# MODIFIED TRACER TESTING METHODOLOGY FOR LONG DETENTION TIMES

American Water Works Association
Pacific Northwest Section

PNWS-AWWA Section Conference
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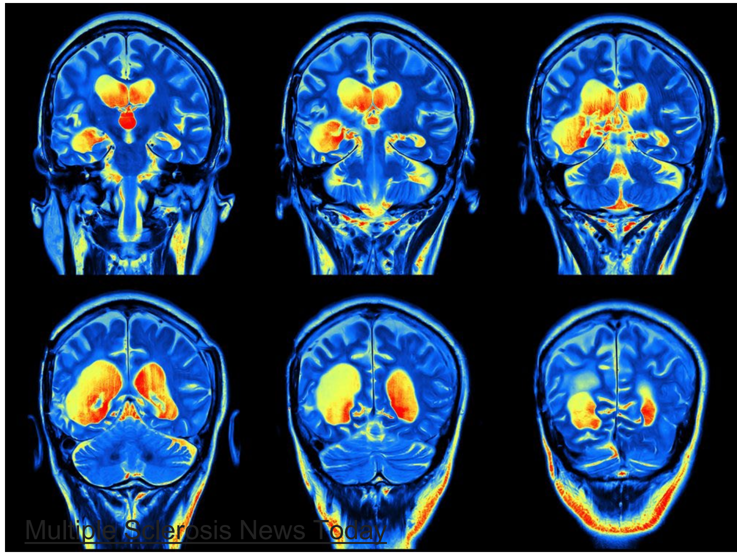
# AGENDA

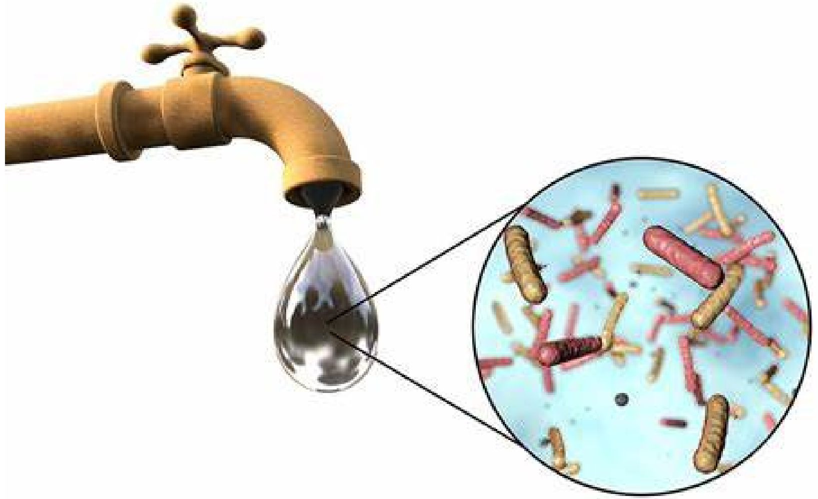
1. What is and why do Tracer Testing?
2. Determining Hydraulic Efficiency
3. Factors that determine Disinfection Efficiency
4. Tracer Testing Parameters and Tracer Testing Methods
5. Modified Tracer Methods
6. Questions

# What is Tracer Testing?

- *Tracking the path* of the tracer in the water
- Add a *known quantity* of tracer (or chemical) in the water channel and monitor the tracer residual downstream
- Water channel to be representative of a *measurable contact time* between the point of residual monitoring or disinfectant application
- *Constant, uninterrupted flow* through process segment of the plant being tested is imperative
- Determine system's contact time ($T_{10}$) or tracer residual at a particular flow rate
  - $T_{10}$ is time taken for 10% of the tracer to pass through the sampling point
- Chemical used - $CaCl_3$, NaF, $H_2SiF_6$


Multiple Sclerosis News Today

# Why do we do Tracer Testing?



1. Process Design Validation
   - Validate basis of disinfection design
   - Determine level of inactivation achieved via disinfection
   - Understand the impact of flow characteristics in clearwell, pipeline, post disinfection

2. Regulatory Compliance ~ SWTR Disinfection Requirements
   - Prevent consumer exposure to pathogenic organisms in drinking water
   - Achieve minimum 3-log reduction of *Giardia*, 4-log reduction of viruses, and 2-log reduction of *Cryptosporidium*
   - Reduction occurs through various stages of physical and chemical treatments at WTP
   - Water quality parameters like pH and temperature also impact disinfection efficiency

# Determining Hydraulic Efficiency

Determine hydraulic efficiency / baffling factor of the plant processes:

Hydraulic Efficiency or Baffling Factor

$$= \frac{\text{Time 10\% of Tracer Passed}}{\text{Theoretical Time 100\% of Tracer Passed (HRT)}}$$

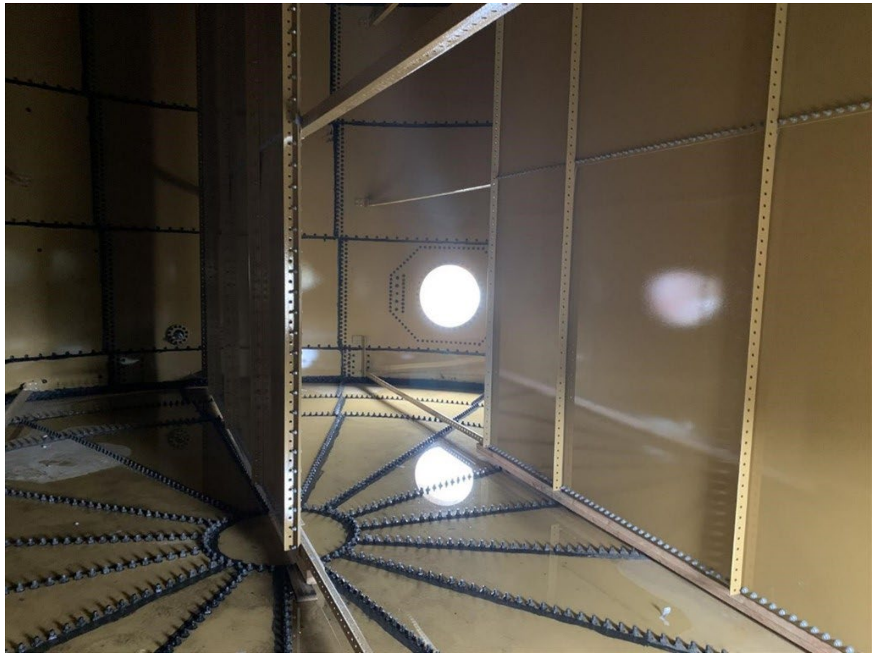
$= T_{10} / T_{th}$

Where $T_{th}$ = Volume of wetwell / Flowrate

Higher Baffling Factor or Hydraulic Efficiency →

Good circulation within water channel →

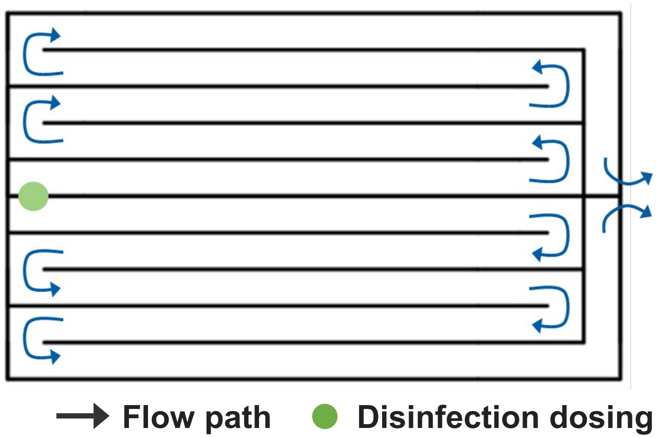
Little to no short circuiting



**EPA SWTR Disinfection Benchmark: Baffling Classifications**

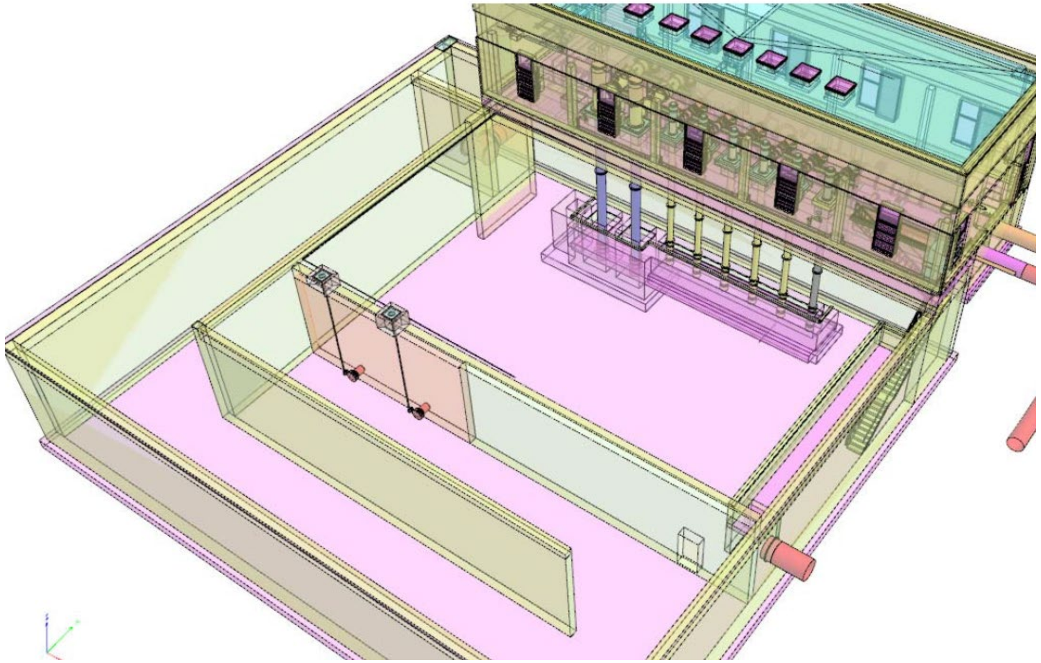
| Baffling Condition | T10/T | Baffling Description |
| --- | --- | --- |
| Unbaffled (mixed flow) | 0.1 | None, agitated basin, very low length to width ratio, high inlet and outlet flow velocities. Can be approximately achieved in flash mix tank |
| Poor | 0.3 | Single or multiple unbaffled inlets and outlets, no intra-basin baffles |
| Average | 0.5 | Baffled inlet or outlet with some intra-basin baffles |
| Superior | 0.7 | Perforated inlet baffle, serpentine or perforated intra-basin baffles, outlet weir or perforated launders |
| Perfect (plug flow) | 1.0 | Very high length to width ratio (pipeline flow), perforated inlet, outlet, and intra-basin baffles |

# Factors that determine Disinfection Efficiency




1. Disinfectant dose
2. Residence time
   - CT = disinfectant dose (mg/L) x contact time (min)
3. pH and temperature
   - Disinfection kinetics increase linearly with increase in temperature
   - At lower temperatures, disinfection is slower and higher doses are needed
   - Lower pH facilitates the formation of free chlorine residual, improving disinfection efficiency
4. Physical process features like wetwell geometry, baffles
   - Wetwell geometry can create dead zones and short-circuiting
   - This can be prevented by installing baffles that ensure proper dispersion through the chamber
5. Background substances
   - Organic matter, hardness, metals, etc.
   - Can inactivate the disinfectant by reacting and neutralizing it
   - Can also create a protective barrier around the microorganisms (color, UVT)

# Tracer Testing Parameters



1. Flow Rate
   - 5% standard deviation during testing
   - EPA allowance ~ 91% of $Q_{max}$
2. Water Elevation
3. Tank or chamber geometry
4. Duration of Tracer Test – 2 to 3 HRTs
5. Tracer Chemical and Injection
   - Should not compete with background concentrations in water
   - Must not endanger water quality
   - May already being added or readily available, safe to handle, easy to measure
   - Injection at a point of good mixing that mimics actual WTP conditions
6. Sample Location and Frequency
   - Monitor end point of chosen segment
   - Easy access to flow stream without needing to pump sample
   - Grab samples with hand-held sensors, online measurement, or sent to lab

# Methods of Tracer Testing

| PHYSICAL / EMPIRICAL METHOD | | DESKTOP / COMPUTER MODELLING |
|---|---|---|
| SLUG DOSE | CONSTANT CONCENTRATION | CFD MODELLING |
| • Simple bulk injection of tracer<br>• Large instantaneous dose<br>• Intensive mixing required<br>• Mass balance to determine total recovery at monitoring location<br>• Longer sampling period may be required<br>• Typically used if injecting chemical that isn't used in treatment process | • Constant rate injection<br>• Step-dose of known concentration until desired concentration is achieved at monitoring location<br>• Feed equipment required to provide constant rate of dosing<br>• Advantageous if using a chemical that is already being fed | • Computation Fluid Dynamics<br>• Analyze fluid flow through numerical analysis<br>• User input – plant process characteristics, assumptions<br>• Virtual particle tracking allows simulation of residence time distribution for each clearwell configuration and flow rate condition |

# Limitation of Methods

Desktop methods

- Washington and Colorado have compared published and anticipated values versus empirical methods
- Noted that values could show variations or negative bias

CFD modelling

- Powerful tool but based on assumptions, inputs and model complexity; doesn't account for model errors

*"All models are wrong, some are useful" – George Box*

Physical/Empirical methods

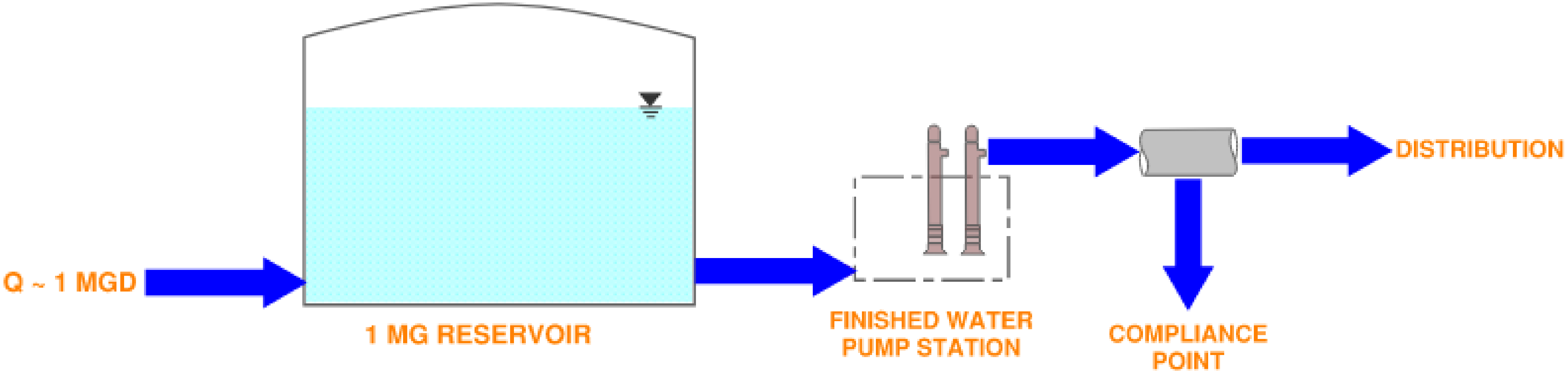
- Feasibility of conducting test for 2-3 hydraulic retention times
- Tracer recovery and analytical limitations
- Risk of operator error

* *2017 – Washington's Tracer Study Project, WSDOH and G&O, PNWS-AWWA Tri-Cities Conference*
* *Colorado guidance - https://cdphe.colorado.gov/swtr*

# Modified Tracer Methods

Is running a tracer test for 2-3 HRT feasible?

Is running a tracer test for the full duration until full tracer decay is achieved feasible?




Example: WTP with 1-mgd max plant capacity and a 1-million-gallon clearwell (or reservoir). To conduct a conventional tracer test to achieve total recovery or decay of tracer element over 2-3 HRTs (standard), the testing duration would be 3 days!

# Modified Tracer Methods

- Modified Techniques using Conventional Tracer Methods –

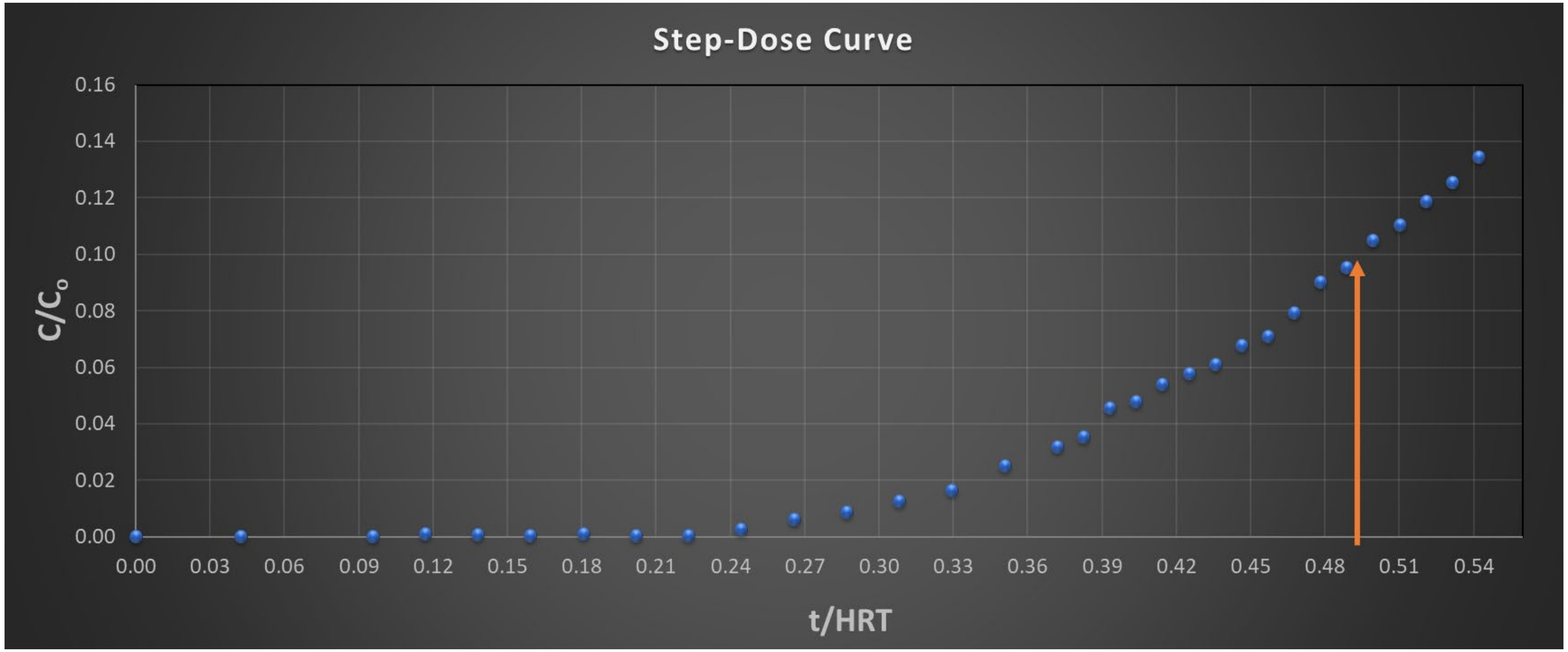
  1. Slug-dose but terminate when 10% of tracer has been recovered
     - Very difficult to confirm spiking and total tracer recovery, not recommended

  2. Constant Concentration Method but terminate early at $T_{10}$
     - Should be considered if conditions can be closely monitored

- Verify dosing mass / concentration immediately downstream of injection

# Modified - California Department of Public Health

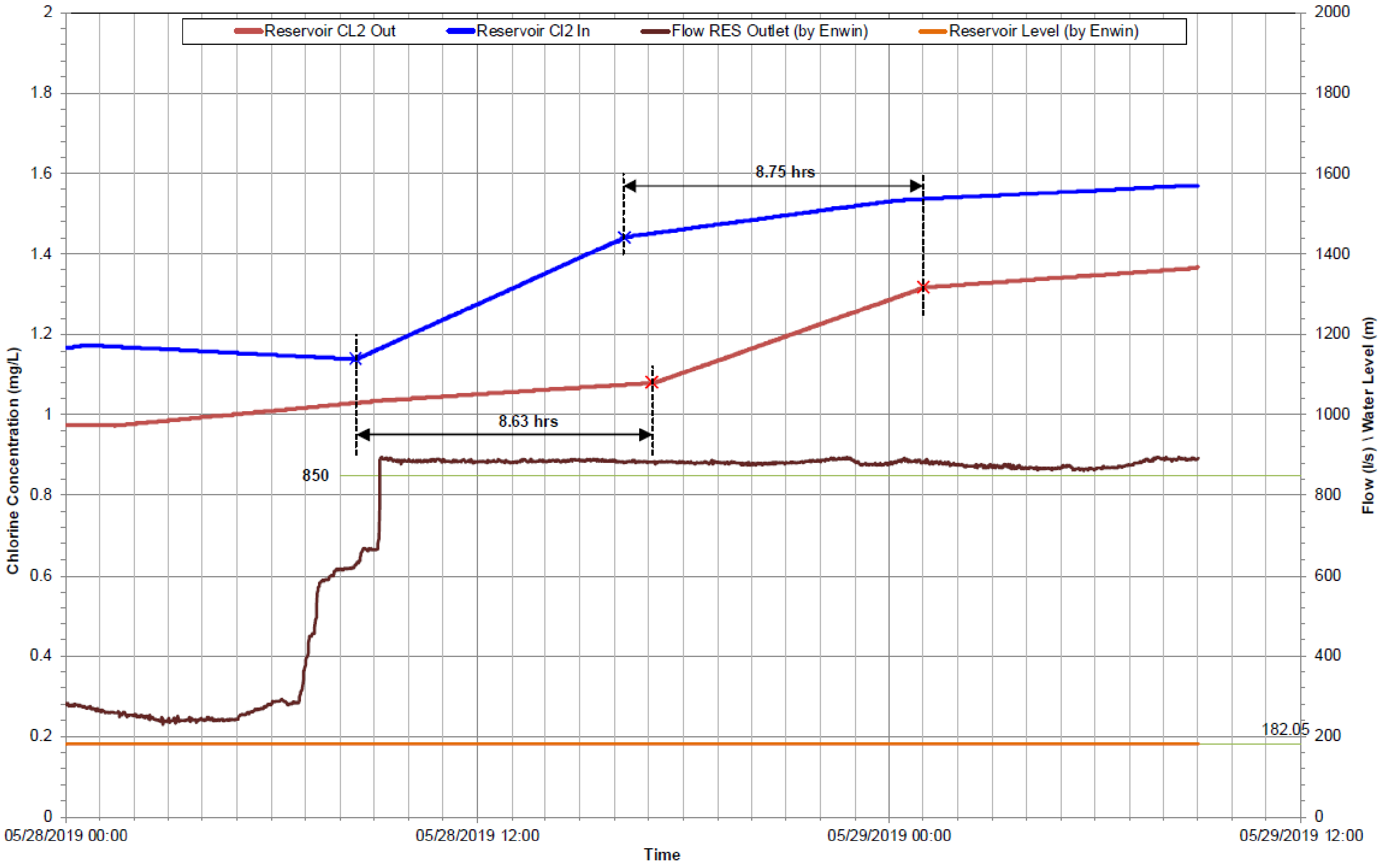
- 2008 – Schott G. Clearwell Tracer Study Results, Five Points. Mendicino District
  - Long HRTs, not feasible to run 2-3 HRTs
  - Modified Step-Dose
  - Good quality assurance / quality control
  - Operated test until slightly over 10% of tracer was recovered
  - Allowed higher tracer concentration to be used (3.0 to 6.7 mg/L fluoride)




2019. Schott. AWWA Sacramento Presentation

# Modified Tracer Method - Canada

- CFD Model predicted 0.75
- Tracer testing calculated >0.8
- Possible issues with QA/QC
- Limitations of free chlorine with decay

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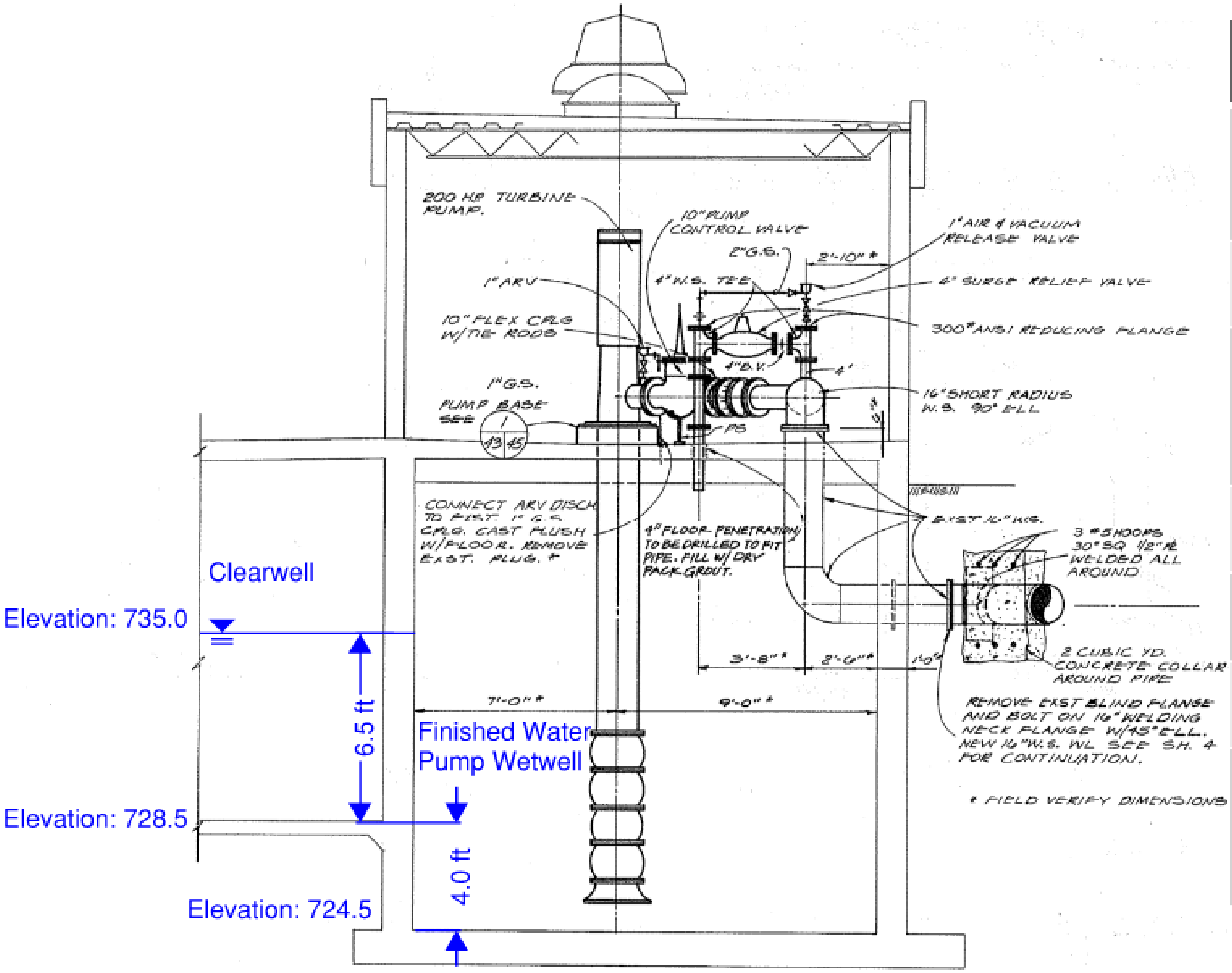
# Modified Tracer Test conducted at Lewiston, ID




Sump Volume: 47.5x16x4 = 3,040 CF = 22,739 gallons
CW Volume: 100x45x6.5 = 29,250 CF = 218,790 gallons

| PARAMETER | TRACER TESTING CONDITIONS |
|---|---|
| Tracer Test Methodology | Test 1: Fluoride Step-Feed<br>Test 2: Fluoride Decay |
| Plant Flow Rate | 4,200 gpm (6 mgd) |
| Clearwell Level | 85% Full (measured in the pump wetwell) |
| Tracer Chemical | Fluoride |
| Duration of tracer test | 4 hours total |
| Sample Location | Finished Water Pump Discharge |
| Sample Frequency | 15-min frequency prior to study<br>1-min sample collection during study |

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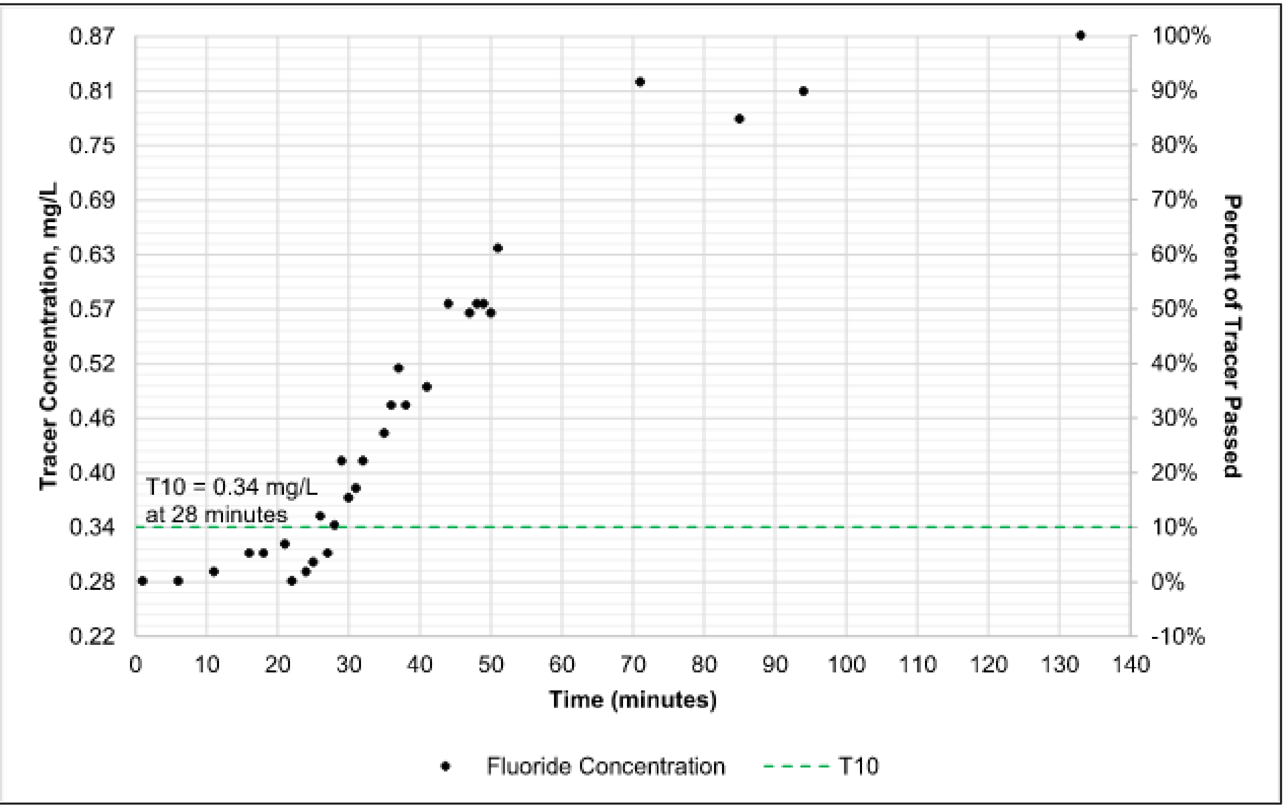
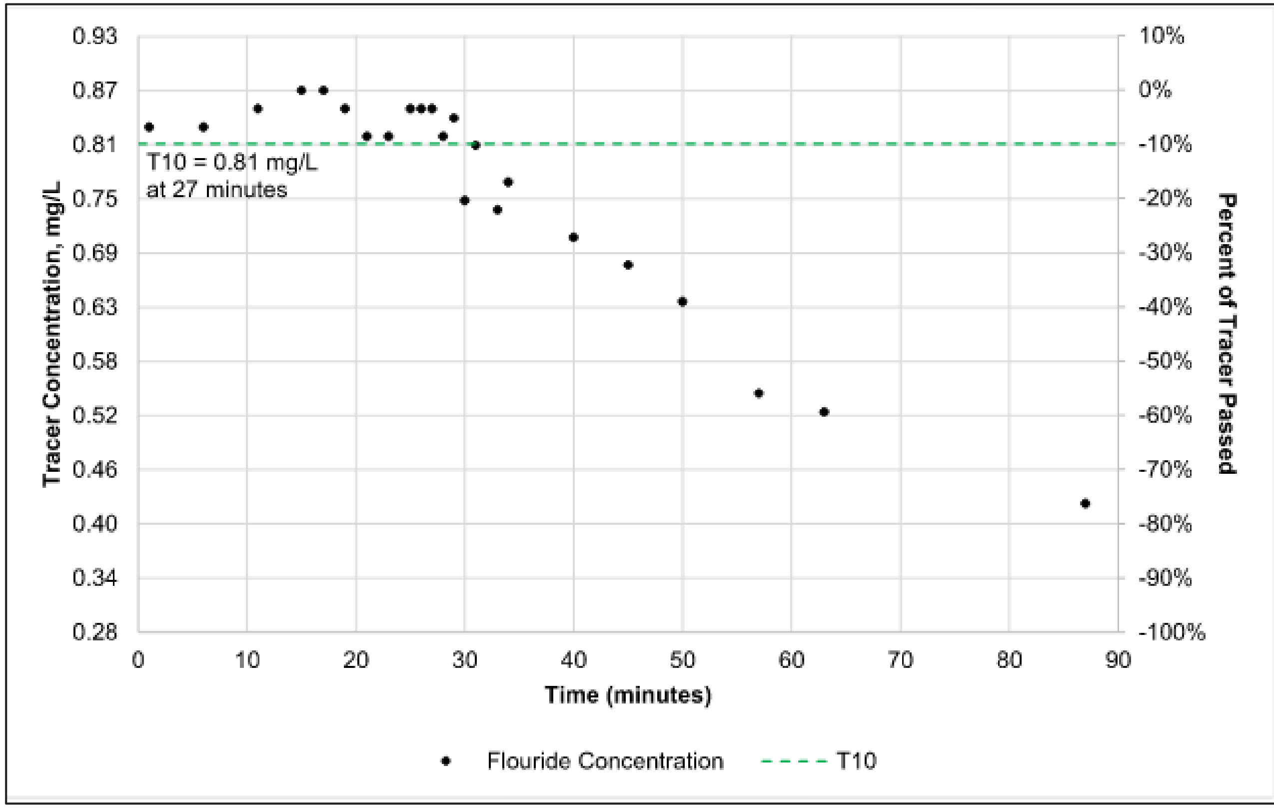



Fluoride Lead Step Feed
Baffling Factor = 0.62




Fluoride Lag Step Feed
Baffling Factor = 0.59

# RECAP

- Tracer testing is very valuable to confirm design assumptions
- Historical estimated methods can be optimistic
- CFD modeling can give good starting point
- Modified methods available for challenging situations

# QUESTIONS?

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