

OVERVIEW OF TRACER STUDIES AND BAFFLING FACTORS

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Presentation Outline

- Background/definitions
- Guidance resources
- Washington state specific requirements
- Tracer study basics
- Baffling efficiency
- Summary/close

Some Definitions/Nomenclature

HRT – Hydraulic Residence Time (aka 'T')

$$HRT = V/Q$$

BF – Baffling Factor (aka 'T_{10}/T')

$$BF = T_{10}/HRT$$

T_{10} – Time for 10% of the tracer to pass through the basin

$$T_{10} = BF \times (V/Q)$$

Background

- Surface water treatment requires primary disinfection for *Giardia* and virus inactivation
- Inactivation ratio (IR) and Disinfection contact time (CT)
- Tracer studies may be required to determine that adequate disinfection contact time can be provided and to confirm or revise engineering design assumptions
- Assumptions regarding CT basin configuration, baffling, and theoretical flow patterns may not meet actual conditions

Disinfection Monitoring

- Three water quality parameters:
  - pH
  - Temperature
  - Disinfection residual concentration

  - PLUS…

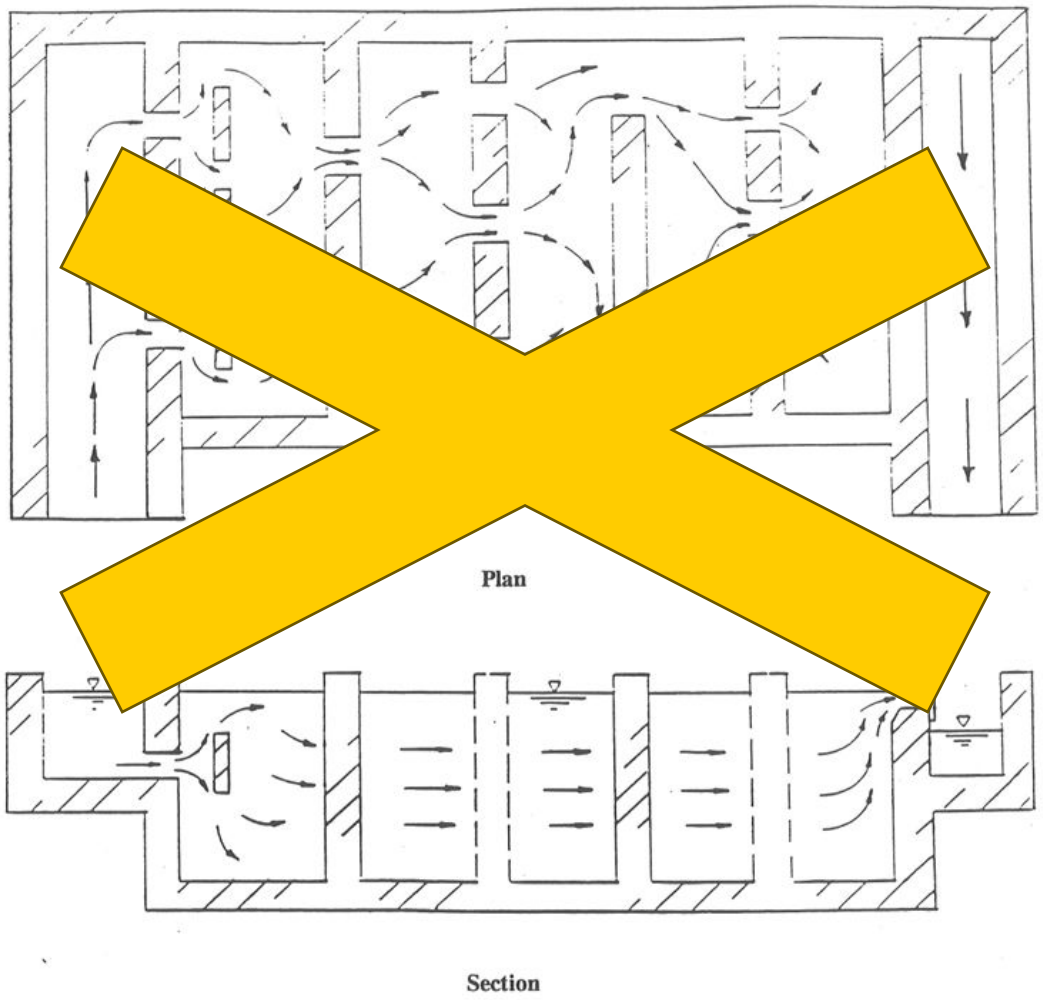
Effective volume

$$Time = \frac{Volume\ x\ Baffling\ efficiency}{Flowrate}$$

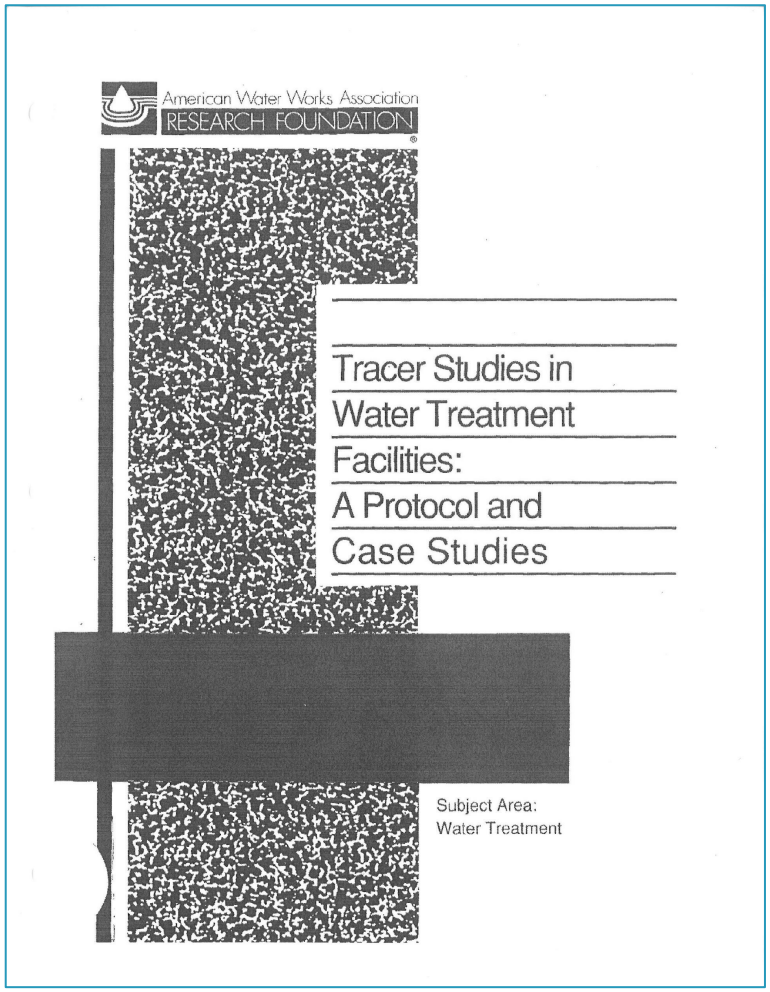
SWTR – Guidance

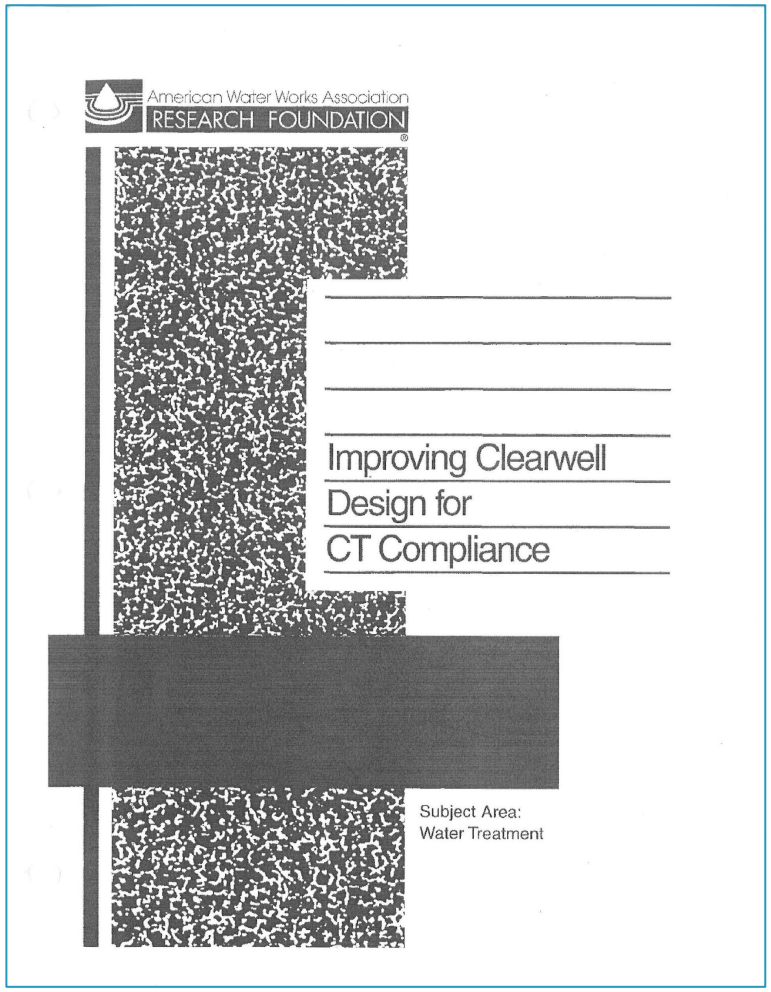
Baffling Conditions	T_{10}/T	Baffling Description
Unbaffled	0.1	None, agitated basin, [illegible]gth to width ratio, high inlet and o[illegible]ties.
Poor		Single o[illegible]d inlets and outlets, no
Average	0.[illegible]	[illegible]and outlet with some intra-basin
Superior		Perfora[illegible]erpentine or perforated intra-basin b[illegible]or perforated launderers.
Perfect Plug Flow	1.0	Very high length to width [illegible]o (pipeline flow), perforated inlet, outlet, and intra-basin baffles.

"Superior" Baffling – Really??



WaterRF – Updated References





Washington State Specific Requirements

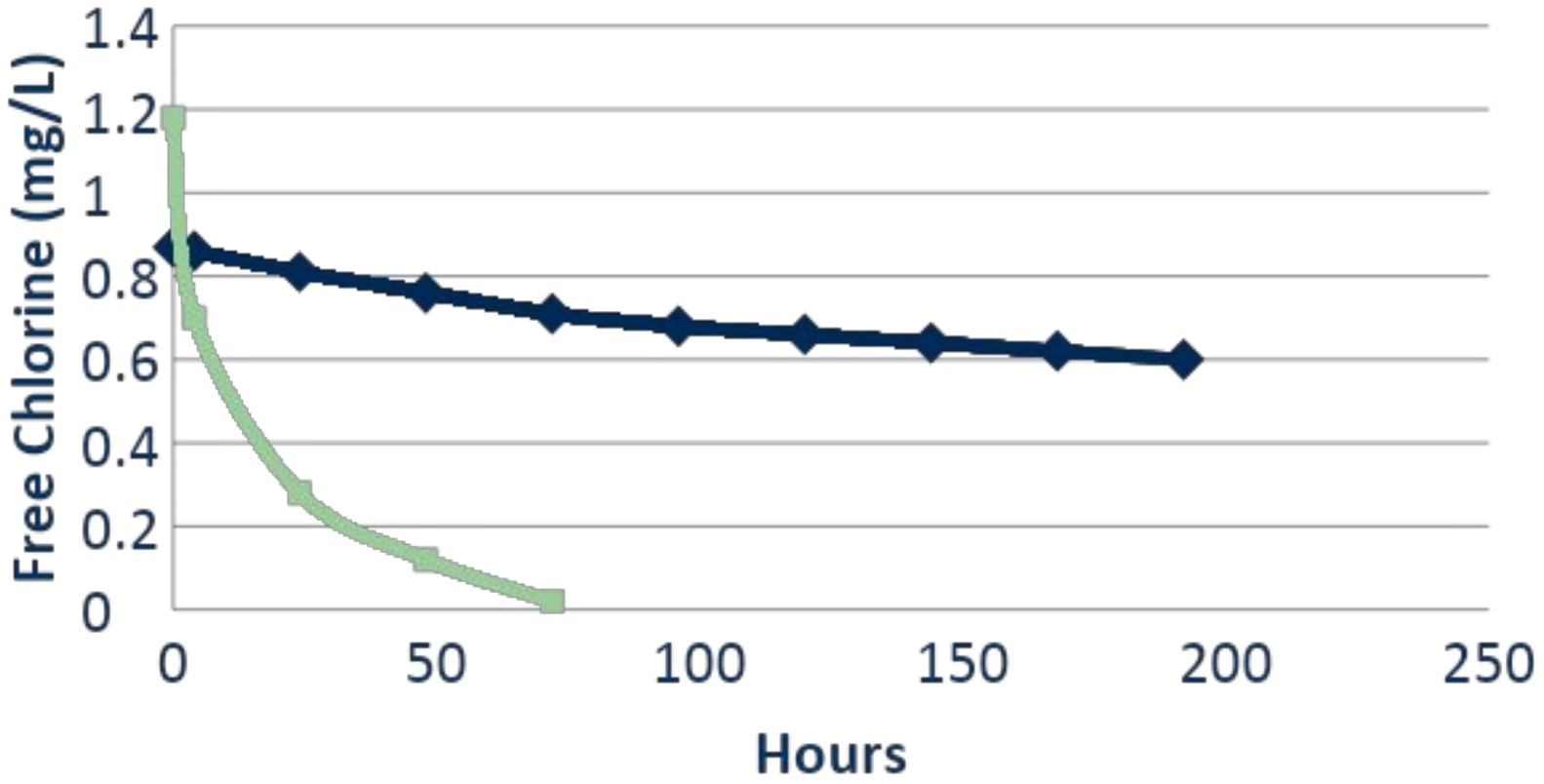
- Claimed BF >0.1 for surface water treatment plants require a tracer study be done
- Must submit a tracer study plan to DOH before conducting a tracer study (WAC 246-290-636(5))
- Refer to our Water System Design Manual, Appendix B.4 for a complete checklist of requirements

Tracer Selection

- Conservative (non-reactive, mass balance)
- Non-toxic (ANSI/NSF 60 approved)
- Easily measured and consideration of analytical methods
- Should mimic water
- Target dose is feasible
- Chemical feed equipment available, injection method
- Consumer acceptance
- Fluoride, Lithium, Sodium, Chloride, and Calcium (in some very limited cases, hypochlorite might be an option)

Chlorine as a Tracer?

Chlorine decay



Tracer Study Methods

- Slug Dose
  - Analytically more challenging
  - Prone to density currents due to concentrated solutions
  - Concentration/volume must be carefully calculated
  - Results require additional work/manipulation
  - Generally not recommended
- Step Dose
  - More easily controlled
  - Options for lead and lag side study
  - Results are easily determined directly, visual/graphical
  - Generally recommended

Sampling – Challenges/Concerns

- Tracer Analysis
- Sampling location
- Flow Conditions
- Manpower

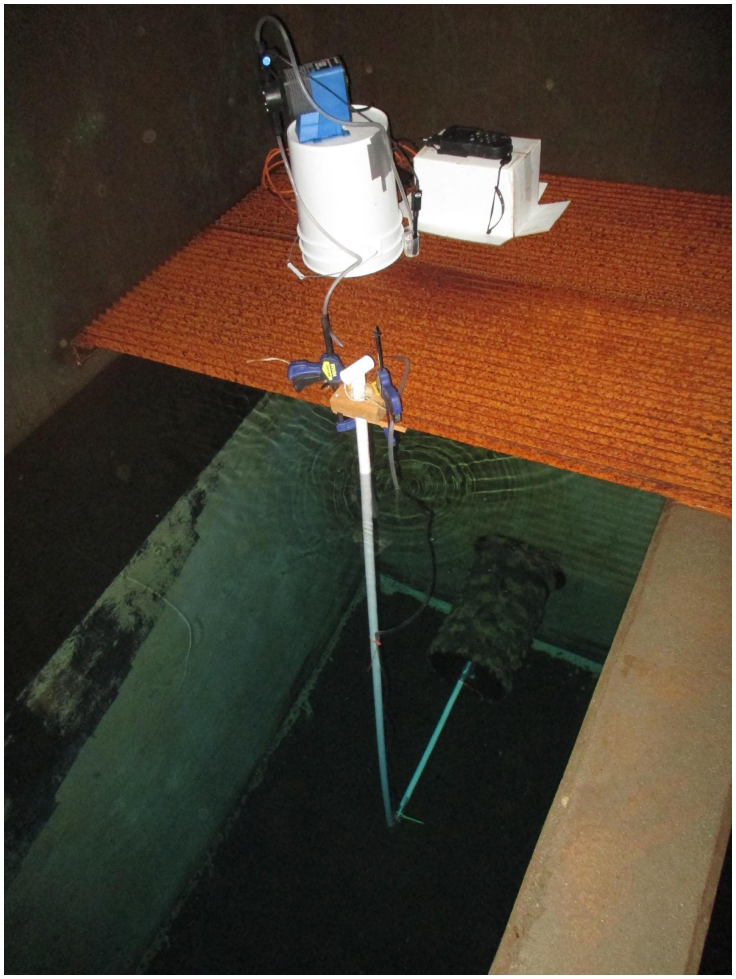


Photo credit: Gray & Osborne

Sampling Frequency & Duration

- Often enough so that T_{10}/T can be clearly identified

Period	Time between samples
Start to 0.25T	0.025T
0.25T to 1.5T	0.042T
1.5T to 2T	0.050T
2T to 3T	0.100T
3T to 4T	0.200T

Source: Teefy 1999

- Shortly after the point of tracer injection (frequency 0.10T) to confirm constant tracer addition and accurately estimate recovery
- Flow and clearwell level measurements continuously
- Continue to at least 95% recovery

Flow Rates

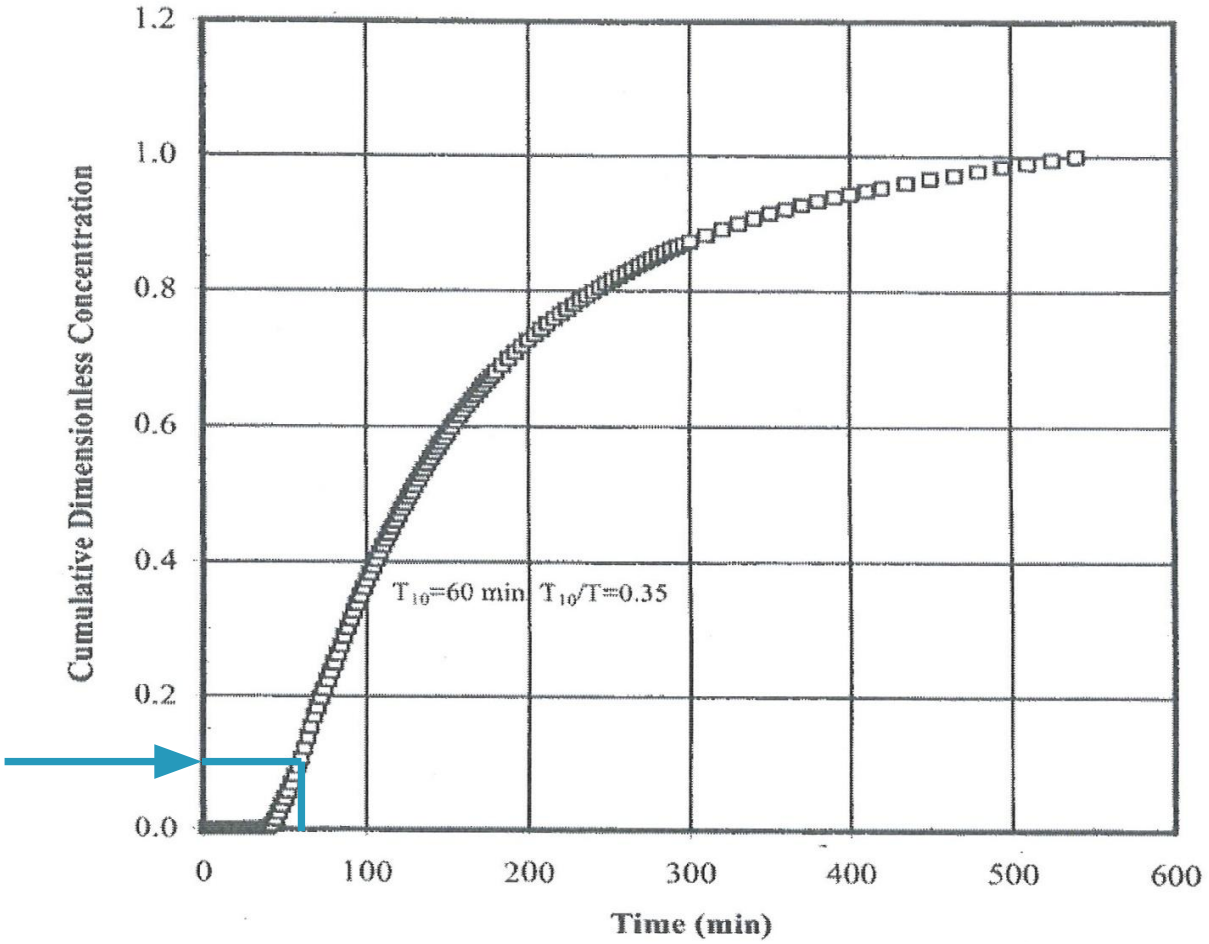
- Preferably 3 or 4 flow rates (normal low, average, and at least 91% of peak hourly flows)
- Option for computational fluid dynamic (CFD) modeling
- Anticipate changes in flow due to routine operations
- May need a plan to address excess water at higher flows

Data and Instrumentation

- **Critical** for the evaluation of the data
- Analytical method (range, sensitivity, accuracy, field or laboratory analysis)
- Field and facility instruments
- Level measurements – target to maintain near-constant water level
- Field data sheets

Example Step Dose Curve

T10/T = 0.35; HRT = 170 min; Test run for three HRTs



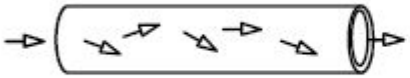
Baffling Efficiency

Influenced by basin geometry and transport of water

- Inlet conditions
- Outlet features
- Internal features, such as baffles
- Length to width ratios of channels
- Flow rate and residence time
- Velocity contours
- Stagnant and recirculation zones

Baffling Efficiency (cont)

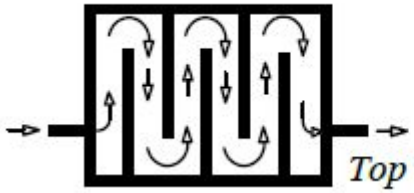
Higher Baffling Efficiency (BE) means less short circuiting



"Perfect"

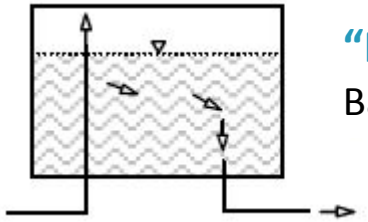
Baffling Efficiency = 100%

Plug flow through a significant length of pipe, little/no short-circuiting



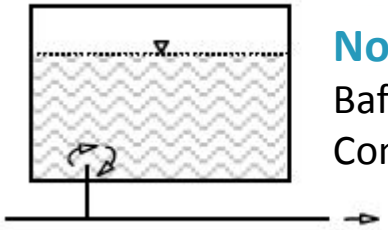
Baffled Tanks: "Average" to "Superior"

Baffling Efficiency = 20-70%



"Poor" Circulation

Baffling Efficiency ≤10%

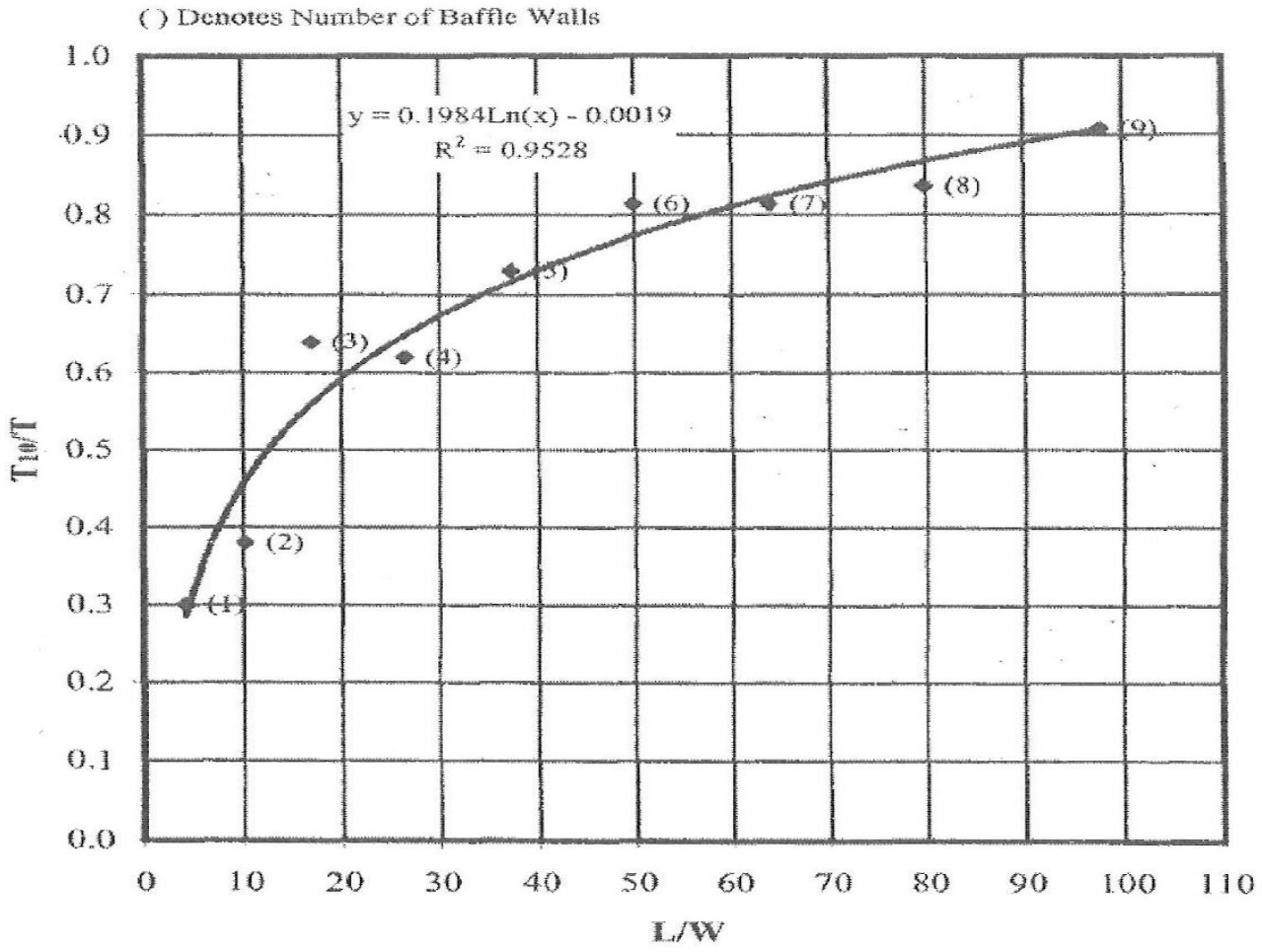


None

Baffling Efficiency = 0%

Complete short-circuiting possible

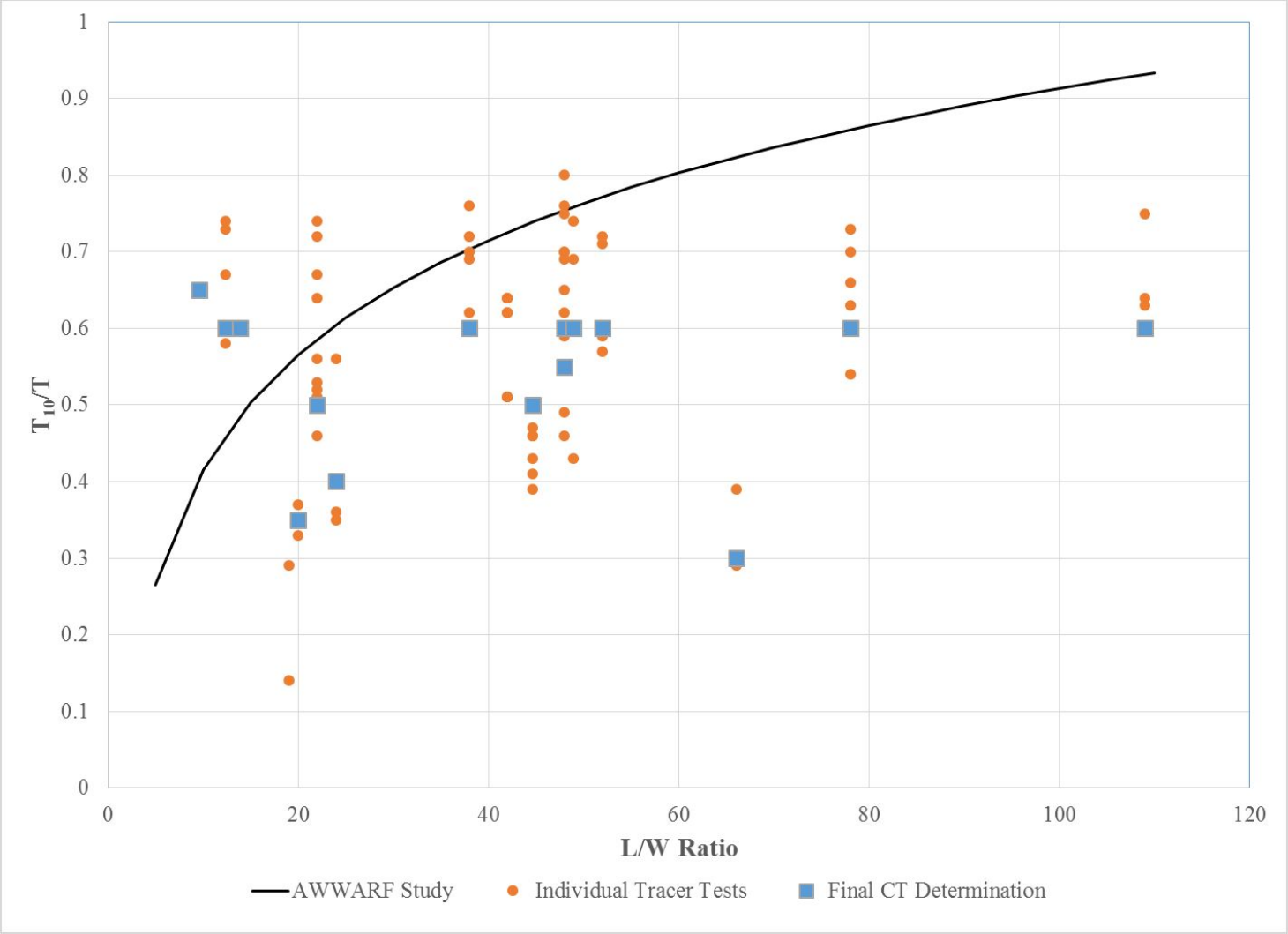
Baffled Rectangular Tank – Literature Values



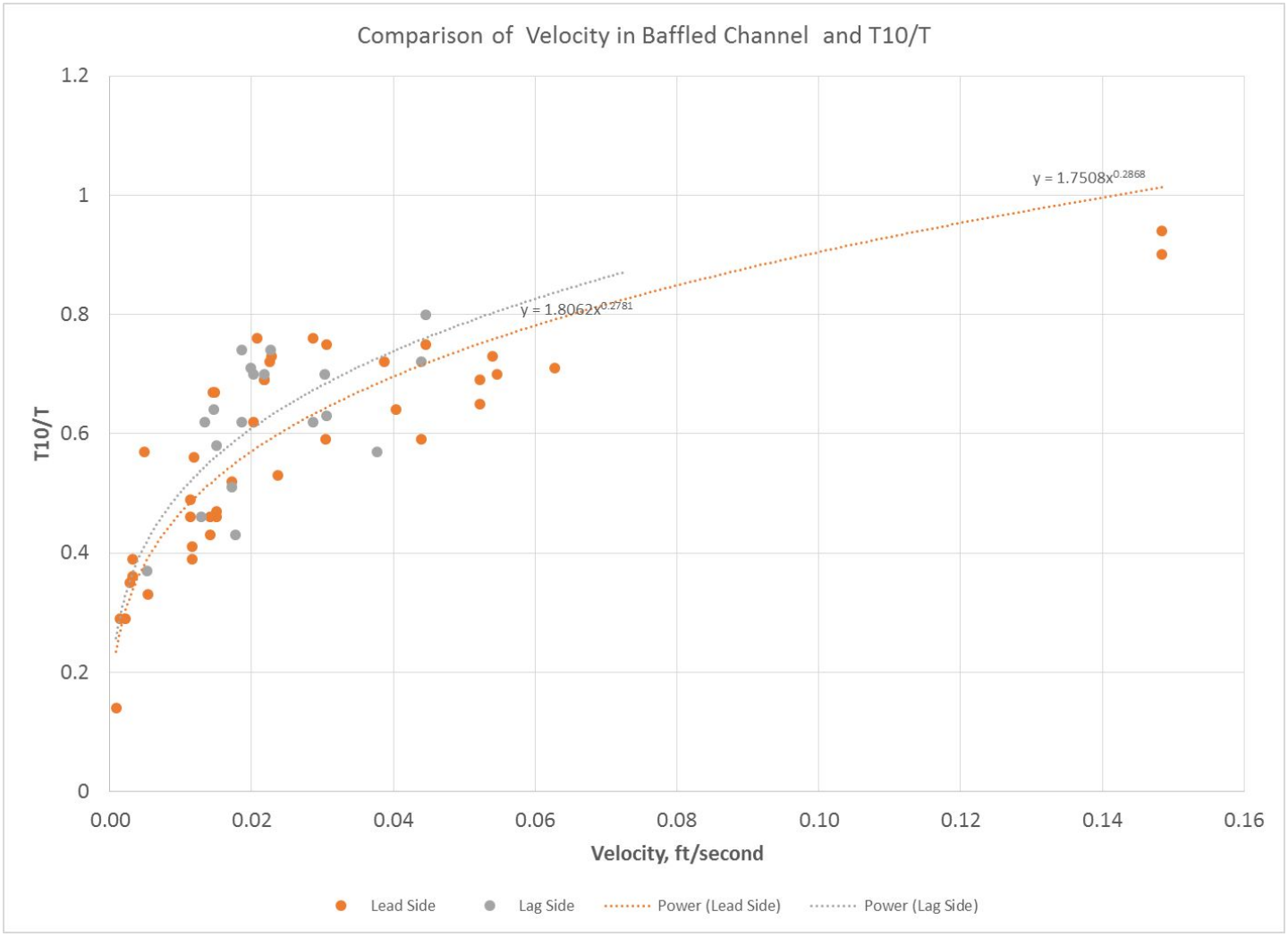
Length to width ratio are often used to predict T_{10}/T.

Source: AWWARF 1999

Wa DOH 2016 Tracer Study Project



Wa DOH 2016 Tracer Study Project (cont.)



Some Challenges

- Multiple clearwells/reservoirs – flow splitting
- Deep clearwells/reservoirs with very low flows
- Large diameter pipe may not provide BF=1.0 in some cases
- Large clearwells/reservoirs with long HRT
- Dual purpose reservoirs

Summary

- Disinfection contact time is a key part of treatment – CT
- Tracer studies are a key factor in determining reasonable baffling efficiencies
- Having a good plan going into a tracer study can help lead to success

References

- Crozes G., et al., 1999. *Improving Clearwell Design for CT Compliance.* AWWA Research Foundation. Denver, Co.
- Porter R.L., Stewart K.P., Feagin N., Perry S. 2018. *Baffling efficiency insights gained from tracer studies at 32 Washington treatment plants.* AWWA Wat Sci. ;e1115.
- Teefy, S. 1996. *Tracer Studies in Water Treatment Facilities: A Protocol and Case Studies.* AWWA Research Foundation. Denver, Co.
- Washington State Department of Health. *Water System Design Manual, Appendix B*. DOH publication 331-123.
- USEPA 1990. *Guidance Manual for Compliance with the Filtration and Disinfection Requirements for Public Water Systems Using Surface Water Sources – Appendix C: Determination of Disinfectant Contact Time*. USEPA, Washington, DC.

Questions?

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