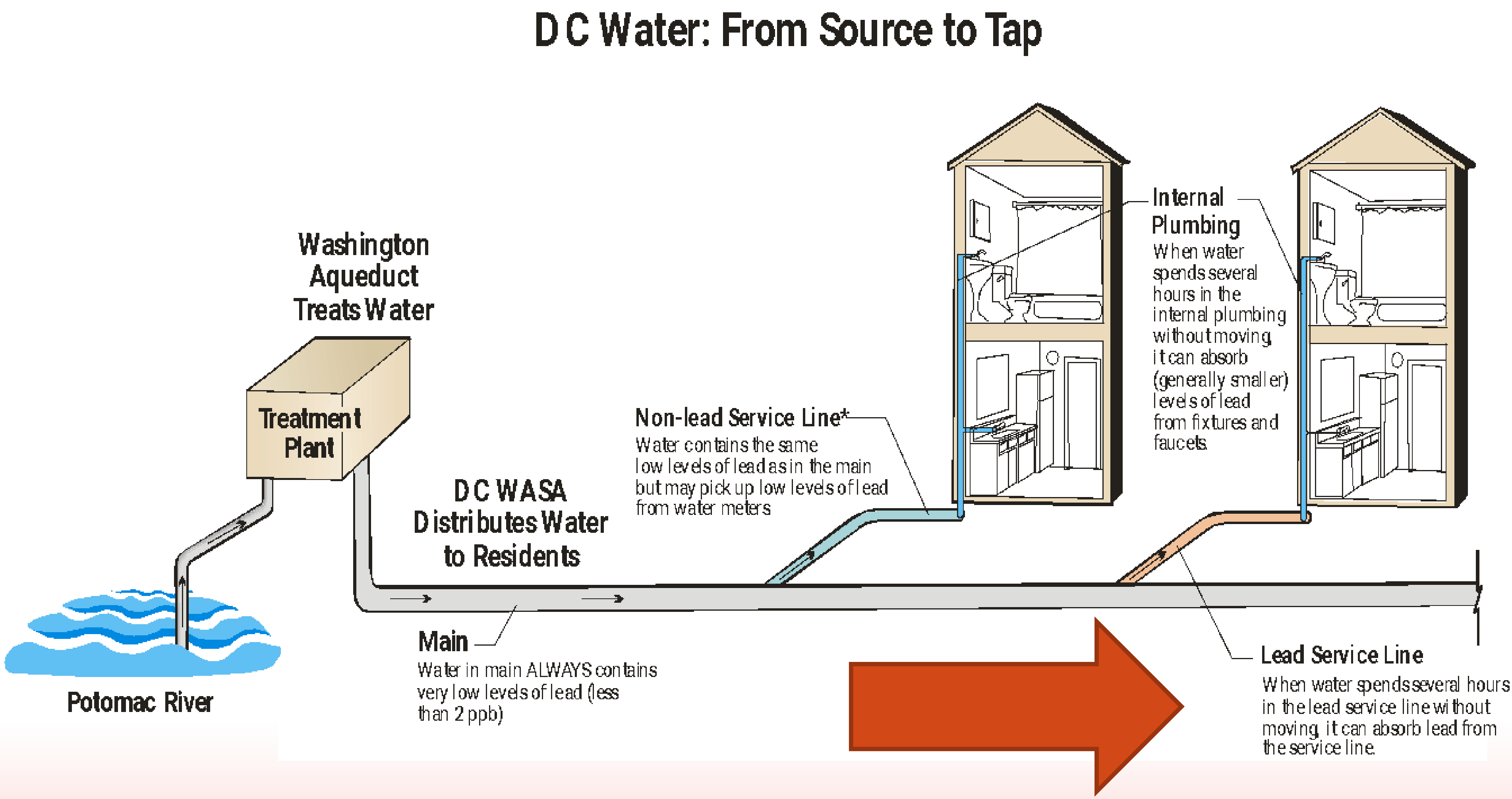
Hardness

- Dissolved calcium and magnesium
- Would like some Calcium Carbonate
- Usually not an issue in Midwest
- Can be if stripped out by process such softening or Reverse Osmosis

Buffer Intensity

- Measure of resistance of water to pH changes
- If low, can impacted by uncovered storage, corrosion, nitrification.

How does Lead Get Into Drinking Water?



*A small fraction of homes have brass service lines that can also contribute low levels of lead.

Role of Oxidants

Dissolved Oxygen

- Dissolved gas (CO_2) potential increase corrosion
- DO reacts with Fe^{2+} & converts to Fe^{3+}
- May also increase pipe tubercle and copper pitting
- Adding Chlorine may increase copper corrosion

Oxidant Type

- Chlorine is shown to increase and decrease corrosion in soft waters
- Chlorine is a strong oxidant makes lead lose 4 electrons instead of 2
- Forms insoluble compound that protects pipe

Role of ORP

- Drinking water ranges 400mV to 600 mV
- Low ORP weakens existing scale
- Switch from Chlorine to chloramine may reduce ORP

Ohio Environmental Protection Agency

- Corrosion Control Treatment Recommendation Form

1. Review present water quality.

1. Review water treatment options.

1. Project future water quality.

Directions for Making Treatment Determinations

Step 1

- Examine Lead and Copper Data
- pH >7.8 and Alkalinities between 30 -100 $CaCO_3$/L usually not corrosive
- $CaCO_3$/L > 100 frequently high copper

Step 2

- Collect background chemistry data
- See building blocks
- **Check for radon and arsenic as their removal strategies may impact corrosion control programs**

Step 3

- Look up DIC
- Evaluate treatment options
- Evaluate your current treatment to optimize cost and effectiveness
- Make changes when possible

Decision Tree –Over Lead & Copper

pH <

No

Go to next

Orthophosphate addition with pH adjustment

<5 Mg C/L

Mg C/L

>15 Mg C/L

Raise pH in 0.5 & DIC
<u>To 5-10 mg C/L using</u>

- Soda Ash
- Potash
- Caustic & Sodium Bicarbonate
- Limestone

<u>Raise pH in 0.5</u>

- Soda Ash
- Potash
- Caustic
- Aeration

<u>Raise pH in 0.25</u>

- Aeration
- Caustic
- Soda Ash
- Potash

Decision Tree –Over Lead Only

Very Little Difference

pH <

No

Go to next

Orthophosphate addition with pH adjustment

<5 Mg C/L

5-12 Mg C/L

>12 Mg C/L

Raise pH in 0.5 & DIC
To 5-10 mg C/L using

- Soda Ash
- Potash
- Caustic & Sodium Bicarbonate
- Limestone

Raise pH in 0.5

- Soda Ash
- Potash
- Caustic
- Aeration

Raise pH in 0.25

- Aeration
- Caustic
- Soda Ash
- Potash

Decision Tree – Over Copper Only

Is pH

No

Orthophosphate addition with pH adjustment

DIC?

< 5

Raise DIC
To 5-10 mg C/L using
- Soda Ash
- Potash
- Caustic & Sodium Bicarbonate
- limestone

5-12

Raise pH in 0.5
- Soda ash
- Potash
- Caustic
- Aeration

13-35

Raise pH in .3
1. Aeration
2. Caustic
3. Potassium Hydroxide

>35

Raise pH to 7.2-7.8
- Use Aeration and Orthophosphate
Or
- Blended Phosphate

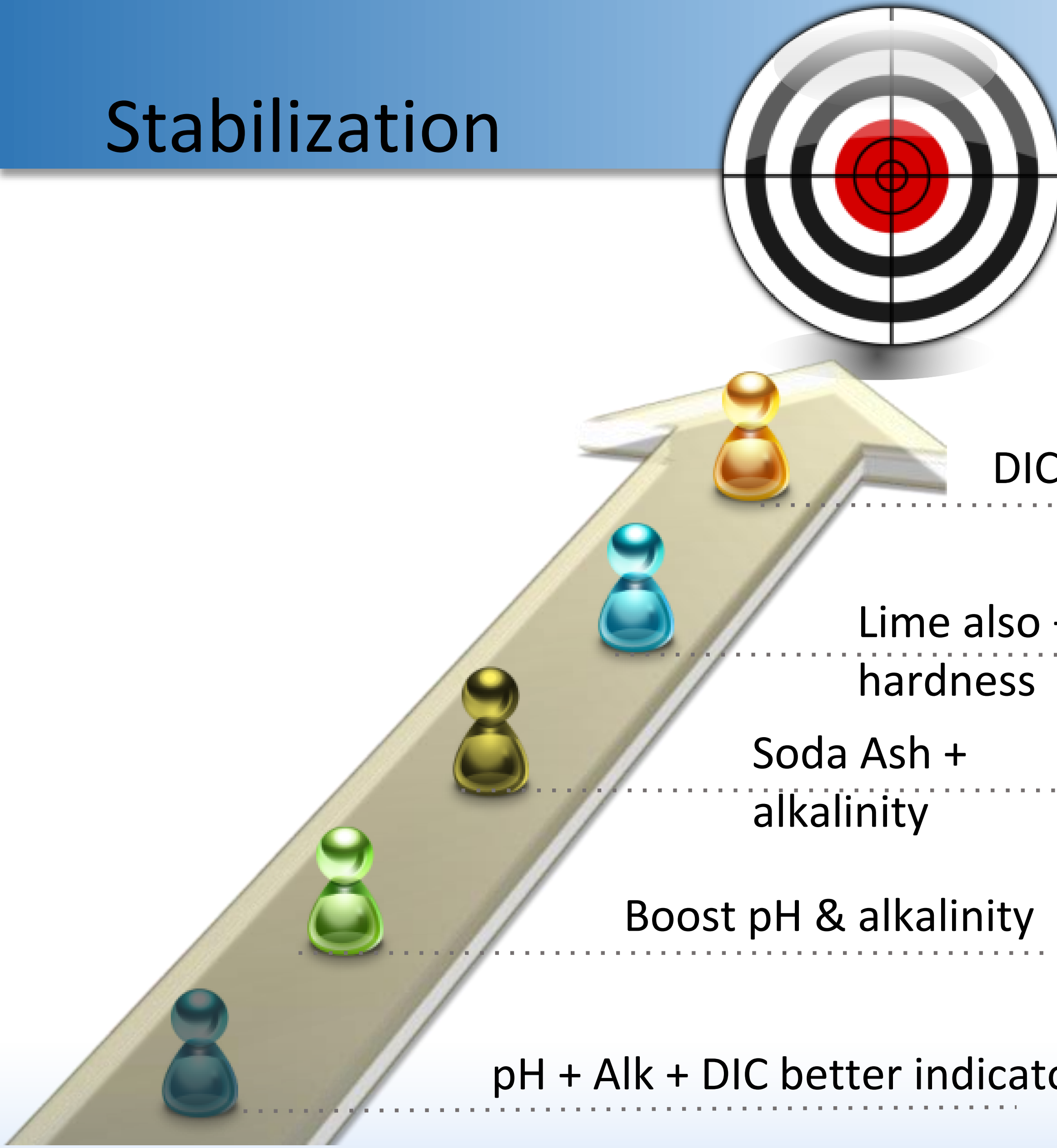
Make your choice

Option 1
Do Nothing – Manage best you can

Option 2
Add pH control

Option 3
Add Phosphate

Stabilization



CORROSION CONTROL MECHANISM

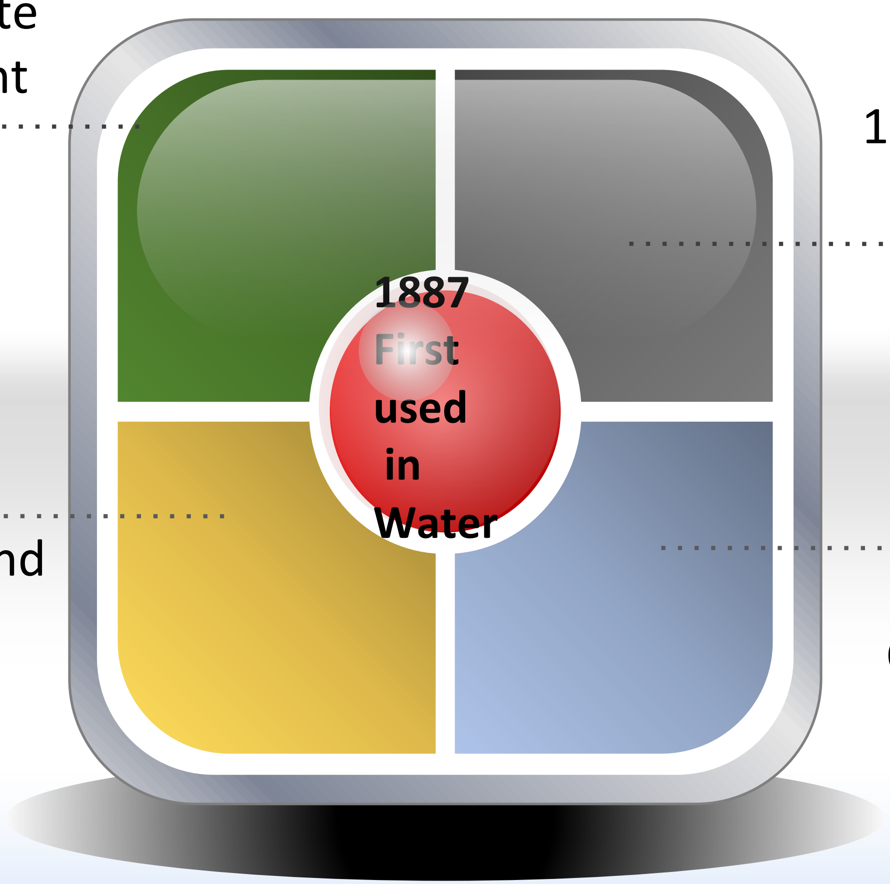
“Barrier Protection”

How do Phosphates work?

Phosphates - How Proven are they?

1930's – Hexametaphosphate threshold treatment

1960's – Blended Phosphates



1990's – Lead and Copper Rules

1970's – Zinc Orthophosphates

What is the Role of Phosphate in Drinking Water?

Corrosion Control

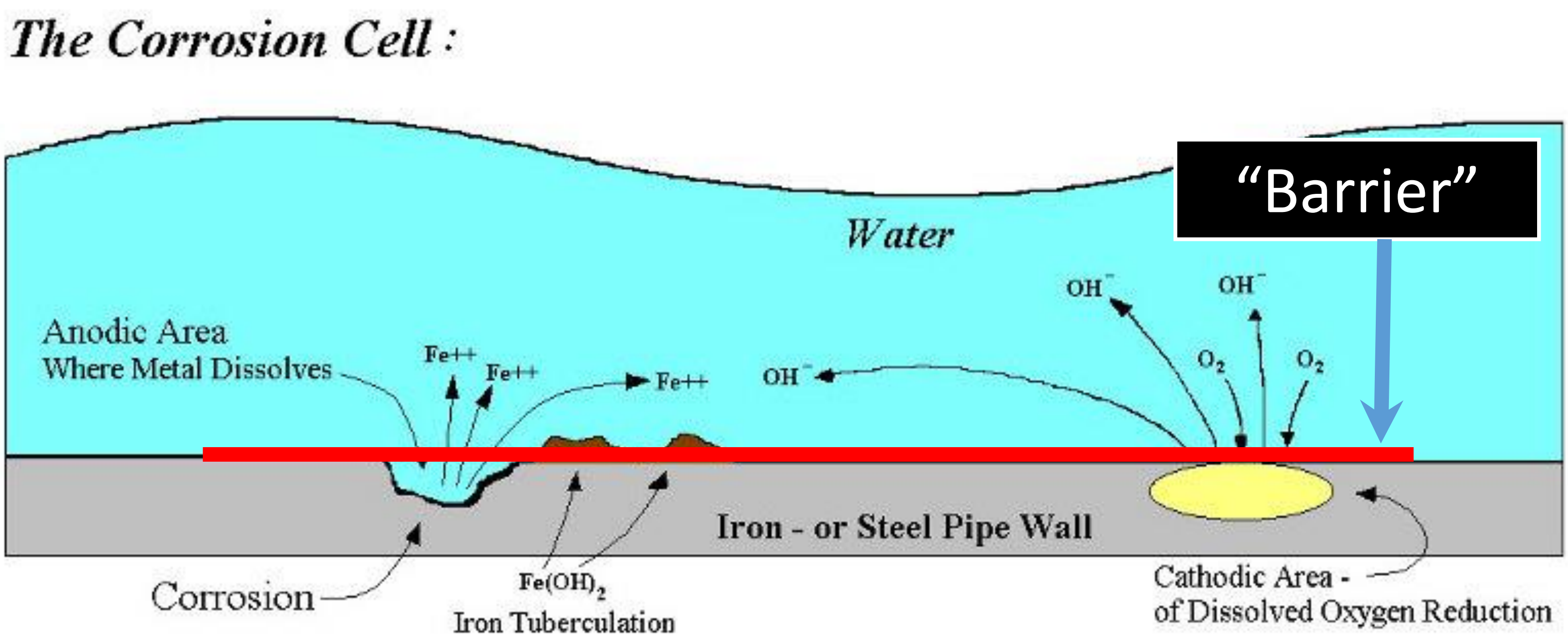
- Combine with Calcium Hardness
- Form a Barrier
- Prevent Corrosion
  - Lead
  - Copper
  - Steel

Sequester

- Secondary Standards
  - Iron > .3 mg/l
  - Manganese >.05 mg/l
- No Filter Plant
- Breakthrough in Filter

OFTEN - Both

What Happens when a Phosphate is Added?



A "Coating" is laid down to shut down the process. Some phosphates are better at Anodic Corrosion and others better at Cathodic

Good Scale vs Bad

Calcium Carbonate scale rarely form on lead and copper (New in OCCT)

Phosphate scale good with proper pH and hardness

If feed Alum, may interfere with strong scale

Keys for a good Barrier

pH

Best between 7 to 8 range

Hardness

Calcium (CaCO3)Hardness Key – Usually 70% / 30% magnesium – not always

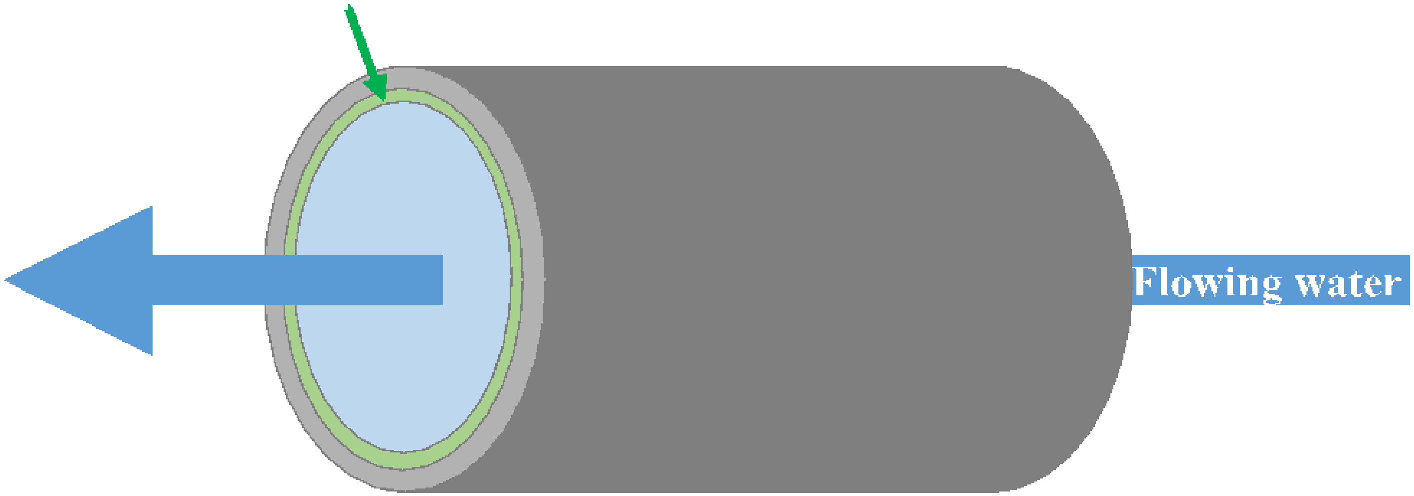
Clean up?

Is there Iron that needs tied up too?

What's Your Target

Copper, Steel, Lead?

Formation of scale within the distribution system



3

Anodic and Cathodic protection

Anodic "Phosphate"

- Corrosive "situation" occurs
- Ferrous Iron begins its transformation
- Phosphate "Blocks" Fe from leaching into water
- Corrosion stopped

Cathodic "Phosphate"

- Corrosive "situation" occurs
- Oxygen tries to penetrate into pipe wall
- Phosphate "Blocks" Oxygen from getting to pipe to continue the corrosion process

How do I choose Blend?

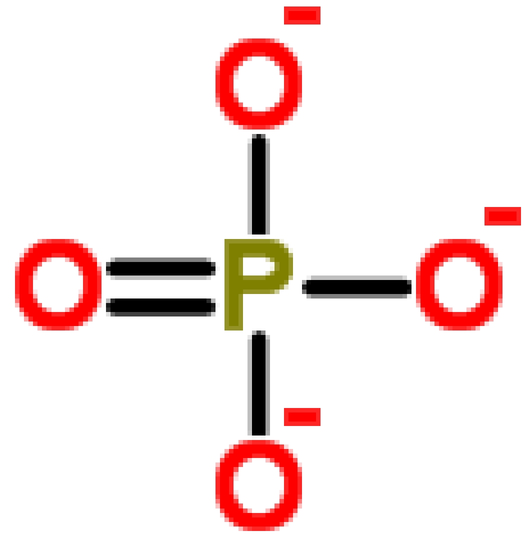
- Are you Groundwater or Surface Water?
- Primary need for phosphate?
  - Corrosion?
    - Copper, Steel, or Lead?
  - Sequester?
    - Iron – Manganese?
- Which ranks higher?
- Do you have filter plant?
- Water Characteristics?

Ortho Phosphate – Anodic Inhibitor

Does Not Sequester

pH and calcium Hardness important, DIC / Alkalinity

Good for Lead with proper pH



Phosphoric Acid

Monosodium Phosphate

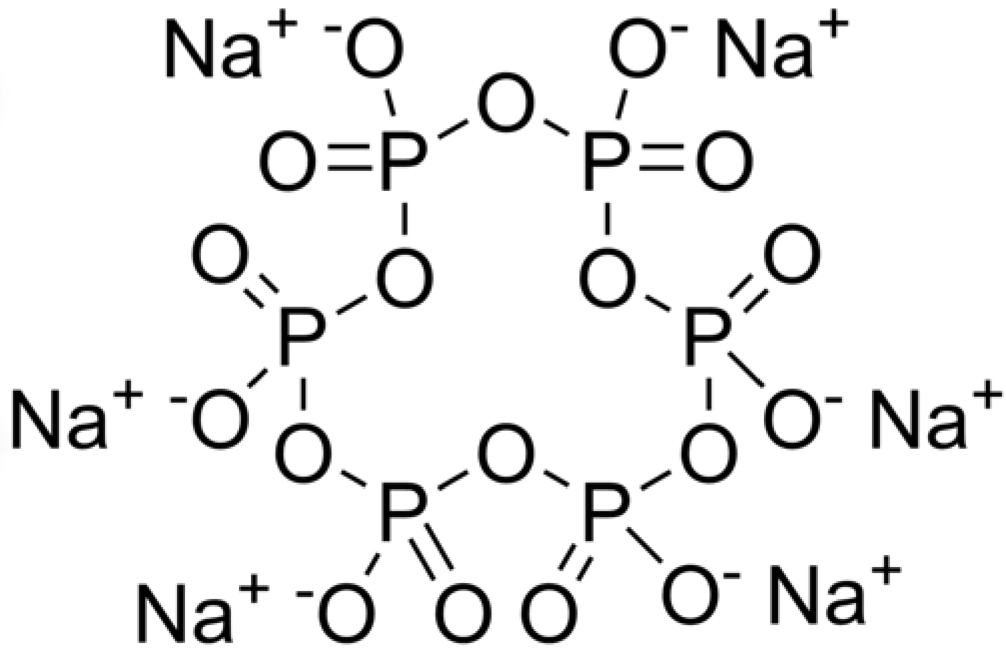
Di Potassium Phosphate

Blended Phosphate – Anodic (& Cathodic) Inhibitor

Does Sequester Iron, Manganese, & Calcium

Good Corrosion control, depending on ortho

Removes scales and improve chlorine residuals



ortho | SHMP | STPP | SAPP | TKPP

Other Factors to Consider

- Injection point of phosphate in relation to chlorine
- Phosphate testing –run an ortho test
- Dosing –
  - Factors change over time
- Aeration and Filtration
- Lower pH and higher temperature will cause faster reversion

Ortho – Poly Blends

- Provide Sequestering and Corrosion Control
- Effective over a broad ph range
- Good Copper control in high hardness waters
- Modest galvanic control

Issues with Feeding Phosphates?

Can feed too much

- Polyphosphate can scour lines

Can feed too little

- Breakthrough of discoloration
- Weak scale formed

Too much chlorine can breakdown phosphate

How Do You Measure Success?

Sequestering Application

- ”Cleaner” Water
- Better Flushes
- No breakdown of Phosphate
  - No increase in ortho reading

Corrosion Application

- Better Coupon results
- Better Flushes
- Few line breaks
- Fewer pinhole copper leaks
- Compliance with lead and copper

Corrosion Coupon Study

- **University of Washington Coupon Study Guidelines**
  - **90 day time period**
  - **Steel, Copper, Lead, and Deposition Coupons**
  - **1 to 1.5 gallons per minute continuous flow**

Corrosion Coupon Rack

Corrosion Coupon Information

Coupon Calculations

Weight loss in grams x K-factor
Metal Density x Metal Area in Square inches x Time in hours
Equals Mils per Year Reading

Copper K-factor 534810, Lead K-factor 551041,
Mild Steel K-factor 535298
Copper density 8.89 Lead density 11.35 Steel density 7.87
Copper Surface Area One hole coupon 3.382
Copper Surface Area Two hole coupon 3.24
Lead Surface Area 3.4130
Steel Surface Area 3.3833
Flow rate for coupon rack
2 gallon per minutes/7.48 = 0.27 cubic feet per minute/60 =
0.0045 feet per sec
0.083 x 0.75 = 0.0625
0.0625 x 0.785 x 0.0625 = 0.003
0.0045/0.003= 1.5 ft per sec

Corrosion Coupon Information Cont.

Corrosion Rate Scale

Mild Steel C1010

0.0 to 2.0 Mils per Year Minimal
Corrosion
2.0 to 5.0 mils per year Mild corrosion
5.0 to 10.0 Mils per year Moderate
Corrosion
Greater that 10 Mils per year Severe Corrosion

Copper CDA110/ Lead

0.0 to 0.2 Mils per year Minimal
Corrosion
0.2 to 0.5 Mils per year Mild Corrosion
0.5 to 1.0 Mils per year Moderate
Corrosion
Greater that 1.0 Severe
Corrosion

Actual Coupons

Before Program

After Program

Coupon progression after program starts

Corrosion rates are always changing

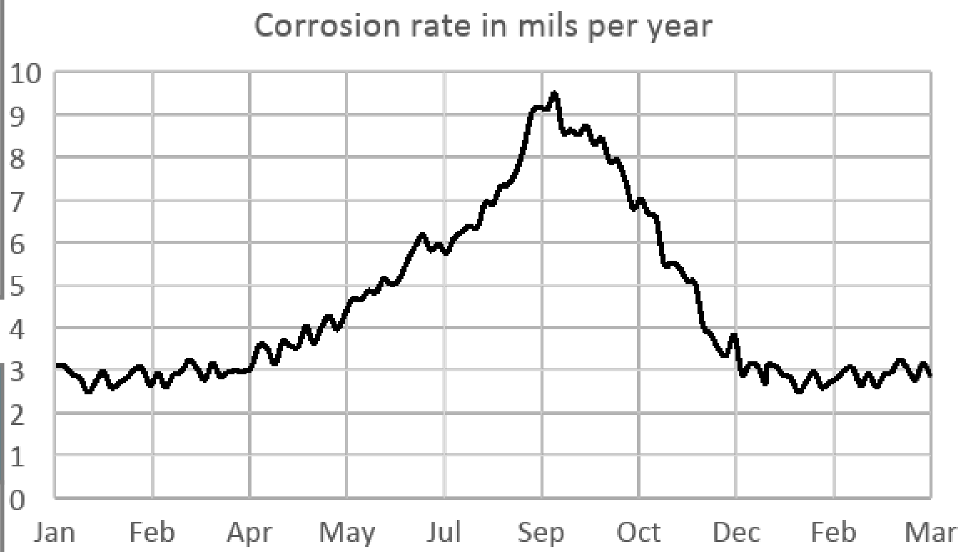
Factors influencing corrosion

- Water qualtity changes
- Temperature
- pH-values
- Dissolved oxygen
- Blends of finished water

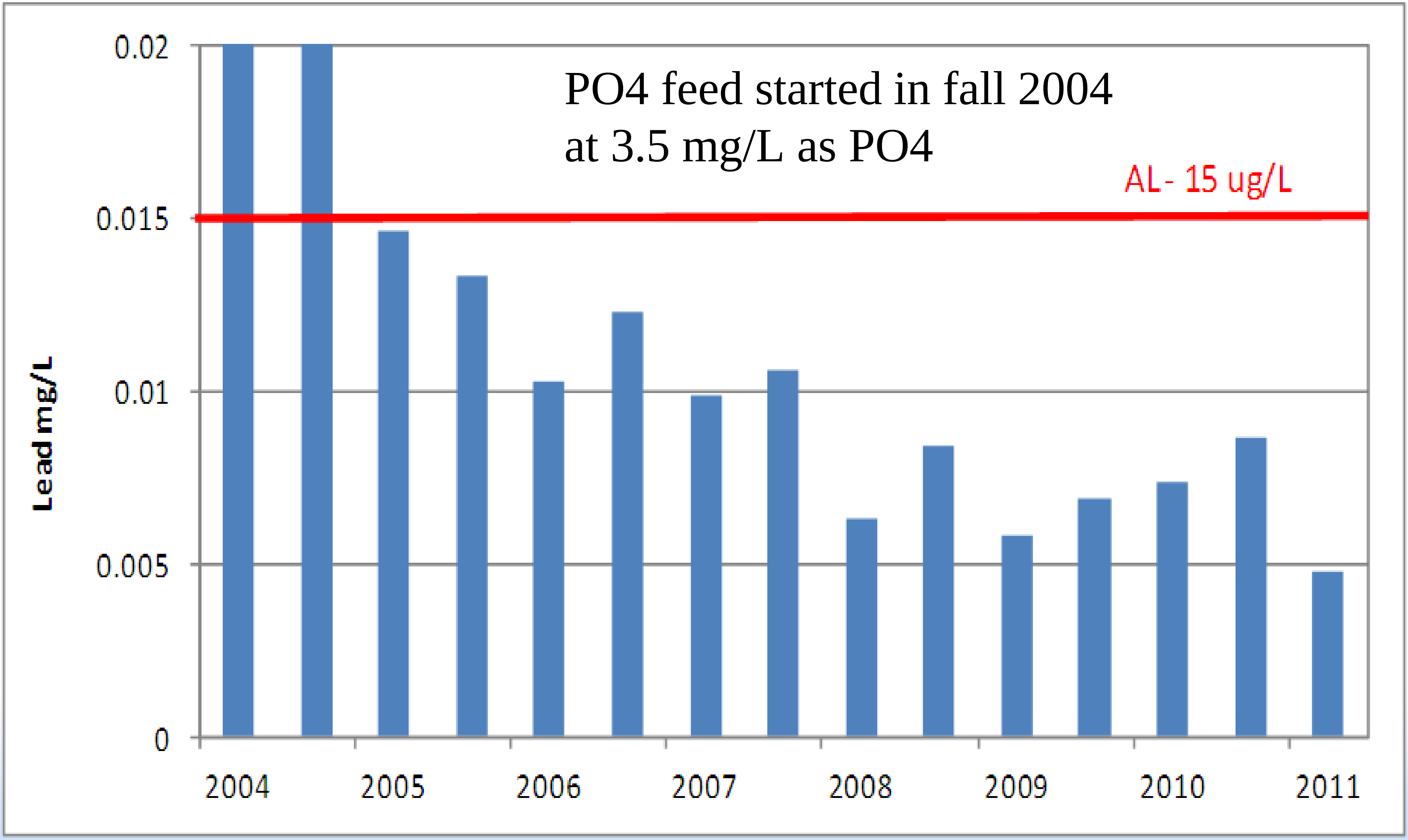
Conclusion

- Need for instant monitoring
- Adjustment of corrosion control

Corrosion rate of a Southeastern US surface water system:

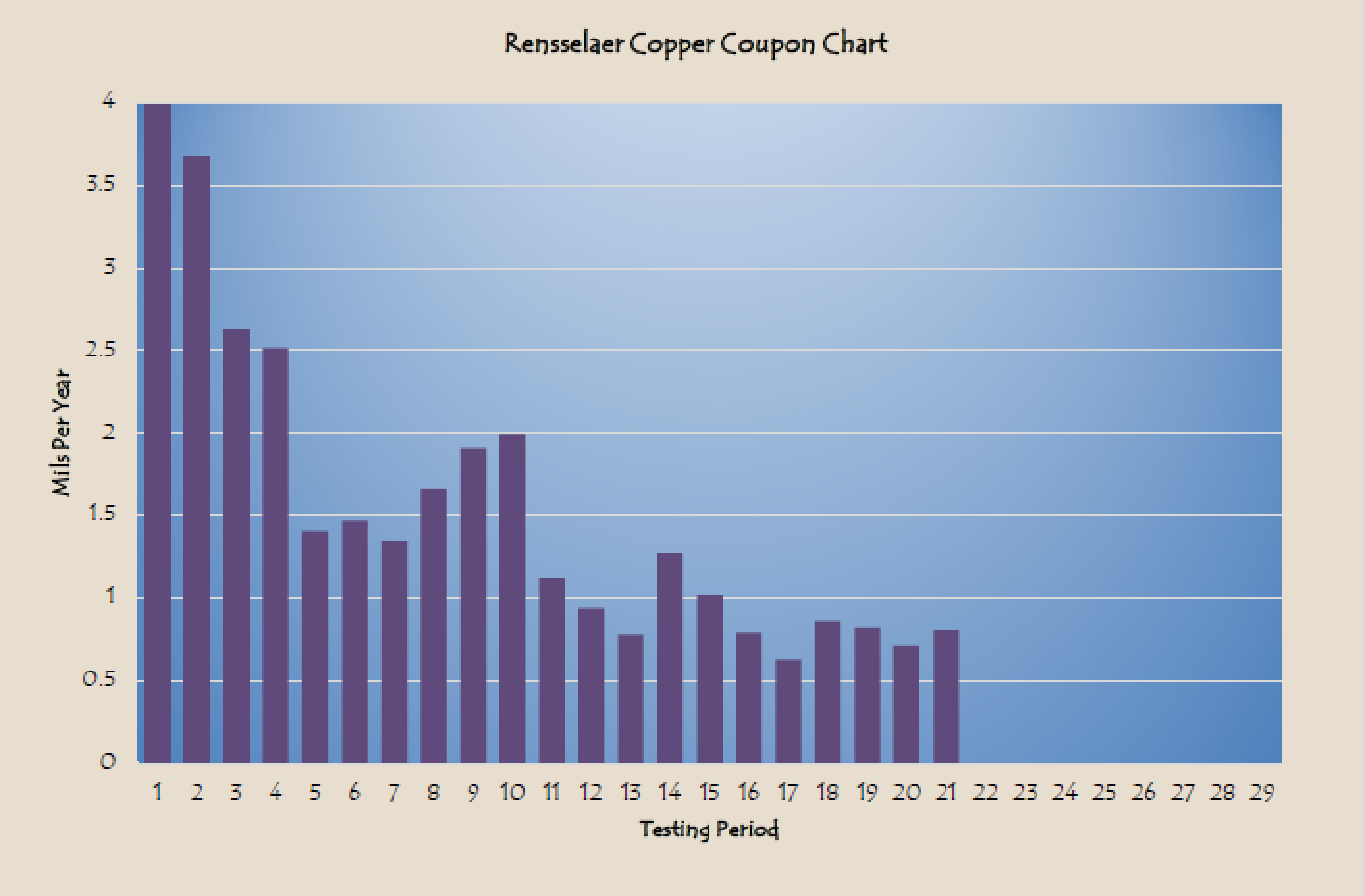


LCR Lead Compliance Data

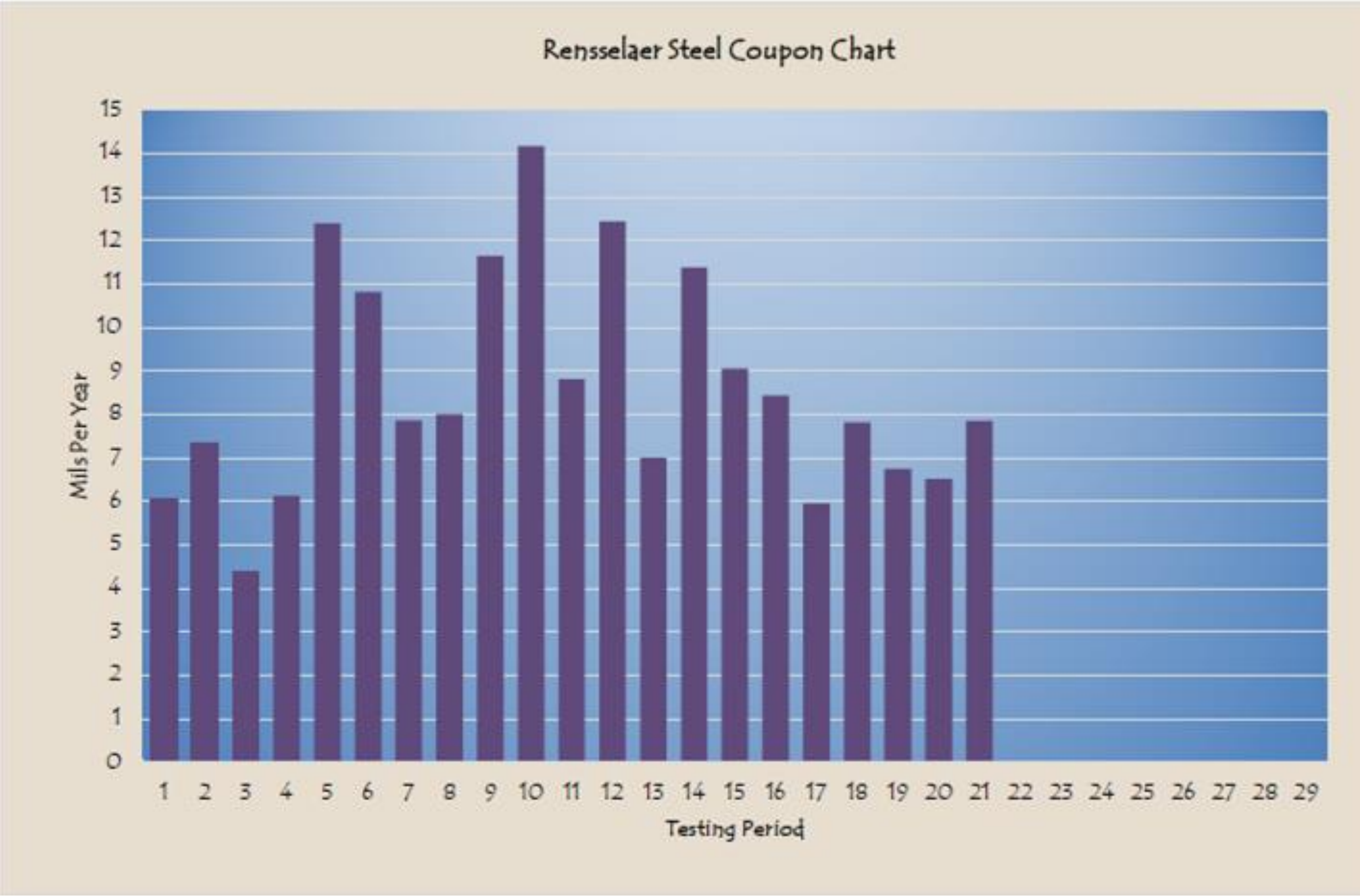


Coupon Serial No.	Date Installed	Date Removed	Original Weight (g)	Final Weight (g)		Exposure	Weight Loss (g)	Exposure (hours)		Mils per Year		
A 77694	29-Aug-12	17-Oct-12	11.820	11.409		49 days	0.411	1176		7.04		
A 77695	29-Aug-12	17-Oct-12	11.660	12.257		49 days	-0.597	1176		-10.23		
A 82201	17-Oct-12	15-Nov-12	10.980	10.274		29 days	0.706	696		20.44		
A 82200	17-Oct-12	8-Jan-13	11.047	9.650		83 days	1.397	1992				14.13
A 82203	15-Nov-12	8-Jan-13	11.035	10.965		54 days	0.07	1296			1.09	
A 82206	8-Jan-13	1-Apr-13	11.111	10.844		83 days	0.267	1992				2.70
A 82207	8-Jan-13	1-Apr-13	11.036	10.679		83 days	0.357	1992				3.61
A82211	1-Apr-13	17-Jun-13	11.008	10.798		77 days	0.21	1848				2.29
A82210	1-Apr-13	17-Jun-13	10.767	10.705		77 days	0.062	1848				0.68

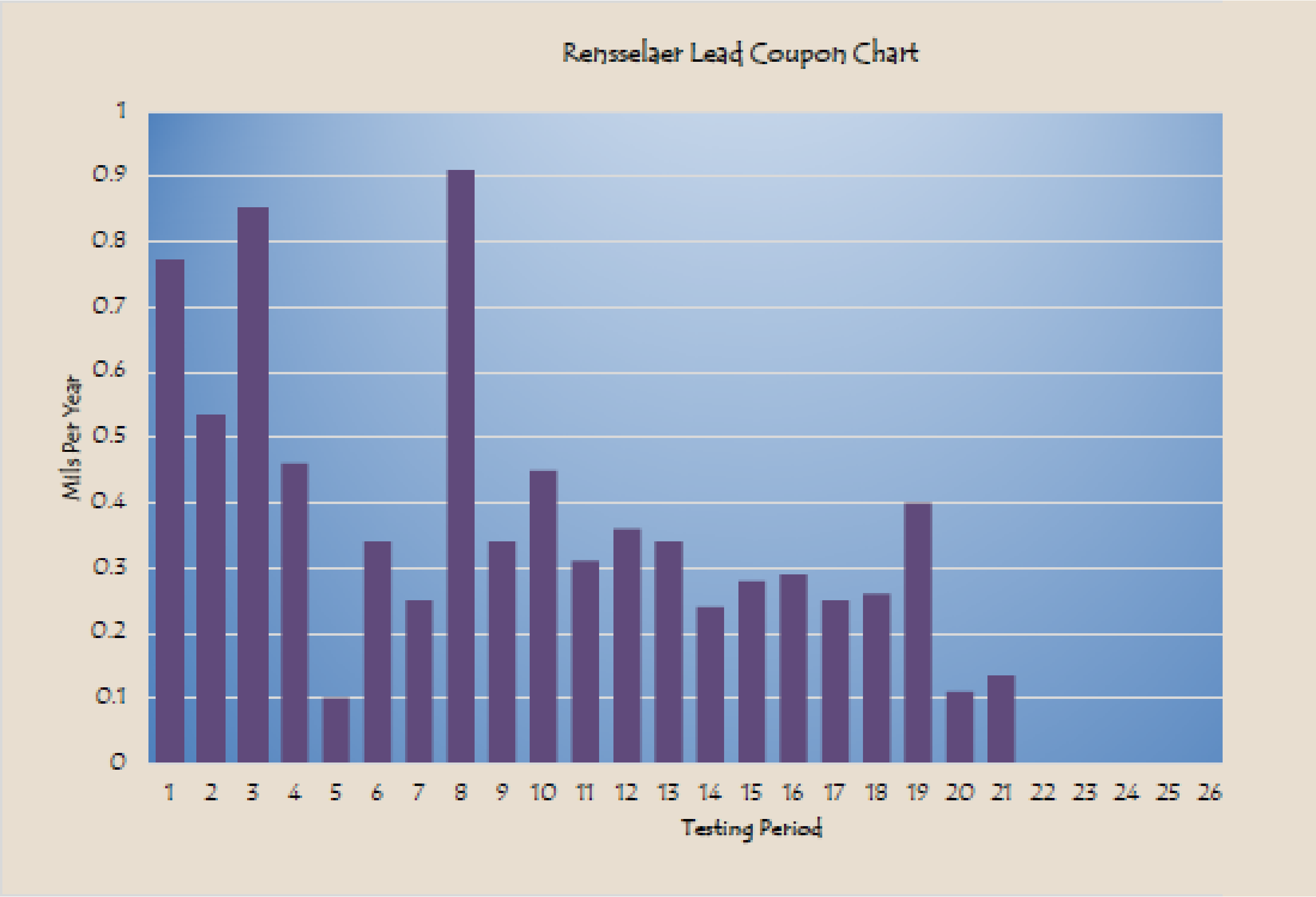
Copper Coupon Information



Steel Coupon Information



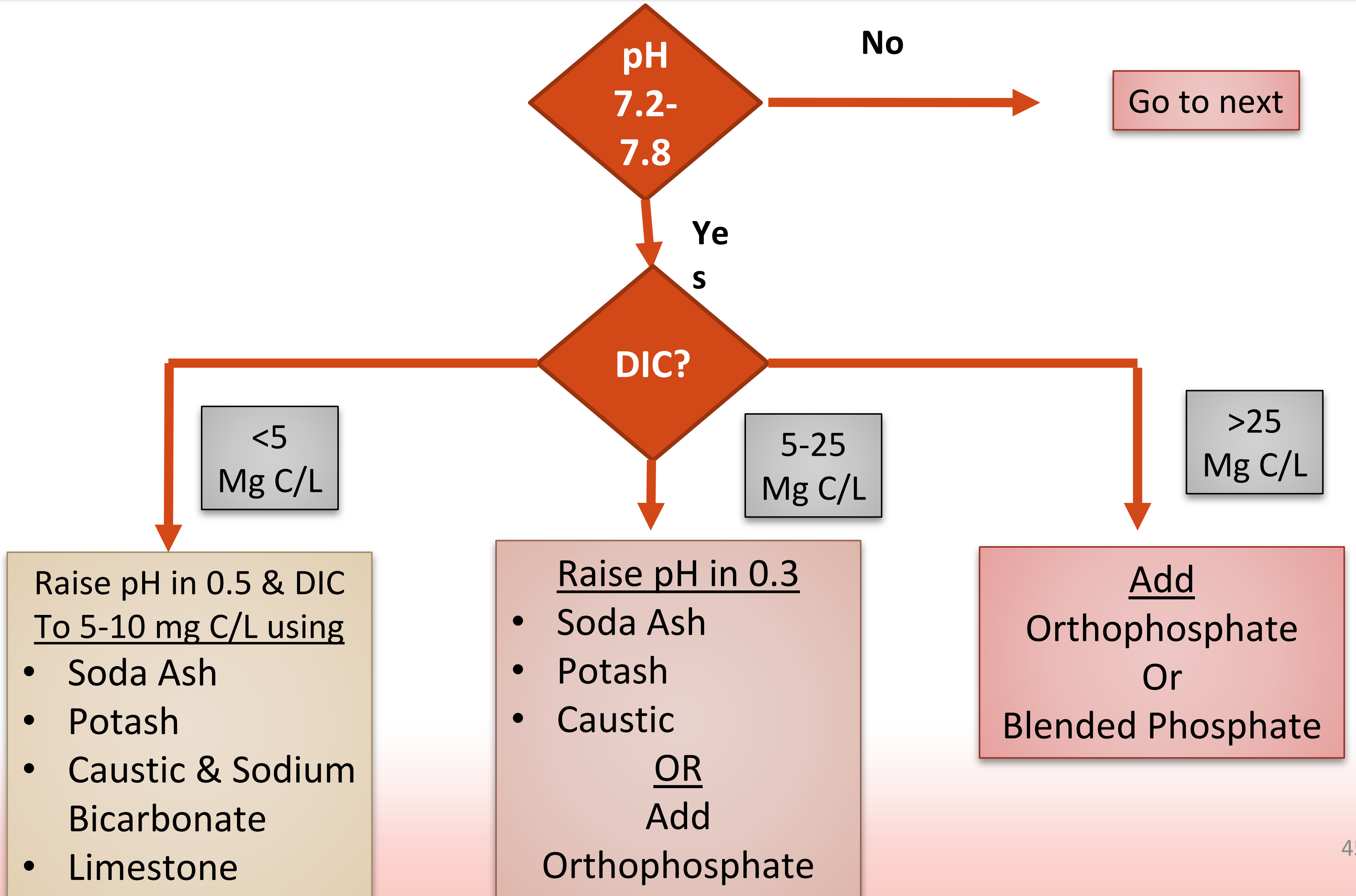
Lead Coupon Information



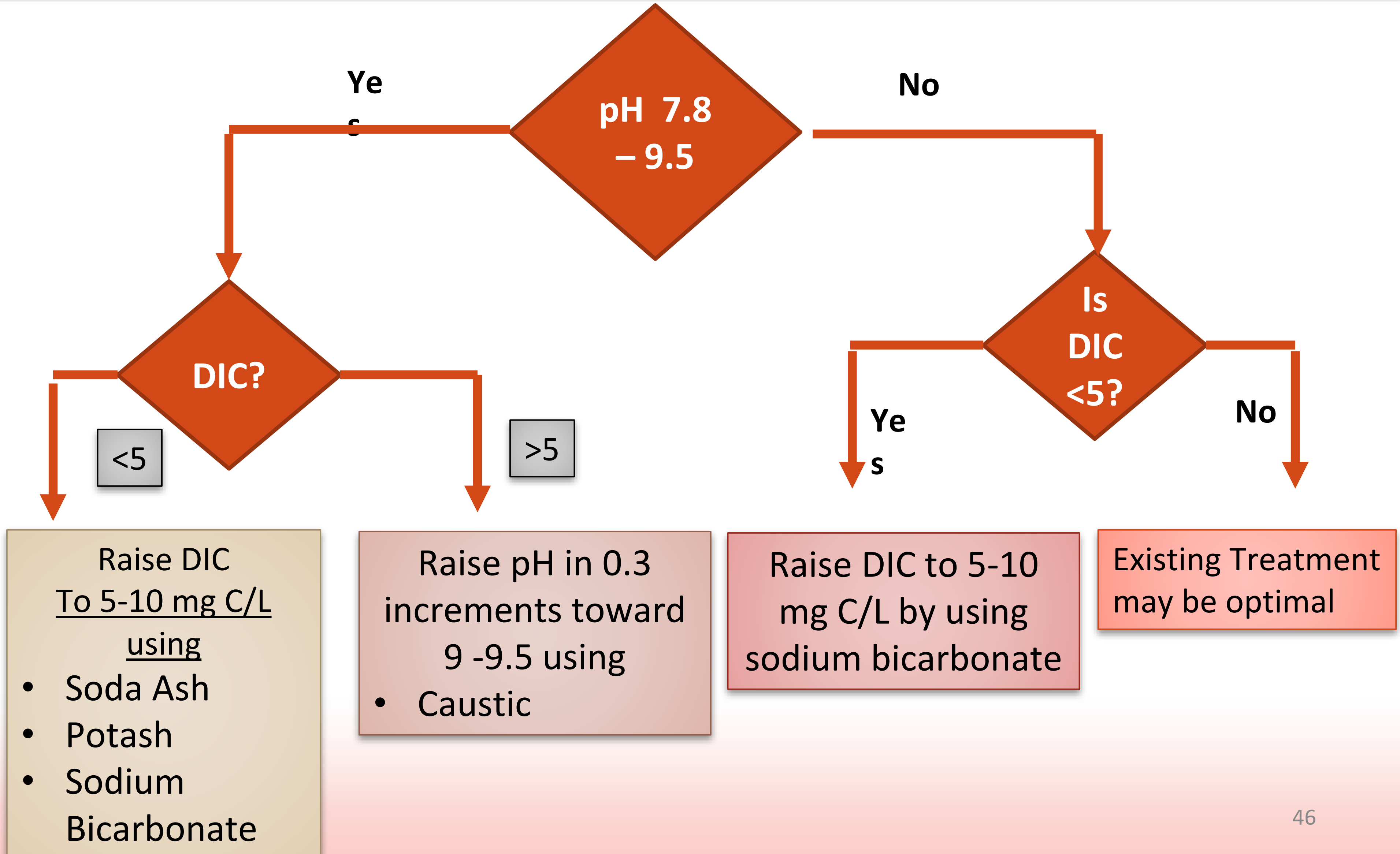
Lead and Copper exceed recommended limits – What Next?

- Implement an approved program.
- Alter the parameters that are approved.

Decision Tree – Over Lead & Copper



Decision Tree – Over Lead & Copper



Pipe Rig Loop

1. The disadvantage of coupon rack it uses finished water as it flows out to distribution system.
2. EPA is recommending a Pipe Rig Loop using finished water through piping from your system that you alter with your purposed treatment prior to pumping into your distribution system.

All Done – Questions?

Dennis Thurston (765)-967-0355
emddennis@frontier.com
Russ Teders (419)-615-3441
rteders@getwsu.com