Distribution Reservoir Management: Evaluating & Maintaining Water Quality in Reservoirs & Tanks

Cheryl Capron
Seattle Public Utilities

PNWS-AWWA Conference
May 2013

Resources

Recommended Standards For Water Works (10 States Standards)

- Great Lakes – Upper Mississippi River Board of State & Provincial Public Health & Environmental Managers
- Chapter 7, Finished Water Storage

Ten States Standards – Chapter 7

- Protection from contamination & trespassers
- Drains
- Stored water age
- Overflow
- Access
- Vents
- Silt Stops

WDOH On-line Resources

- Washington Water System Design Manual
  - Chapter 9, Reservoir Design & Volume
    - Section 9.6, Reservoir Appurtenant Design
- Sanitary Protection of Reservoirs

- http://www.doh.wa.gov/CommunityandEnvironment/DrinkingWater/WaterSystemDesignandPlanning/SystemDesign.aspx

Water System Design

The Water System Design Manual (PDF, DOH 331-123) - A 319-page guidance document is a start-to-finish reference for engineers and others involved in water system design. It covers the design, review and approval of sources, storage reservoirs, booster pump stations, and water treatment facilities, and other aspects of designing water systems.

How to Hire an Engineer (PDF, DOH 311-044) - A 4-page brochure with information for small public water systems on how to hire an engineer when improvements are needed.

Slow Sand Filtration and Diatomaceous Earth Filtration for Small Water Systems (PDF, DOH 331-204) - A 119 page guidance document intended to provide useful information regarding the application, design, and operation of slow sand and diatomaceous earth filtration facilities to the owners, operators, and designers of small water systems that must meet requirements of the surface water treatment rule.

Sanitary Protection of Reservoirs - Hatches (PDF, DOH 331-249) - A one-page illustrated guide with tips for small water system operators on how to deal with storage reservoir hatches.

Sanitary Protection of Reservoirs - Vents (PDF, DOH 331-250) - A one-page illustrated guide with tips for small water system operators on how to deal with storage reservoir vents.

Simple Fixes for Wellhead Openings (PDF, DOH 331-232) - A one-page illustrated guide to fixing common problems that small drinking water systems encounter in protecting wellheads from contamination

Oregon & Idaho

- Idaho incorporates 10 States Standards as a reference
- Oregon Construction Standards
  - OAR 333-061-0050 (6) Finished Water Storage
    - http://public.health.oregon.gov/HealthyEnvironments/DrinkingWater/Rules/Documents/61-0050.pdf
- Your regulators

Looking For Trouble

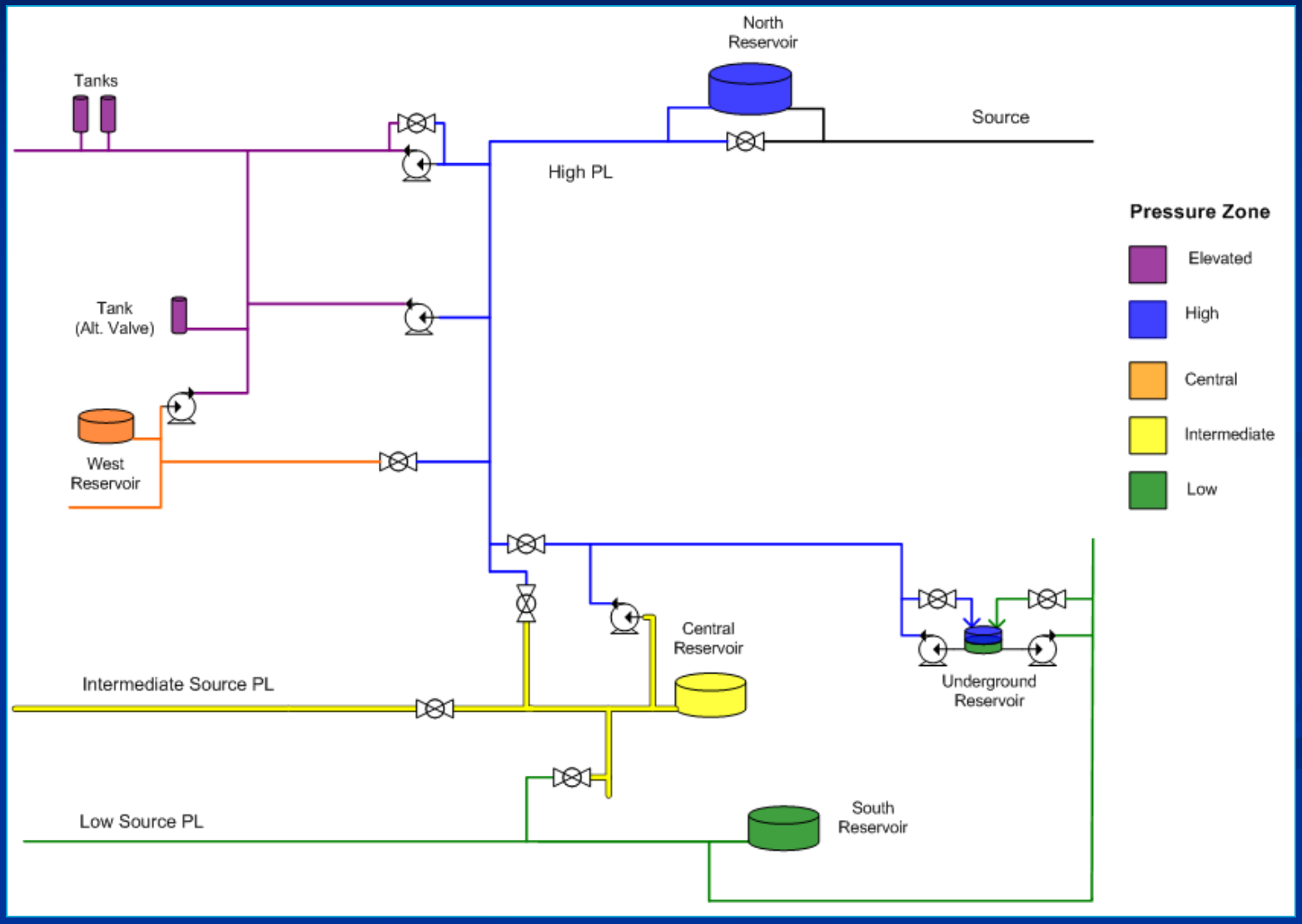
Assess Potential for Problems

- Does the reservoir have a common inlet/outlet?
- Does it have an internal circulation system?
- How old is it?
- Does it meet the current Ten States Standards?

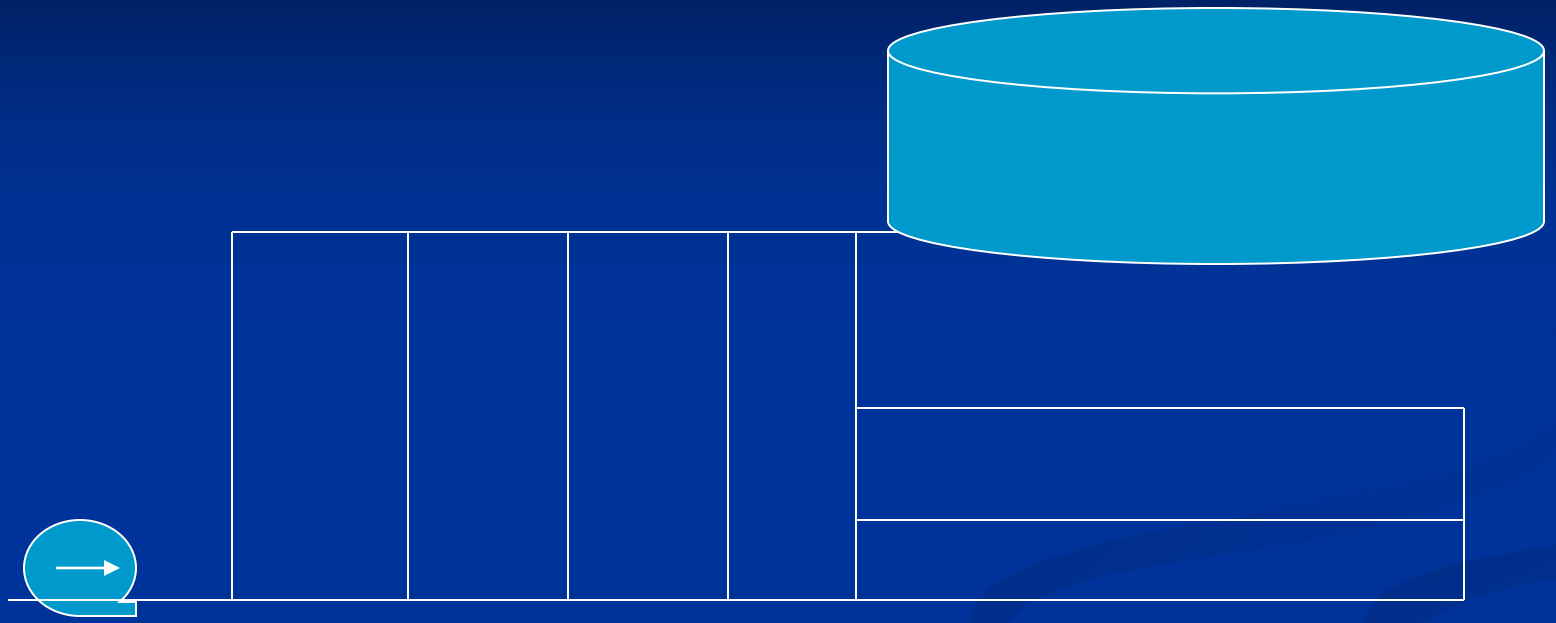
Assess Potential for Problems

- Where is this tank in relation to its source? To its service area?
- What is the hydraulic relationship to other tanks in the zone?
- Is this tank filled by gravity or pumping?
- Is there an altitude valve? How is it used?

Hydraulic Relationships

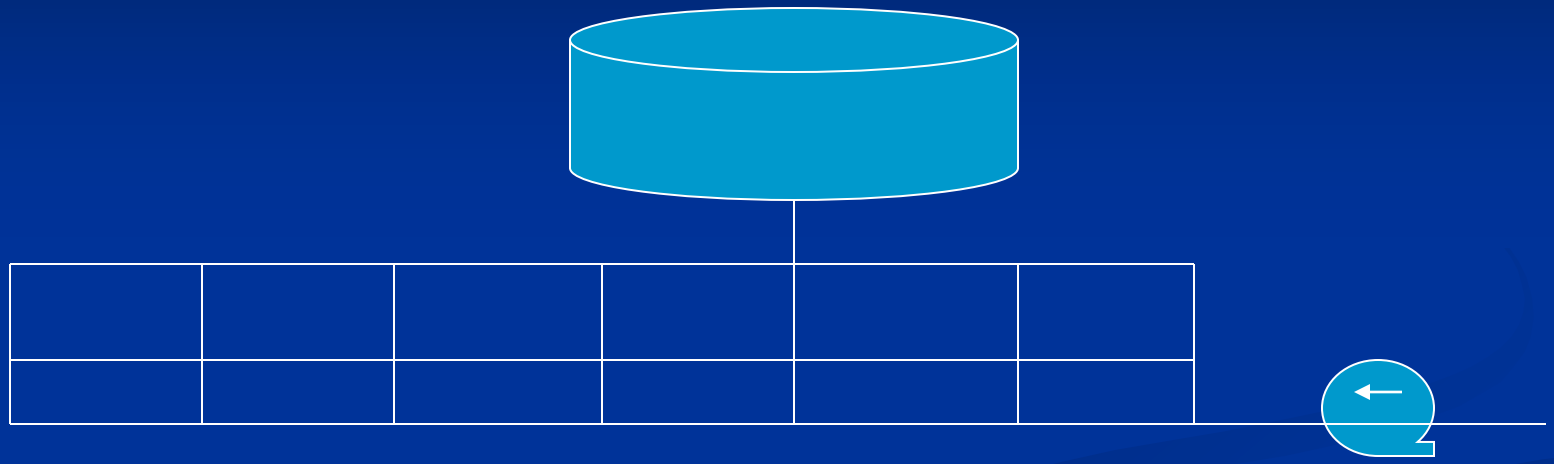


Poor Turnover



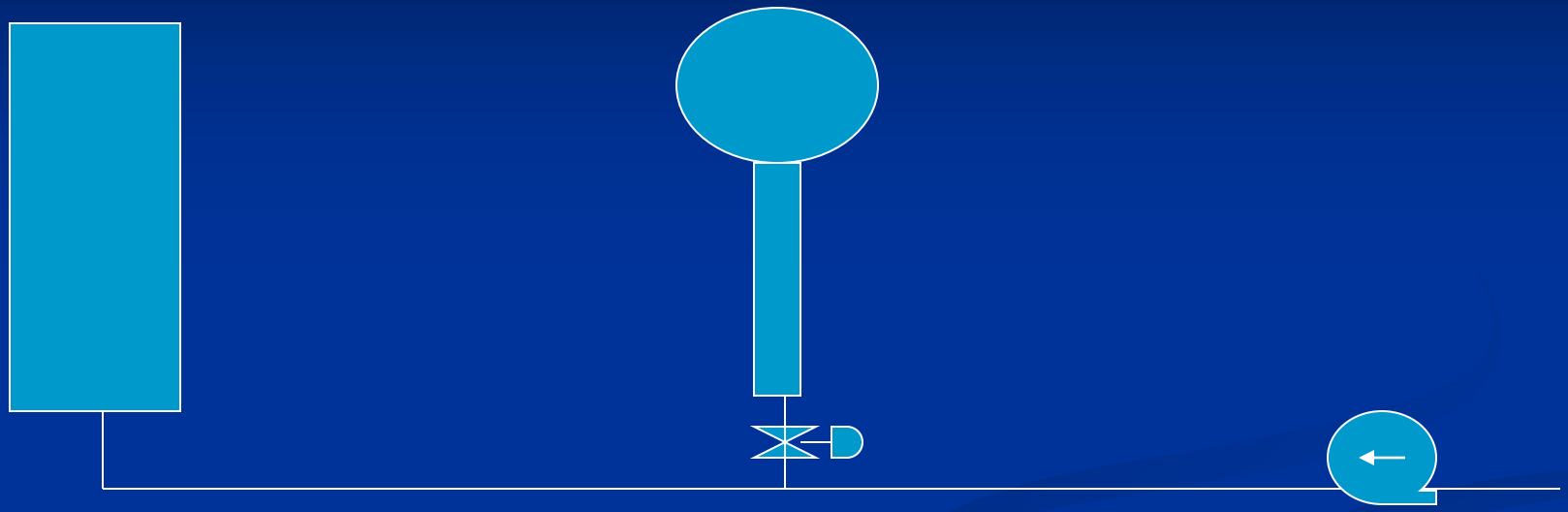
- Too much storage, at far end of zone from pump
- Most of the pump discharge goes directly to zone
- Drawdown is back towards pump; the same slug of water can flow back & forth into the reservoir

Good Turnover



- Storage in center of pressure zone
- Most of pump discharge goes directly to reservoir
- Most of draw-down goes to zone away from pump

Hydraulic Relationships



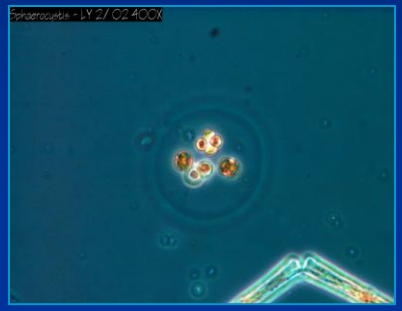
Two tanks in the zone, with an altitude valve on the tank closest to the pump station. The tank with altitude valve turns over less often, because the valve stays closed until the other tank fills and the pump shuts off.

Circulation and Turnover

- How low can you go? How often?
  - The lower you can draw down, the faster you can turn it over
    - Minimum pressure & emergency storage requirements
    - Freezing weather cycles may be different
  - Optimizing pump and energy use could mean longer run-times & less turnover in the tank, because the pump, not the tank, meets the demand

Water Characteristics

- What's in your water?
  I have:
  - Unfiltered surface water
    - Algae & critters
  - Higher DBPs in areas downstream of floating-covered reservoirs



Sphaerocystis

Daphnia

Water Characteristics

- Sediments from unlined cast iron pipe settle out in storage

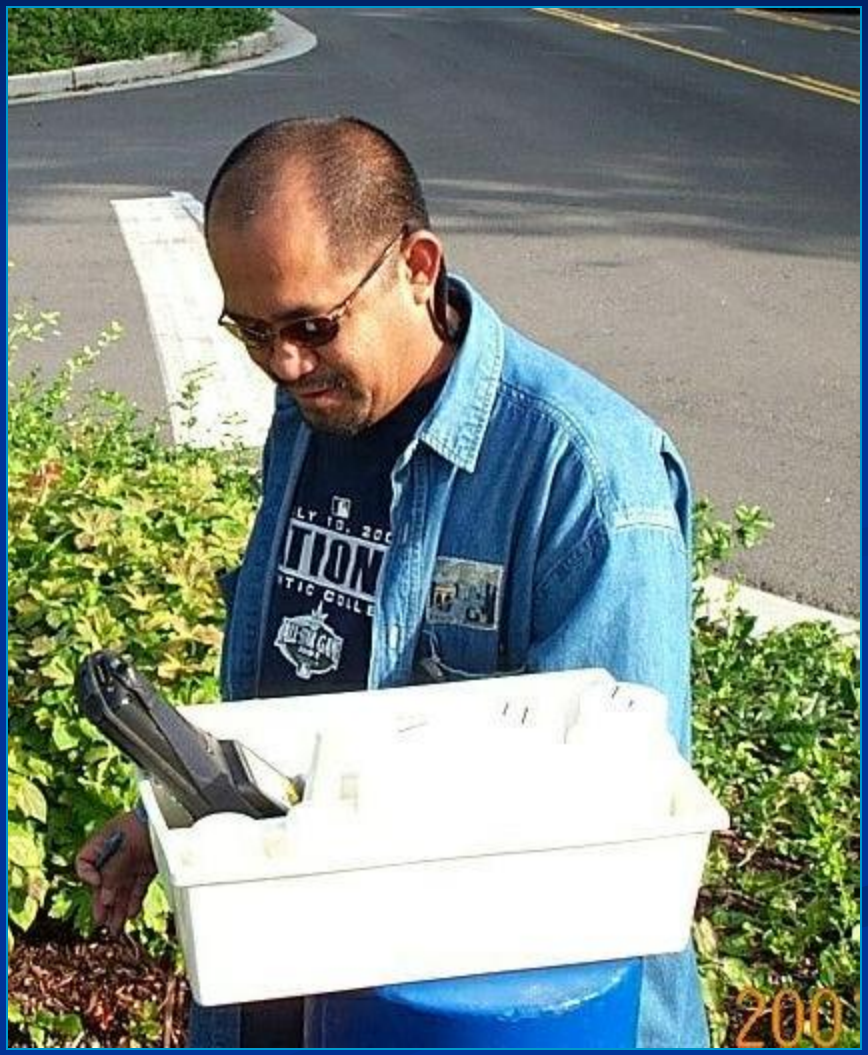
Before & after cleaning

(4 year cycle)

How Do You Find Problems?

Water Quality Monitoring

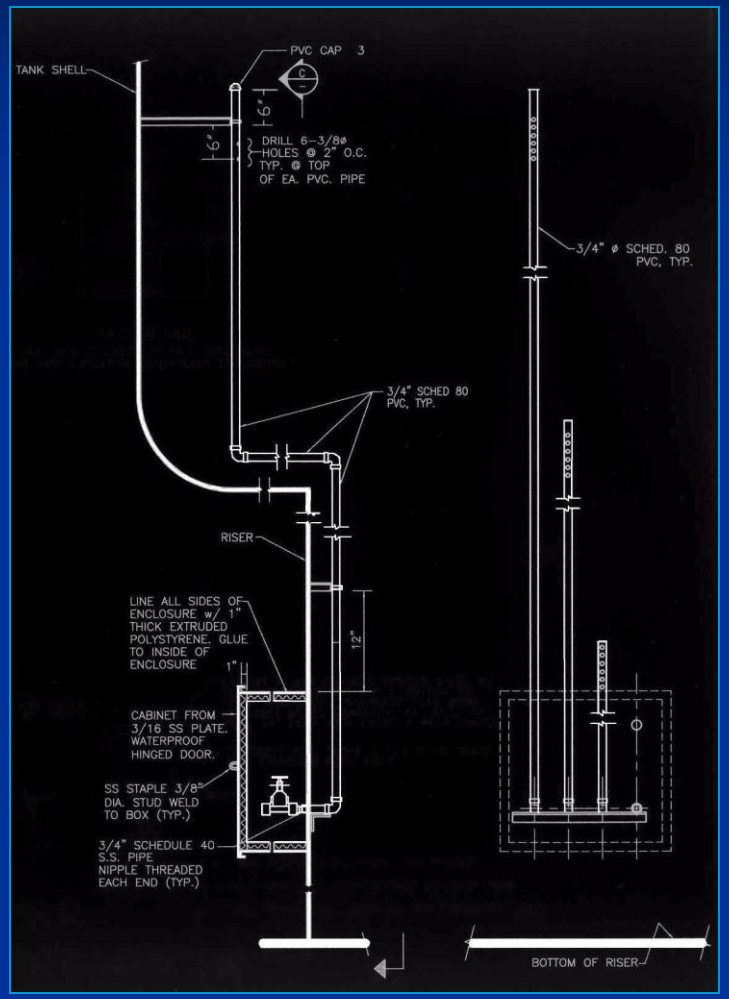
- Cl2 residual
- Water temperature
- T&O samples
- TCR monitoring
- Non-routine coliform samples
- HPC (heterotrophic plate count)



Know the Sample Point

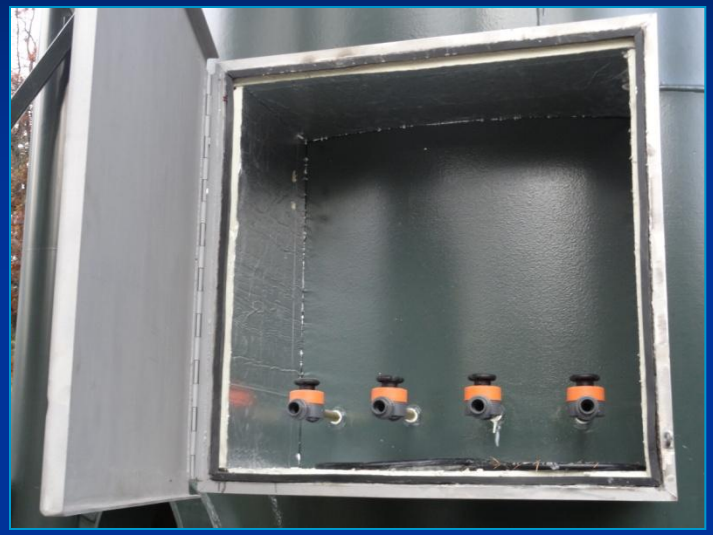
The hole in the wall is the end of the sample tap, 3' off the floor in a 40' high standpipe.

Multiple Level Sample Lines



- Multiple taps give you a better picture of the entire tank
- Knowing the sample point can help explain results that may not make sense at first

Multiple Tap Sample Cabinet



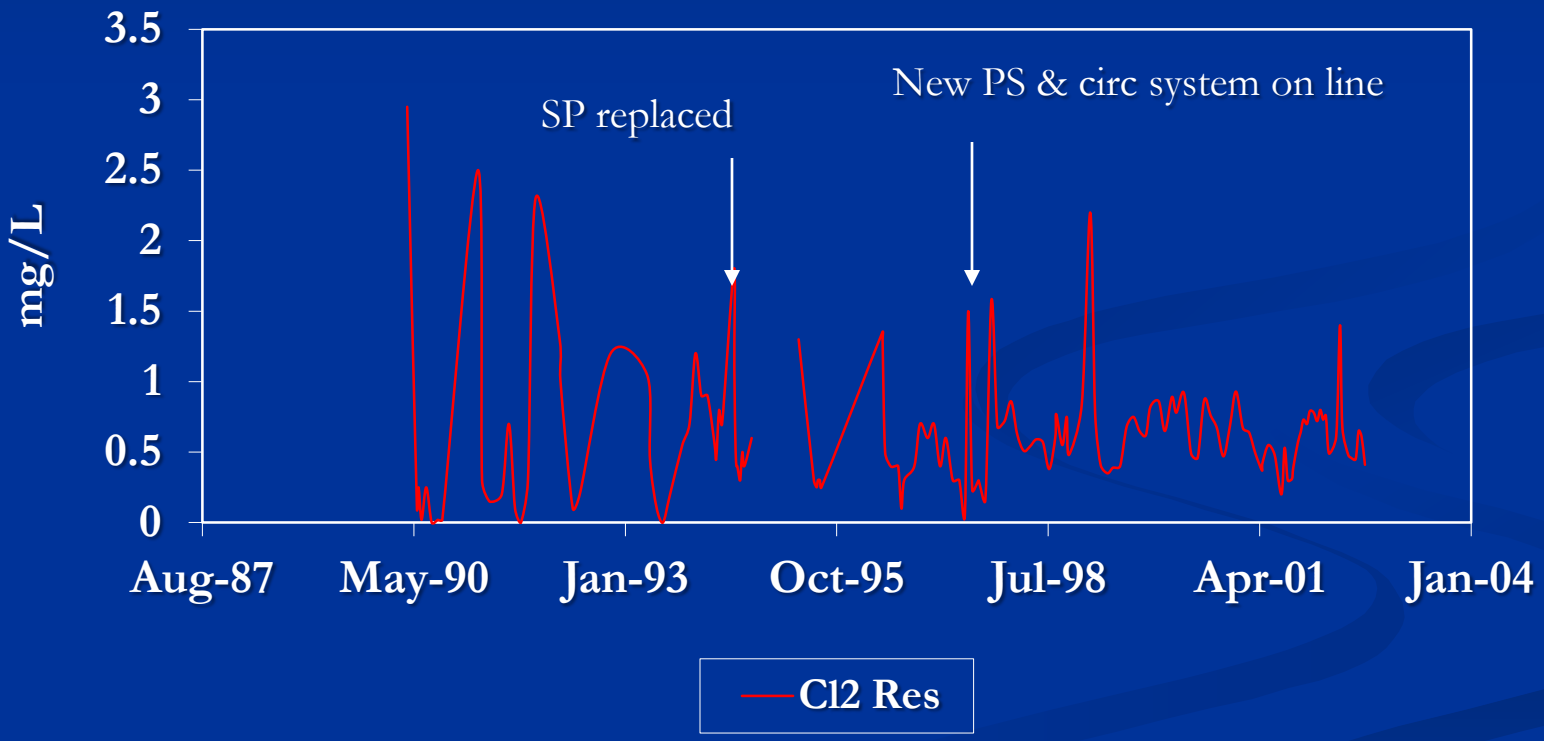
- Transducer on left
- Multiple sample taps
- Sodium hypochlorite can be injected into tank through sample valves

Chlorine Residual - Grab Sample

- It's quick - no fancy equipment or analysis
- Basic data establishes a normal range
- Indicates what effect changes have had

Display Your Data

Grab Sample Cl2 Residual
Charlestown Standpipe



Water Temperature Monitoring

- As temps rise, Cl2 residual drops
  - The warmer the water, the higher the chances are for microbial activity
  - Tank temperatures that are warmer than normal or watermain temperatures may be a sign of poor turnover or stratification

How Often Do You Taste Your Product?

If You Can Taste The Difference

You can do an informal analysis on your water. Just keep notes so you know how it's changing from one time to the next.

Taste & Odor Samples

- Changes in taste and odor signal other changes in water quality

- Comparing the taste of the water in the tank with the taste of the source water will help you figure out if an event is system-wide or developing in the tank
  - Don't taste raw water samples until they've been chlorinated!

TCR Monitoring

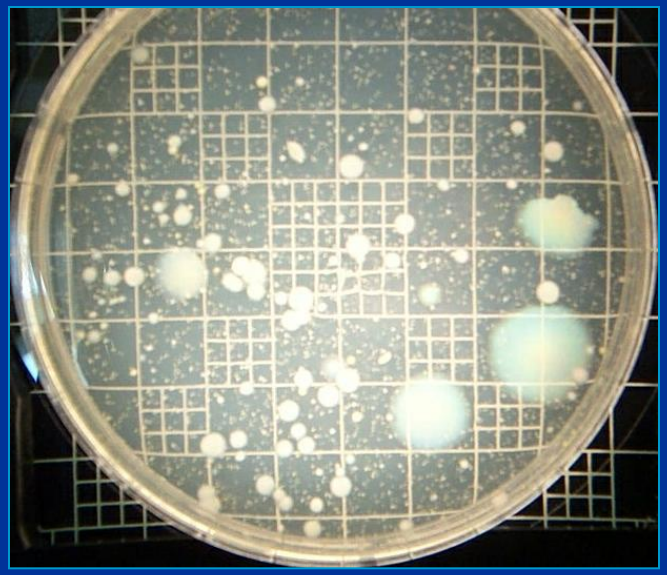
- Analyze data you already have
  - Plot Cl2 residual on a system map
  - Plot positive TC samples on a system map
  - How were you using your pumps then?
  - How did you cycle your tanks then?
  - Were there any low pressure and/or high flow events?
  - Did the tank influence the system, or is it the other way around?

Informational Coliform Samples

- Not required by your TCR monitoring plan
  - Results do not have to be reported

HPC Samples

- HPC indicates other microbial activity. Elevated HPCs in samples with good Cl2 residual are cause for concern.



A tank with HPCs like this is way overdue for cleaning

(This example is a raw water sample.)

Go Outside!

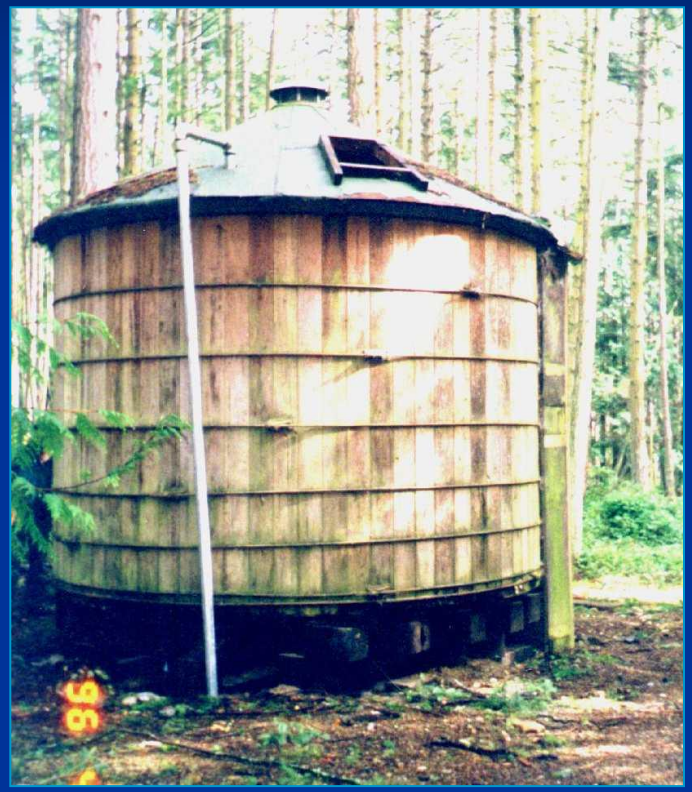


Photo courtesy of Steve Deem, WDOH

- Physical Integrity
  - Corrosion, leaks
- Security
  - Verify no breaches
- Sanitary
  - Water quality
  - Prevent contamination

Visual Inspections

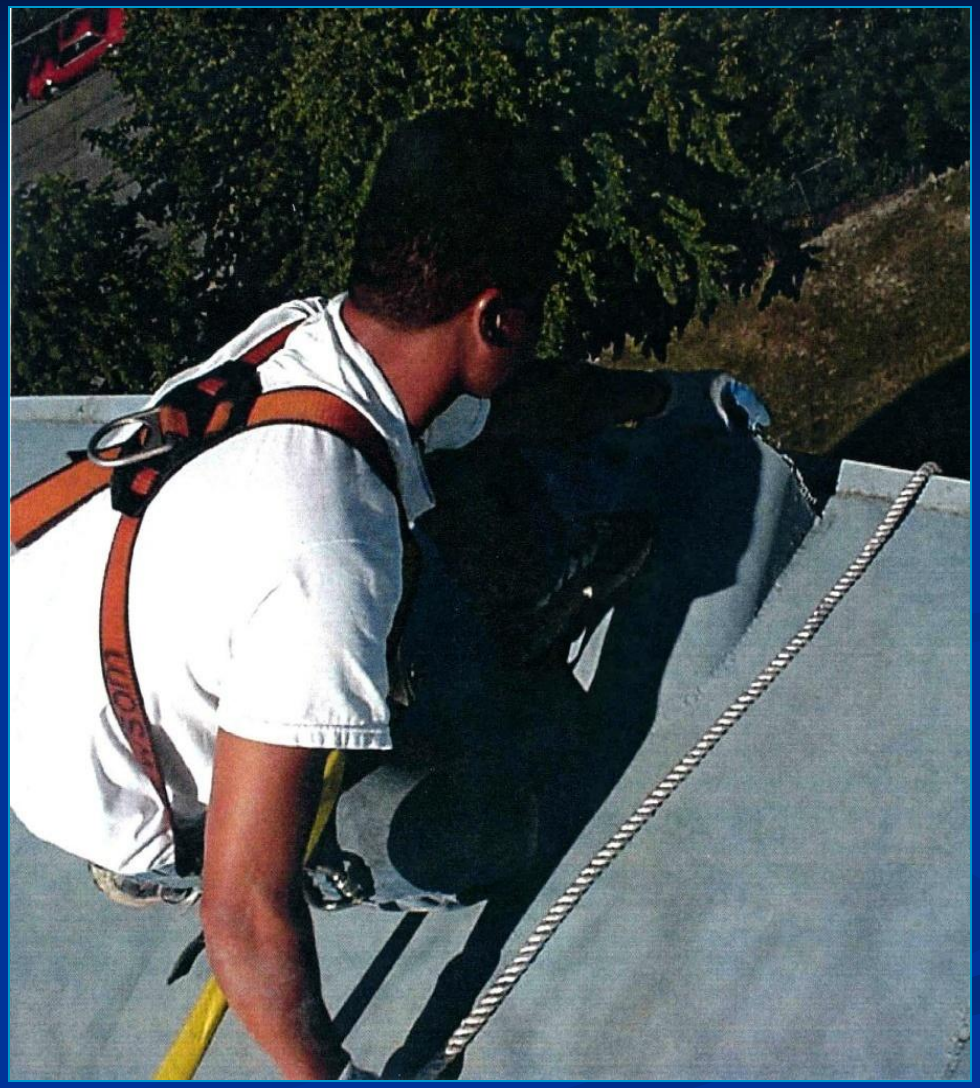
- Quarterly at ground level
  - Sample taps & tubing
  - Evidence of nests
  - Loose or missing screens
  - Holes in screens
    - Mice can get through a ¾" size gap
  - Screen mesh size
  - Air gaps
- Annually on top of elevated tanks
  - Hatches
  - Penetrations
  - Roof drains
  - Vent screens

Animals in the tank are the most likely source of contamination.

Repair loose or missing vent & overflow screens

Securely patch holes in screens

Look for nests



Bird feces and other contaminants on the roof can be washed into the tank.

Clean off roof & unplug drains

Repair leaking hatch covers & seals

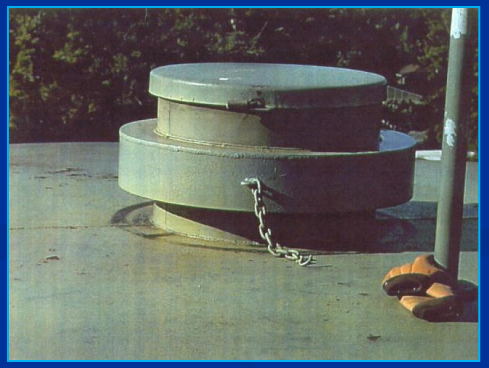
Patch holes corroded in roof

Vent Screens

Courtesy of Steve Deem, WDOH

Reservoir Vents and Hatches

Courtesy of Steve Deem, WDOH



Reservoir Hatches

Courtesy of Steve Deem, WDOH

Roof penetration

Reservoir Roofs – Clean & Clear

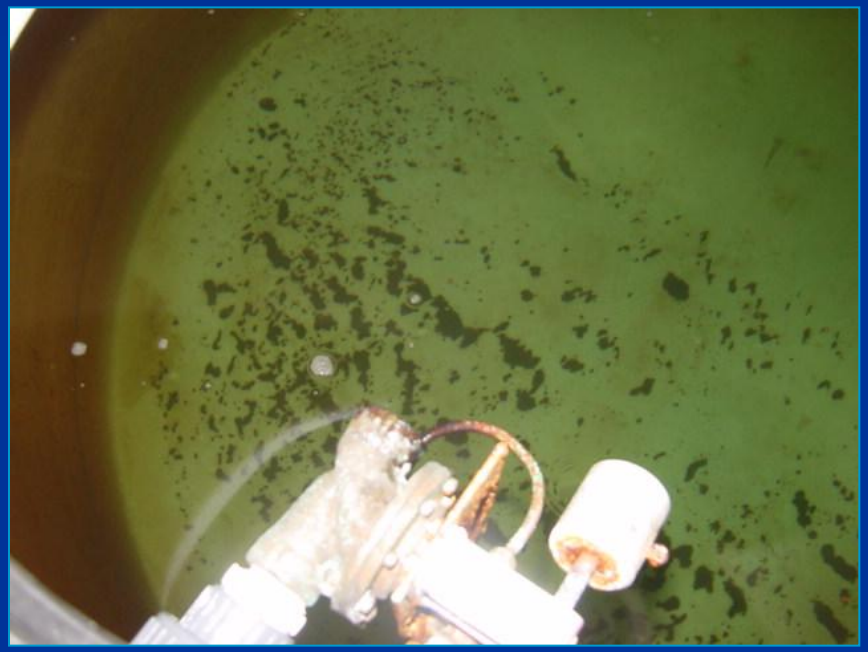
Courtesy of Steve Deem, WDOH

Bird Carcass Near Roof Penetration

Courtesy of Steve Deem, WDOH

What's It Look Like Inside?

Is This Normal?



Are Those…Salamanders?

Courtesy of Steve Deem, WDOH

Open The Hatch Before The Sanitary Survey

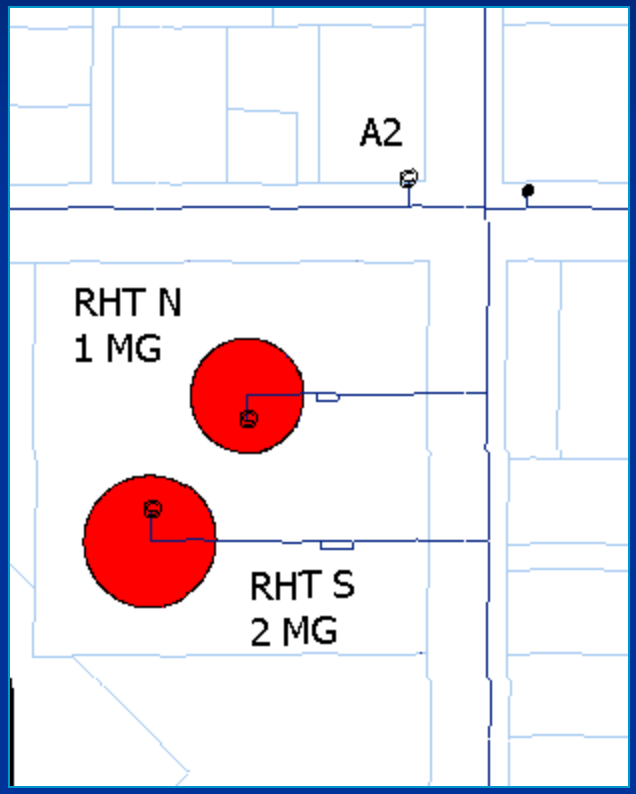
Botryococcus – a type of algae

Overflow & Drain Air Gaps

Courtesy of Steve Deem, WDOH

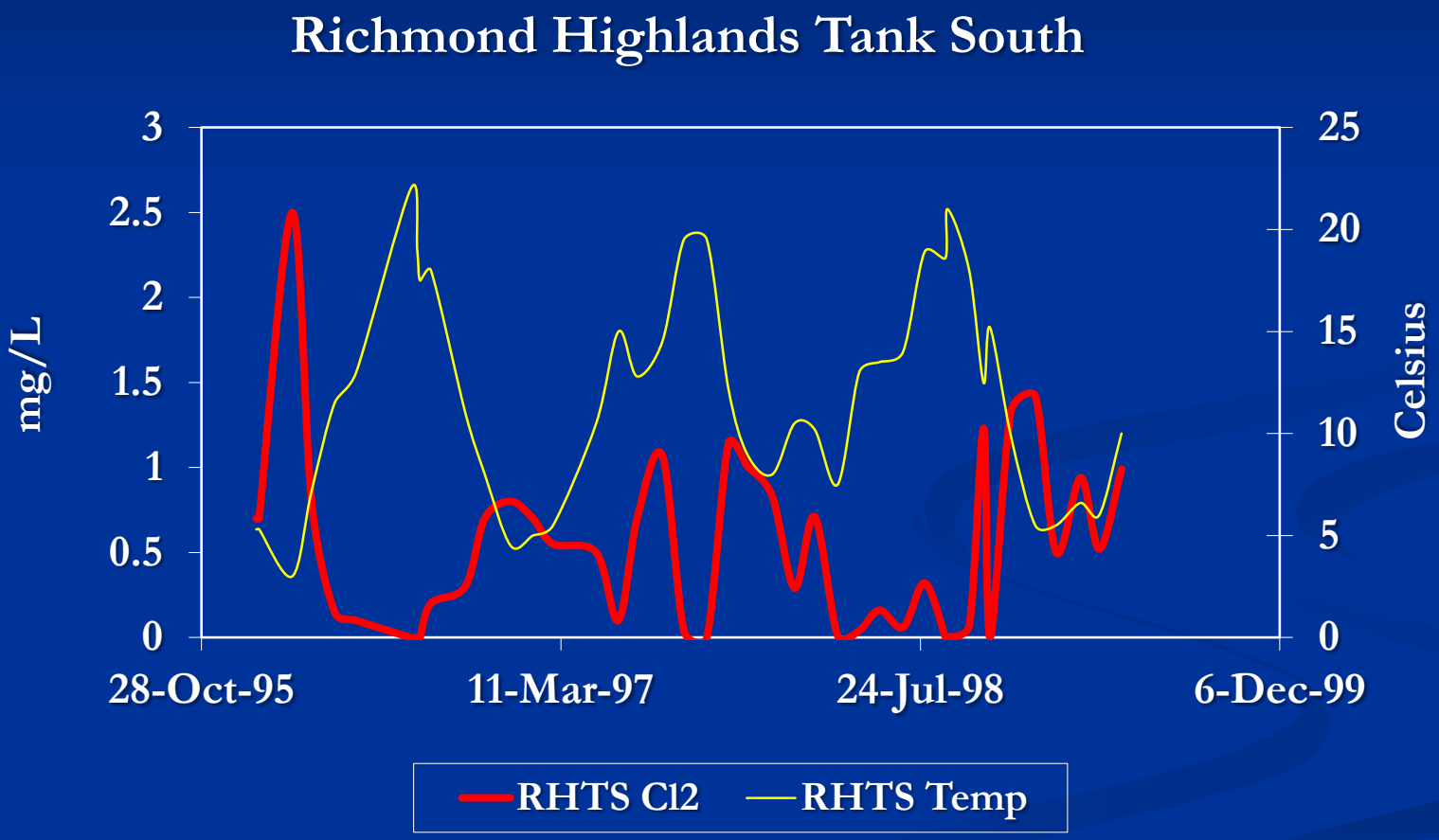
Troubleshooting Using Water Temperature & Chlorine Residual Data

Richmond Highlands Tanks

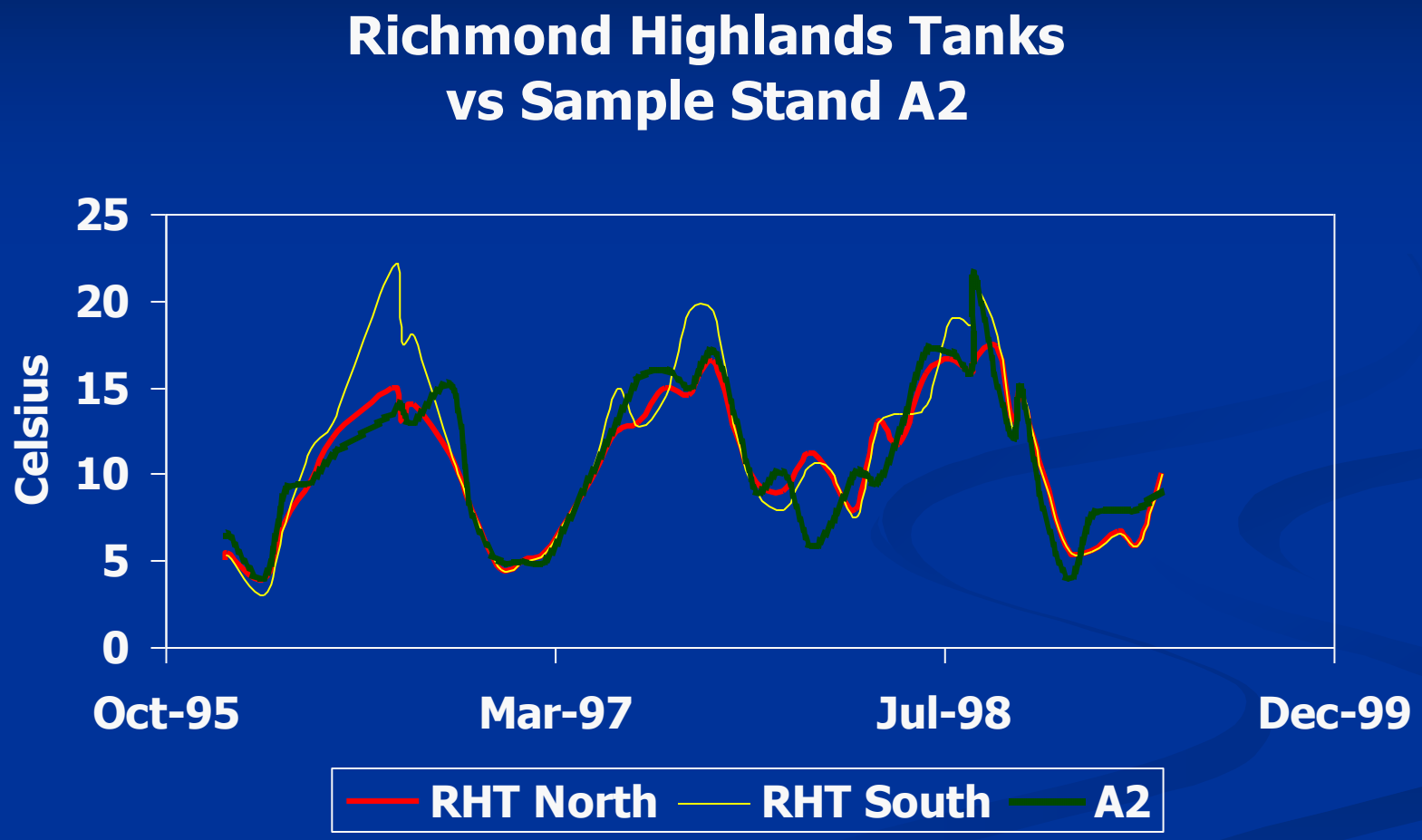


- Each tank has its own inlet/outlet line
- Both tanks are connected to the same feeder line
- Each tank has sample points
- Sample stand A2 is across the street

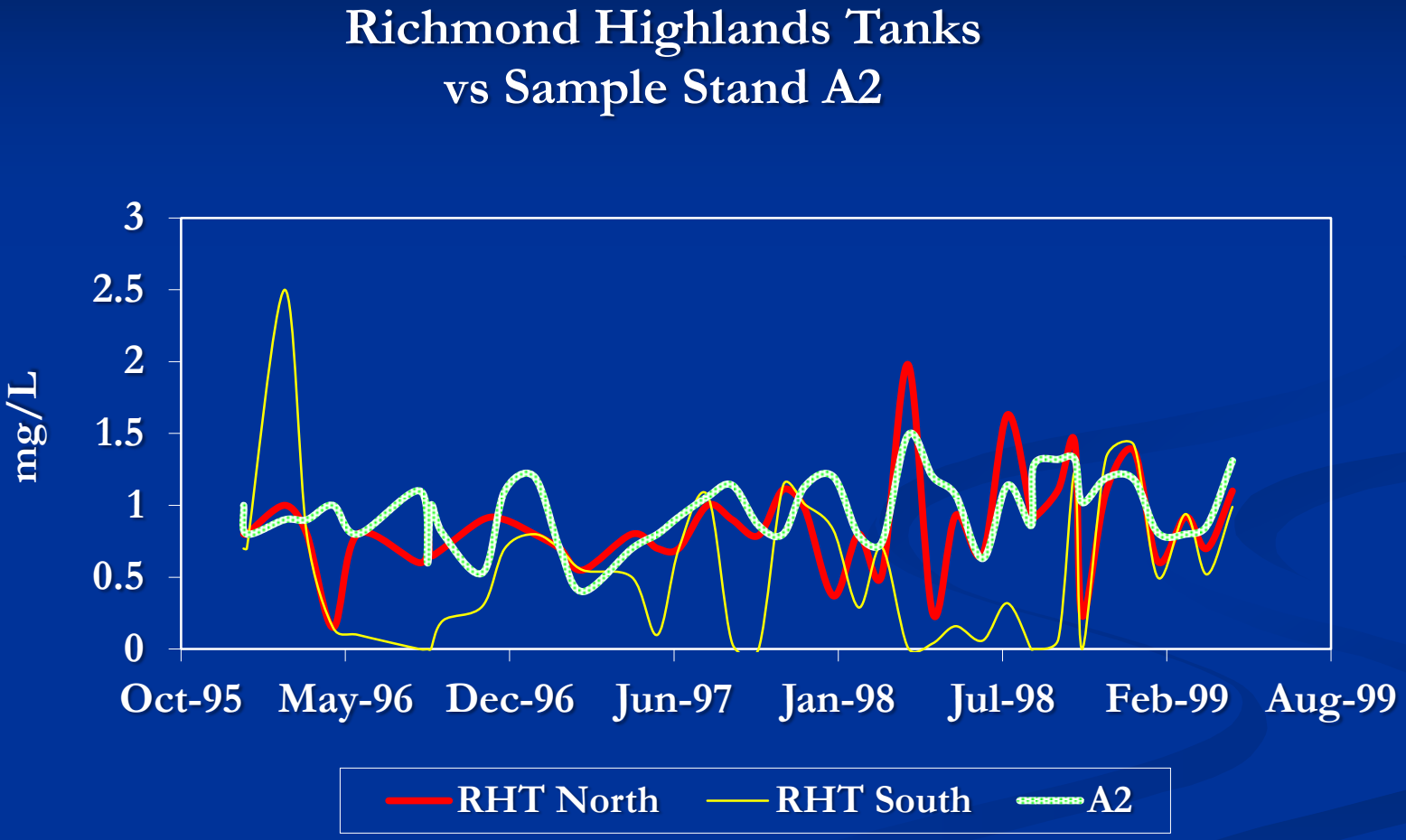
Cl2 Residual vs. Water Temp



Water Temperatures



Chlorine Residuals



Possible Causes

- South tank is larger, with less turnover
- Something is inside the south tank and is creating chlorine demand
- Inconsistency in sample collection
- The north tank is shaded by the south tank, and therefore cooler

What Next?

- Cl2 residual on a different tap on the south tank was the same as in the north tank
  - During tank cleaning at the end of 1998, we found the end of the sample piping in the south tank was near the overflow & usually out of the water
  - We lowered the collection point by 15'
    - Since then, north & south Cl2 are very close

Case Study

High HPCs in Multiple Tanks

Samples

- Month-end samples from five tanks had HPCs ranging from 70 to >5700 (0 is normal)
  - 2 tanks 0.2 - 0.3 mg/L
  - 3 tanks >0.5 mg/L
  - Tank water temps were 14C - 15C

First Steps

- Re-sampled to confirm unusual results and eliminate sampling or lab error
  - Confirmed there were no errors in collection or analysis

First Steps

- Assessed operating conditions
  - Cl2 was 0.7 mg/L in mid-month samples
  - Watermain temps were 15C-16C
  - Tanks were cycling well
  - No significant changes in operation since mid-month samples were collected
  - Distribution system HPCs were normal

Preliminary Analysis

- Tank & watermain temps are consistent, indicating tanks are being well-cycled
  - confirmed by SCADA data & presence of Cl2 residual
- Occurrence in multiple tanks over a wide area & over several pressure zones points to a problem with the supply, not with the individual tanks

Preliminary Conclusions

- With no change in treatment dosages at the source, or in system operations, lower tank Cl2 residual is probably the result of higher Cl2 demand.
  - What would cause higher Cl2 demand?
- Lower velocities or longer residence time in tanks are providing favorable conditions for microbial activity.

Analyze Supply Operations

- What do these tanks have in common?
  - All were receiving unfiltered water from from same source.
  - Tanks were fed either directly from source pipelines, or via reservoirs with no booster Cl2.
  - Other tanks in these areas downstream of booster Cl2 had no HPCs.

Additional Lab Analysis

- HPCs in 4 of the 5 re-samples had declined dramatically; the 5th sample had a significant increase.

- Routine source water sampling indicated a high zooplankton population.

Conclusions

- The elevated HPCs in the tanks were most likely associated with the high amount of zooplankton in the source water.
  - The source is unfiltered. Parts of the zooplankton remained intact, & traveled through the system.
  - HPCs may have indicated re-growth. Where available, booster Cl2 controlled it.

Conclusions

- The event was nearly finished moving through the system at the time re-samples were collected. The re-sample with higher HPCs was from the tank farthest from the source.

Follow-up Actions

- Continue to monitor zooplankton in source and HPCs in tanks.
- Manually boost Cl2 in tanks if HPCs do not decline.
- Revise system operations to route water through existing booster Cl2 points.

Follow-up

- 2 weeks later, the last tank with HPCs had none
- 4 weeks later, HPC in that tank was 457
- Next step - sample from all 3 taps to eliminate problem with tap and determine how widespread it is in tank
- If necessary:
  - Disinfect tank &/or sample taps
  - Drain & clean

Steps to Improvement

Why?
What if?

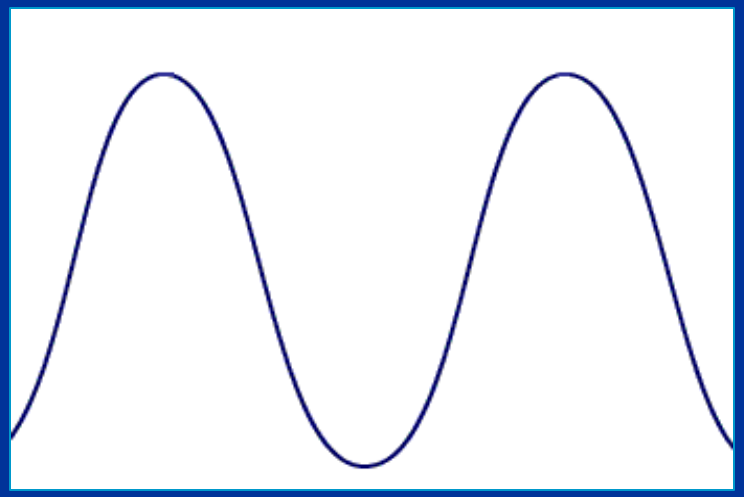
Don’t just watch things happen!

Look

- Rooftop every year
- Ground-level every 1-3 months
- Fix the little problems before they get big

Operational

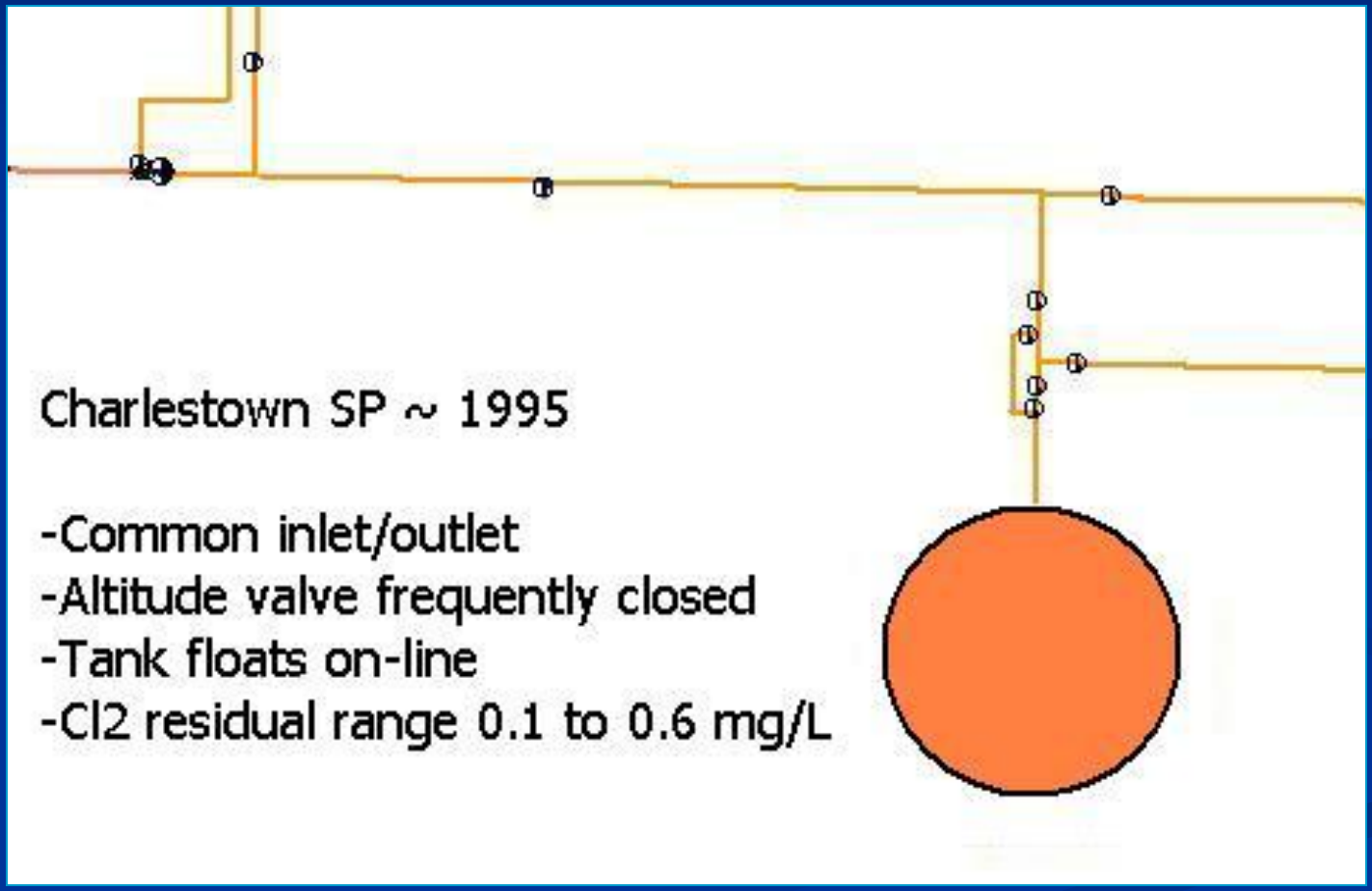
- Move the water
  - Cycle deeply & frequently



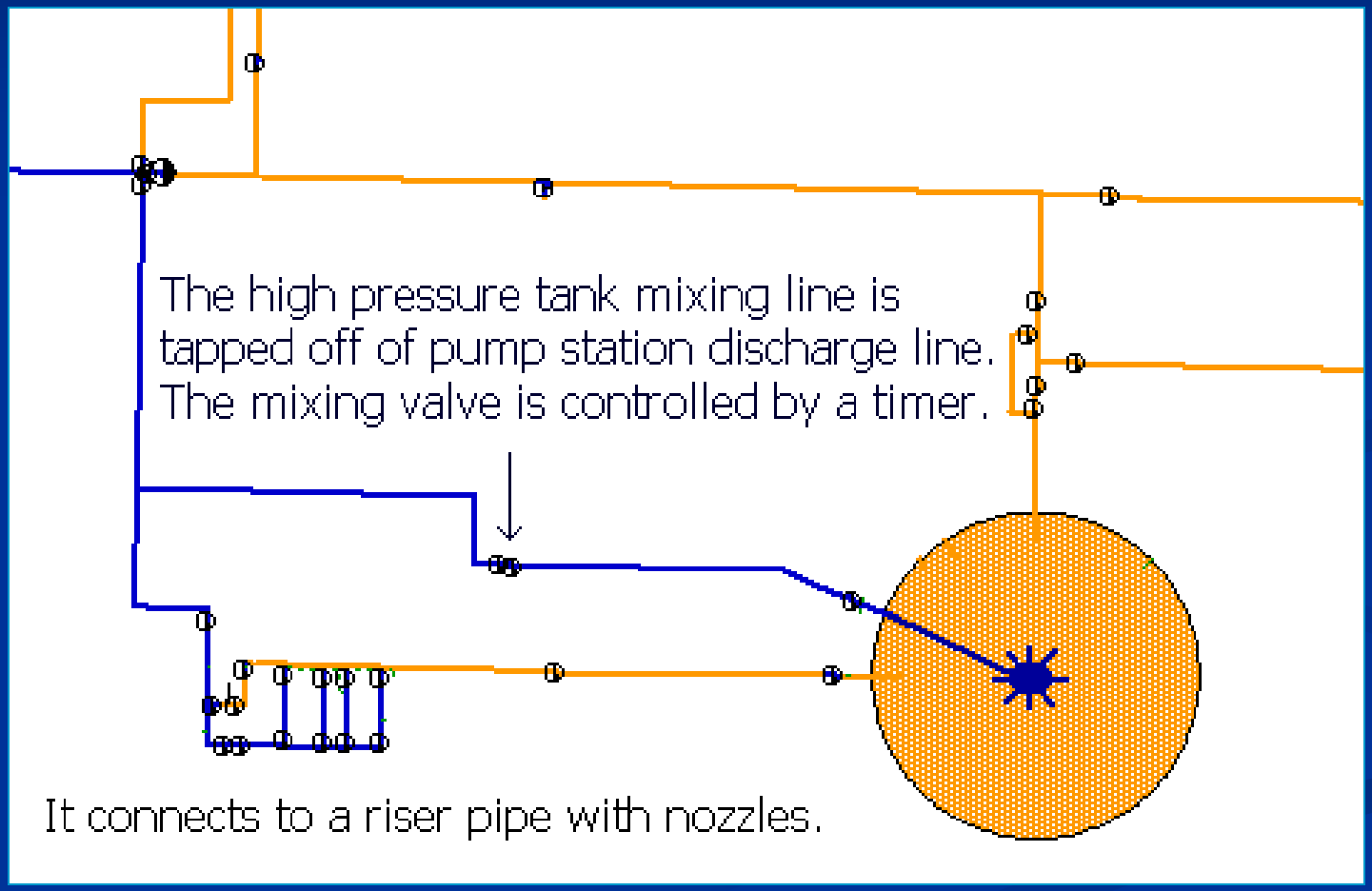
- Maintain Cl2 residual
  - Boost at tank
  - Boost at source

Examples of Structural Changes

Charlestown SP Before Replacement

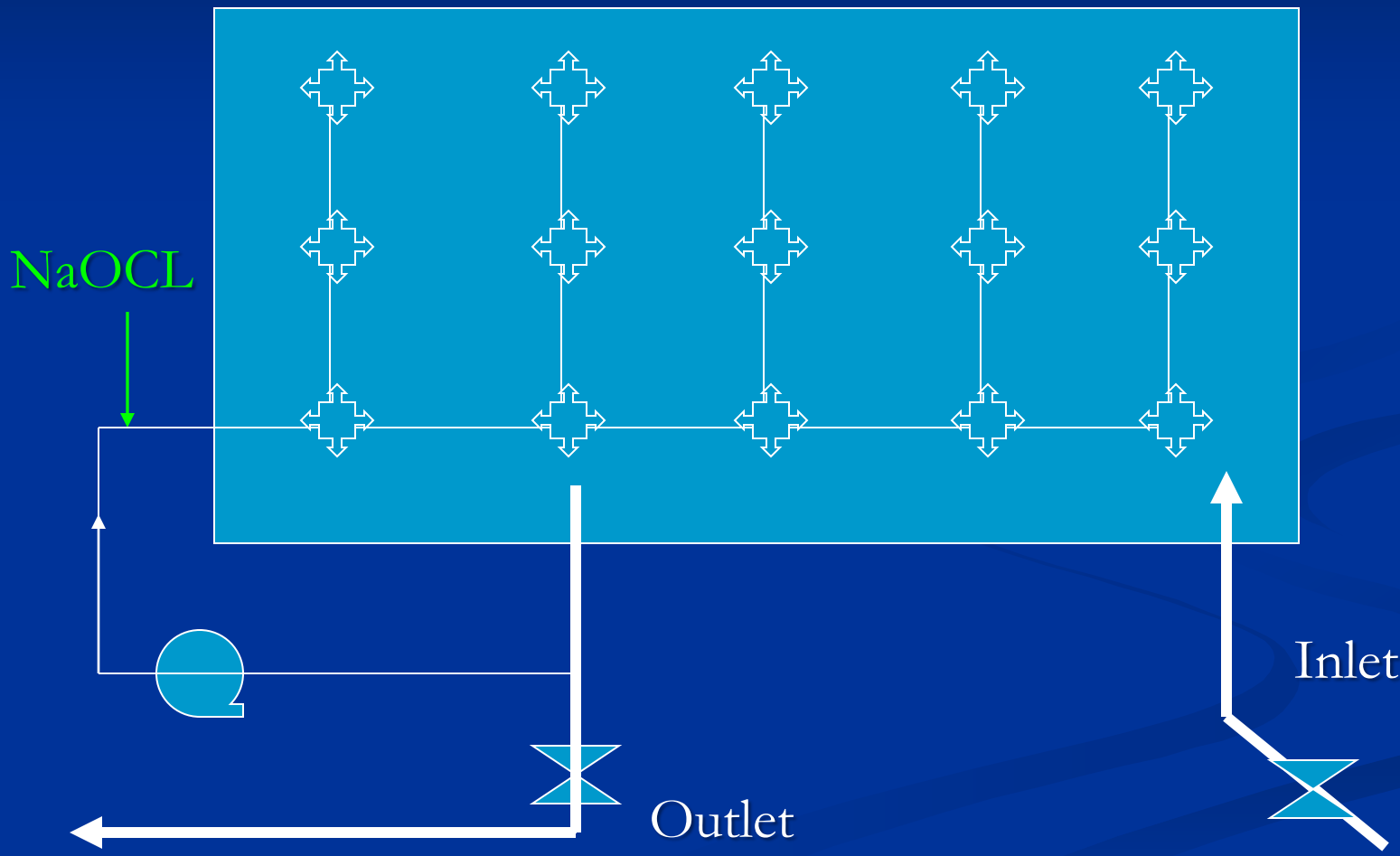


Charlestown SP After Replacement & New PS



Tideflex®
Mixing Systems

Mechanical Recirculation Mixing System



Questions?

- Phone (206) 386.1265
- E-mail: cheryl.capron@seattle.gov