Baffled by CT?

How the City of Anacortes used baffle design and clearwell redundancy to streamline compliance

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PNWS-AWWA

LEARNING OBJECTIVES

- What is the significance of CT?
- Why would a utility do a tracer test?
- How do you do a tracer test?
- How the City of Anacortes achieved regulatory compliance following clearwell and baffling upgrades

CITY OF ANACORTES WTP

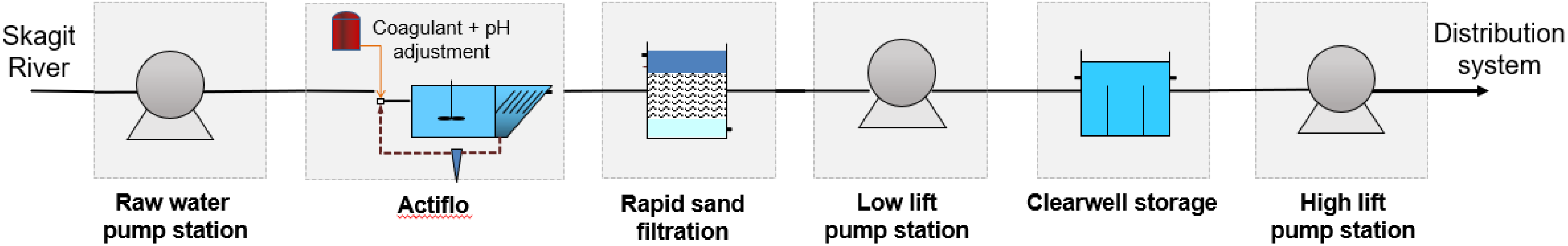
- History: Designed in 2010

- Production capacity:
- 42 MGD

- Hydraulic capacity:
- 54.9 MGD

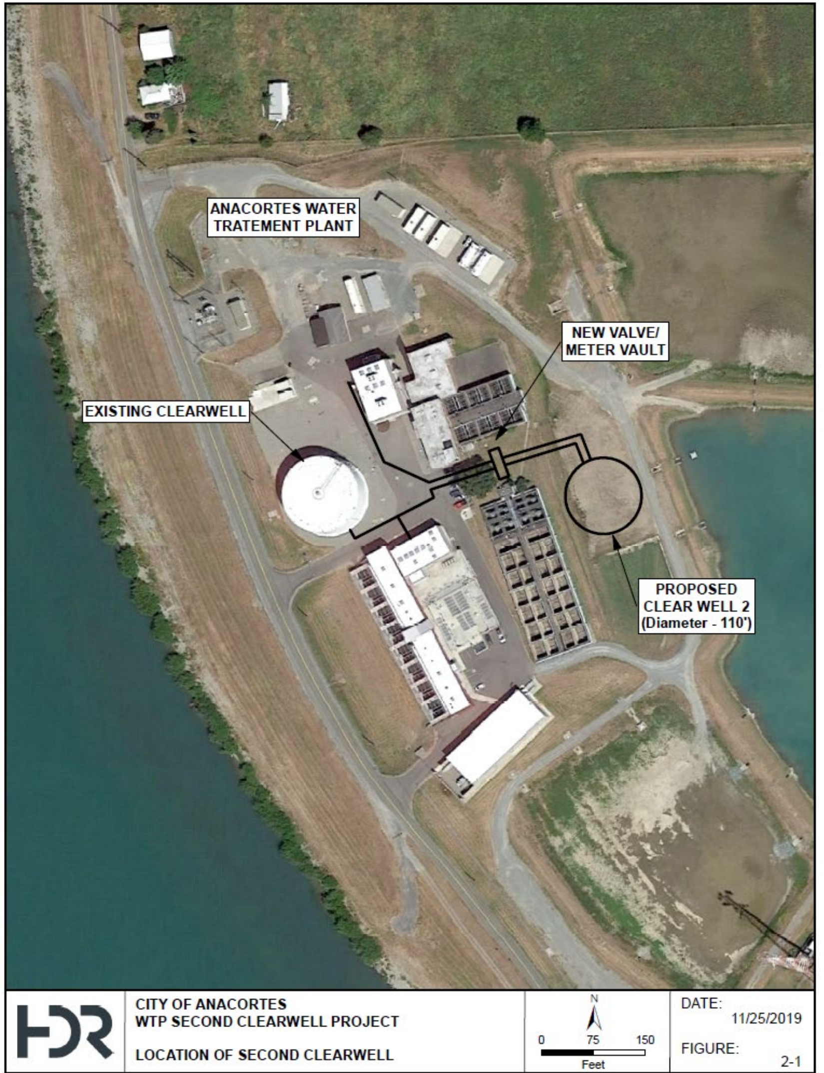
- Source: Skagit River

ANACORTES WTP PROCESS



PROJECT OBJECTIVES

- City of Anacortes WTP had an existing clearwell but required the transmission main to achieve the CT reqs at first customer.
- Existing clearwell (Clearwell 1) has no internal baffles, tracer testing showed a baffling factor of 0.20.
- The objectives of the project were:
    1. Construct a 2nd clearwell tank for the WTP that includes internal baffles for chlorine contacting efficiency.
    2. Install internal baffles in the existing clearwell for improved chlorine contacting efficiency.



WHAT WERE THE REQS?

The requirements for clearwell operations and baffling included:

1. The two clearwells must have identical hydraulic functions (operating and overflow elevations) and operate in parallel.
2. Either clearwell can be taken out-of-service for maintenance without impacting WTP production.
3. Provide a means of measuring and adjusting the flow rate through each clearwell.
4. Clearwell 1 must remain in-service at all times until Clearwell 2 is completed and in service.
5. Baffling Factor goal of 0.30

Why do we care about CT?

Surface Water Treatment Rule regs:

Overview of Requirements				
The purpose of this table is show how the requirements for the IESWTR and LT1ESWTR build on the existing requirements established in the original SWTR.				
APPLICABILITY: PWSs that use surface water or ground water under the direct influence of surface water (Subpart H) that practice slow sand, diatomaceous earth or alternative filtration.		**Final Rule Dates**		
		SWTR 1989	**IESWTR 1998**	**LT1ESWTR 2002**
Population Served	≥10,000	✓	✓	
	< 10,000	✓	N/A (except for sanitary survey provisions)	✓
Regulated Pathogens	99.99% (4-log) removal/inactivation of viruses	✓	Regulated under SWTR	Regulated under SWTR
	99.9% (3-log) removal/inactivation of *Giardia lamblia*	✓	Regulated under SWTR	Regulated under SWTR
	99% (2-log) removal of *Cryptosporidium*		✓	✓

SO what?

- Inactivation determined using <u>CT values,</u> dependent on disinfectant type/water temp/ water pH

Why do we care about CT?

CT = Disinfectant contact time

C (the concentration of free chlorine or other disinfectant in mg/L at the clearwell outlet) x

T (the disinfection contact time in minutes, at or before the first service connection)

For regulatory compliance, we use T10 = time at which 10% of water flow has passed through the clearwell

So you want disinfection credits? Assuming you know disinfectant, water pH, temp……

STEP 1: Use EPA tables to determine CT value required

STEP 2: Determine the T10 of your system via tracer testing or baffling factors

STEP 3: Set your disinfectant concentration accordingly

Baffling factor is an assessment of mixing efficiency

Baffling factor = $T10 / T_{theoretical}$

$T_{theoretical}$ = theoretical detention time = volume/ flow rate

also sometimes called hydraulic detention time (HDT)

T10= Time it takes for 10% of the water to pass through the basin

The term "**baffling factor**" is used to describe the degree of short-circuiting that occurs within a basin.

Accurate BF allows the correct inactivation values to be calculated and allows optimized disinfection performance to be maintained.

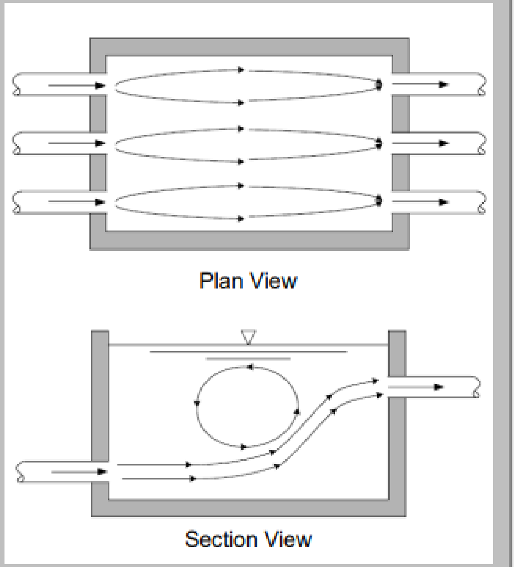


Figure 1: Example of poor baffling conditions of a rectangular clearwell (obtained from US EPA, 2003)

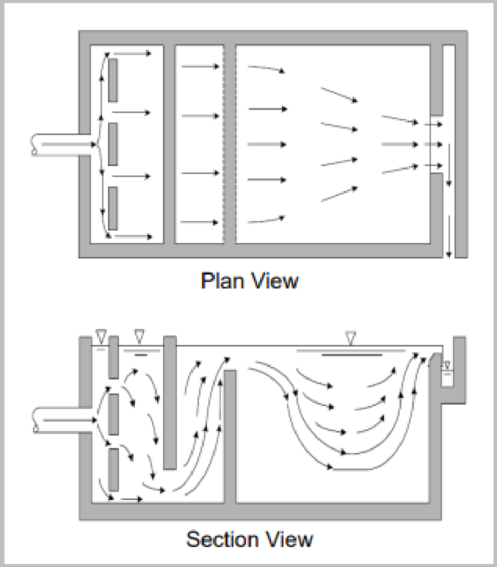


Figure 2: Example of average baffling conditions of a rectangular clearwell (obtained from US EPA, 2003)

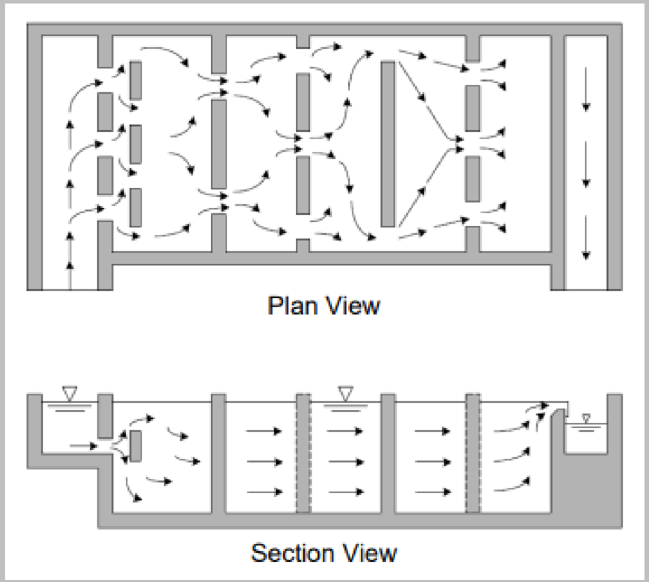


Figure 3: Example of superior baffling conditions of a rectangular clearwell (obtained from US EPA, 2003)

Figure courtesy: “Selection of a Baffling Factor for CT Calculations” Walkerson Clear Water Center, Government of Ontario Fact Sheet Issue 5, Volume 1 2015

Baffling can impact volume requirements up to one order of magnitude!

BAFFLING CONDITION	$T10/T_{theoretical} = BF$	BAFFLING DESCRIPTION
Unbaffled	0.1	No baffles, agitated basin, very low length to width ratio, high inlet and outlet flow velocities
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)

Baffling can impact volume requirements up to one order of magnitude!

Baffling factor = T10/ $T_{theoretical}$ = T10/ (V/Q)

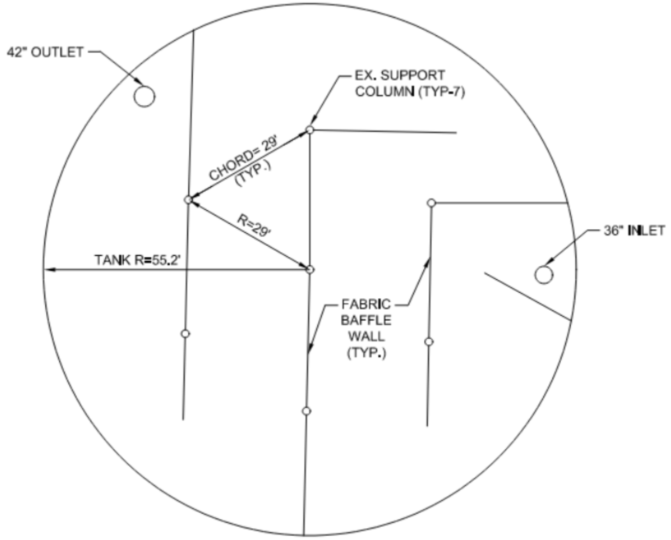
Assume you want a T10 of 12 mins for a flow of 694gpm (1 MGD).
How much more volume would you need for an unbaffled clearwell vs a perfect plug flow?

V = T10 x Q / BF

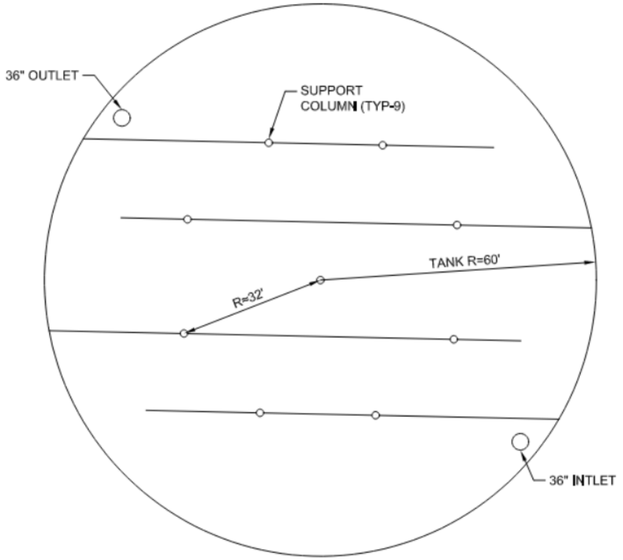
Unbaffled: Volume = 12 min x 694 gpm / 0.1 = 83, 280 gal
Plug flow: Volume = 12 min x 694 gpm / 1 = 8,328 gal

**potential order of magnitude difference in volume needed for disinfectant CT!*

ANACORTES WTP BAFFLE DESIGN



CLEARWELL 1
BAFFLE PLAN



CLEARWELL 2
BAFFLE PLAN

TRACER STUDIES QUANIFY THE AMOUNT OF MIXING IN A BASIN AND THE BF

What is required for a tracer test?

1) Select the target flow rates for the tracer tests.
2) Based on clearwell volume and configuration, estimate the theoretical detention time for each target flow rate.
3) Select the most appropriate tracer chemical and chemical feed method to be used for the testing.
4) Determine the tracer chemical, injection/sample points, and analytical procedures.
5) Conduct the tracer tests.
6) Analyze the data to determine appropriate T10 and BF values for the clearwell.

Other reasons we care about tracer studies

- **Regulatory compliance**
  - For Anacortes- baffling and/or new basin
- Disinfectant application point
- Flow changes
  - Higher peak flows?
- Validating numbers
- Any others?

1. Select the target flow rates for the tracer tests.

Want to test range of operating conditions including worst case (highest flow at lowest operating depth)

- Flow rates selected based on the following criteria:
  - Flow Rate #1 – 10,000 gpm (14.4 MGD)
  - Flow Rate #2 – 21,000 gpm (30.2 MGD)

- Clearwell water depth operated between 27 to 30 ft.
  - Minimum operating water depth = most conservative operating condition
  - Choose depths of 25 ft and 30ft

- Clearwell volume held constant throughout tracer tests

Major lesson #1: Had to work with downstream users for both max and min flow conditions

2. Based on clearwell volume and configuration, estimate the theoretical detention time for each target flow rate.

Clearwell	Volume (MG)			Target test flow rate (MGD)	Target clearwell depth (ft)	$T_{Theoretical}$ = Q/V (T) (minutes)	Anticipated (T_{10}) *assuming T_{10}/T = 0.3 (minutes)
	Clearwell	Contacting component	Total				
1	2.13	.096	2.22	30.2	30	106	32
1	1.77	.096	1.87	14.4	25	187	56
2	2.13	.117	2.24	30.2	30	107	32
2	1.77	.117	1.89	14.4	25	189	57

3. Select the most appropriate tracer chemical and method of chemical feed to be used for the testing.

Fluoride selected as tracer chemical

- Other options include alum, calcium chloride, sodium carbonate. Chloride/fluoride most popular.
- Rationale
  - The City's water distribution system is currently fluoridated.
  - The City is familiar with NaF feed systems and has chemicals on-hand to prepare the tracer solutions.

Major lesson #2: fluoride saturator/injection system design critical!!!

4. Determine the tracer chemical, injection/sample points, and analytical procedures.

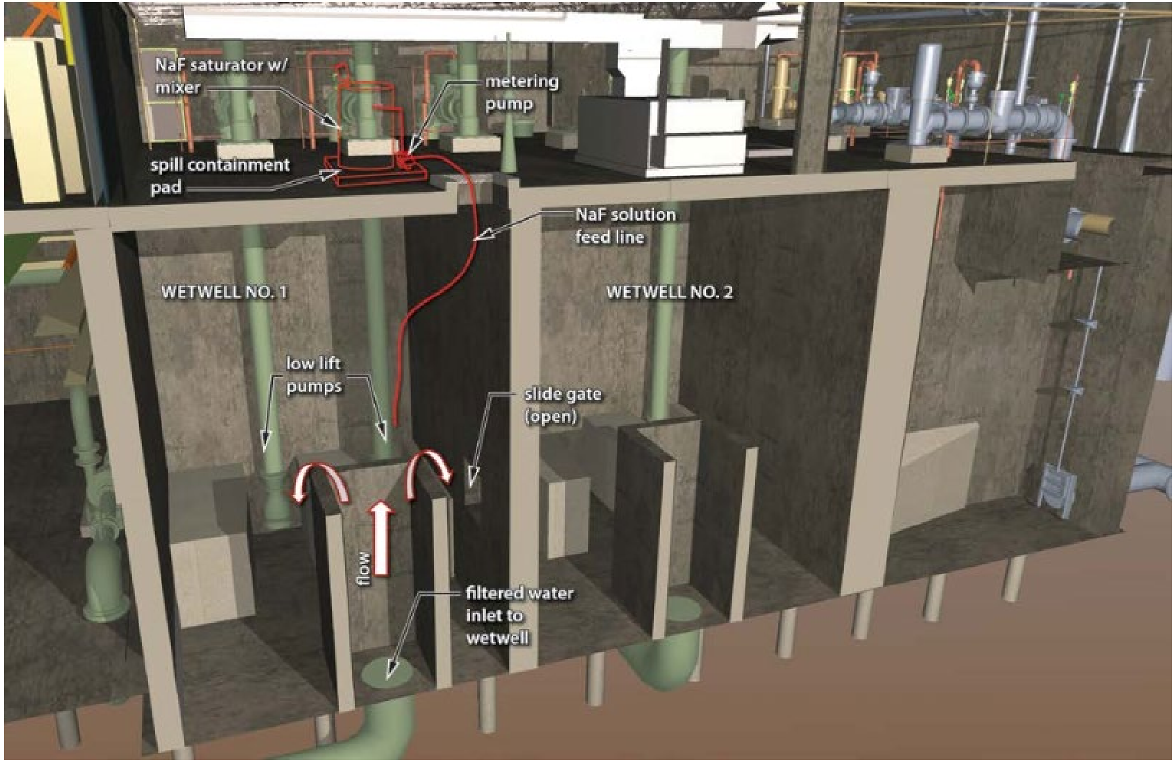
Injection point: Low lift pump station

Tracer measurement points

- Influent to clearwell
- Effluent fluoride concentration from discharge side of high service pumps

Things to think about:

- Where is good mixing
- Where do you have access to pull sample? Sample port/ scoop/ etc? Do you have to pump?
- Automatic vs manual sampling?
- May be 100s of bottles…



4. Determine the tracer chemical, injection/sample points, and analytical procedures.

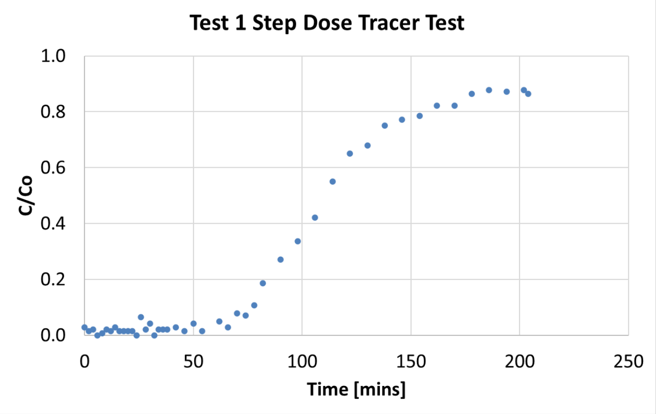
	Approach	Pros	Cons
Slug Dose	Inject a “slug” or set volume of chemical into system until entire dose has passed through	Requires less chemical	Takes longer as all of tracer element must be eliminated from process stream
Step Dose	Inject at a constant dosage until the system reaches steady state	Good if already using chemical in water system	Requires additional pump capacity
Modified Step Dose	Same at step dose, but only run test until 10% of total tracer mass has left the reactor	Shorter run times	Need higher concentration Requires more predictive modeling capabilities

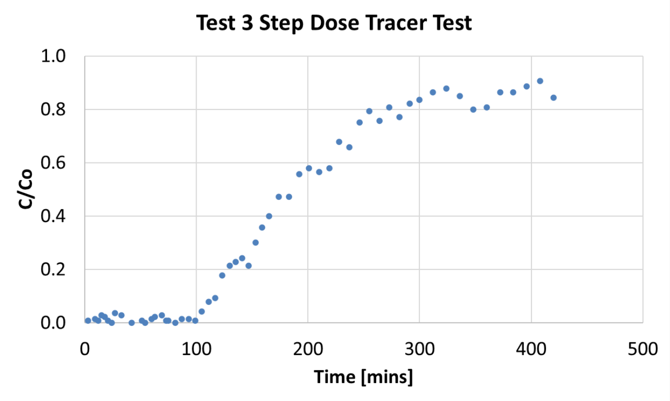
5. Conduct the tracer tests

- Lesson #3- Incorporating tracer tests into ongoing WTF operations requires (sometimes extensive) consideration.

On the day of test 4 , the WTP staff determined that the target flow rate of 14.4 MGD (10,000 gpm) could not be sustained for the planned duration of the test. Therefore, the target flow was adjusted to 16.56 MGD (11,500 gpm).

	Test Flow Rate (MGD)		Clearwell Operating Depth (feet)	
Test	Target	Average and Deviation During Test	Target	Average and Deviation During Test
1	30.24	29.45 +/- 1.60	30.0	30.00 +/- 0.04
2	30.24	30.11 +/- 0.70	30.0	30.02 +/- 0.03
3	14.4	15.24 +/- 0.49	25.0	25.13 +/- 0.06
4	16.6*	17.24 +/- 1.34	25.0	25.05 +/- 0.02





6. Analyze the data to determine appropriate T10 and BF values for the clearwell.

- Use EPA tools for data analysis based on the method selected
- Will have to analyze for all seasons, flow conditions, operating depths, etc

Test	Clearwell	Flow [MGD]	Depth [ft]	Theo. Detention time (T) [mins]	T10 [mins]	T10/T = BF
1	1	29.45	30.00	109	39.1	0.36
2	2	30.11	30.02	107	41.0	0.38
3	2	15.24	25.13	179	68.6	0.38
4	1	17.24	25.05	156	62.5	0.40

CONCLUSIONS

1. A value 0.35 for the T_{10}/T ratio can be assumed for CT compliance using the clearwells.
2. DOH compliant ☺

If CT= 60 mg/min/L, difference in BF= 3.0 vs 3.5?

- CT = conc x BF x volume/Q
- Conc = CT x Q / BF x vol =
- 60 mg*min/L x 42MGD (day/ 1440 min) / 0.3 x 2.1 MG = 2.8 mg/L
- 60 mg*min/L x 42MGD (day/ 1440 min) / 0.35 x 2.1 MG = 2.4 mg/L

Dosing difference = 0.4 mg Cl /L = @ 42 MGD ~3000 lbs NaOCl (sixty 50lb sacks) annually

Thank you!

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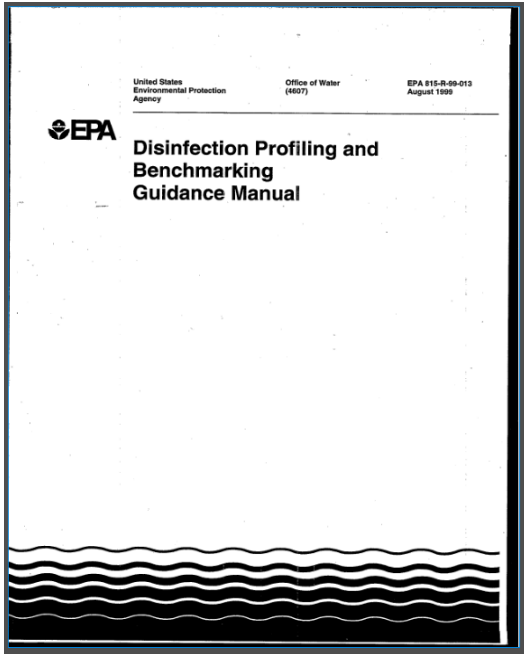
RESOURCES

Chlorine Contact Time for Small Water Systems 331-343 WA DOH
https://doh.wa.gov/sites/default/files/legacy/Documents/Pubs/331-343.pdf

Contact Time (CT) Calculator
https://www.epa.gov/sites/default/files/2016-10/epactcalculator_0.xls

EPA Disinfection Profiling and Benchmarking Guidance Manual
Disinfection Profiling and Benchmarking: Technical Guidance (epa.gov)


United States Environmental Protection Agency
Office of Water (4607)
EPA 815-R-99-013 August 1999
EPA
Disinfection Profiling and Benchmarking Guidance Manual

Regulatory compliance

1. The clearwell target operating depth should be maintained at or near 30 feet to maximize the CT achieved under the widest range of water quality conditions and flow rates.
2. Under typical winter water temperature conditions (4^{o}C), the required *Giardia* Inactivation Ratio (IR) of 1.0 or greater to meet CT compliance is achieved at flow rates up to 38 MGD with a chlorine residual of not less than 1.0 mg/L, pH not greater than 7.0, and clearwell level at 30 feet. At flow rates greater than 38 MGD, the chlorine residual will need to be increased to maintain CT compliance. See Table 13 below.
3. With water temperatures at 10^{o}C, which is a typical temperature in late spring / early summer when some higher system demands may occur, the required *Giardia* IR of 1.0 or greater to meet CT compliance is achieved at all system flow rates with a chlorine residual of not less than 1.0 mg/L, pH not greater than 7.0, and clearwell depth of 25 feet or higher.

Table 10. CT model results for typical winter water conditions.

Operating Depth - 25 FT													
										Giardia			
Flow Rate	Flow Rate	Operating Depth	Clearwell Volume	Theor. HDT	T_{10} / T	Contact Time T10	Chlorine Residual	pH	Water Temp	CT Achieved	Required Inactivation	CT Required	Inactivation Ratio
(gpm)	(MGD)	(ft)	(gal)	(min)		(min)	(mg/L)		(^{o}C)	(mg-min/L)	(log)	(mg-min/L)	(CT_{ach}/CT_{req})
6944	10.00	25.00	1,773,007	255	0.35	89.4	1.00	7.0	4.0	89.4	0.5	28.4	3.14
8332.8	12.00	25.00	1,773,007	213	0.35	74.5	1.00	7.0	4.0	74.5	0.5	28.4	2.62
9721.6	14.00	25.00	1,773,007	182	0.35	63.8	1.00	7.0	4.0	63.8	0.5	28.4	2.24
11110.4	16.00	25.00	1,773,007	160	0.35	55.9	1.00	7.0	4.0	55.9	0.5	28.4	1.96
12499.2	18.00	25.00	1,773,007	142	0.35	49.6	1.00	7.0	4.0	49.6	0.5	28.4	1.75
13888	20.00	25.00	1,773,007	128	0.35	44.7	1.00	7.0	4.0	44.7	0.5	28.4	1.57
15276.8	22.00	25.00	1,773,007	116	0.35	40.6	1.00	7.0	4.0	40.6	0.5	28.4	1.43
16665.6	24.00	25.00	1,773,007	106	0.35	37.2	1.00	7.0	4.0	37.2	0.5	28.4	1.31
18054.4	26.00	25.00	1,773,007	98	0.35	34.4	1.00	7.0	4.0	34.4	0.5	28.4	1.21
19443.2	28.00	25.00	1,773,007	91	0.35	31.9	1.00	7.0	4.0	31.9	0.5	28.4	1.12
20832	30.00	25.00	1,773,007	85	0.35	29.8	1.00	7.0	4.0	29.8	0.5	28.4	1.05
22220.8	32.00	25.00	1,773,007	80	0.35	27.9	1.00	7.0	4.0	27.9	0.5	28.4	0.98
23609.6	34.00	25.00	1,773,007	75	0.35	26.3	1.00	7.0	4.0	26.3	0.5	28.4	0.92
24998.4	36.00	25.00	1,773,007	71	0.35	24.8	1.00	7.0	4.0	24.8	0.5	28.4	0.87
26387.2	38.00	25.00	1,773,007	67	0.35	23.5	1.00	7.0	4.0	23.5	0.5	28.4	0.83
27776	40.00	25.00	1,773,007	64	0.35	22.3	1.00	7.0	4.0	22.3	0.5	28.4	0.79
29164.8	42.00	25.00	1,773,007	61	0.35	21.3	1.00	7.0	4.0	21.3	0.5	28.4	0.75
Notes:	1				2			3	4				5