APPENDIX F

Sample CT Calculations

EXAMPLE 1

Source Water - Surface Water

The source water is surface water from a river.

Treatment Requirements

Based on source water conditions, the treatment requirements are set at:

3.0-log reduction for *Cryptosporidium* and *Giardia*;

4.0-log reduction for viruses.

Filtration Credits (Log Removal)

The treatment facility is a direct filtration plant. Individual filter effluent turbidity was reviewed and meets the limits of 0.2 NTU 95% of the time. Therefore, this facility receives the following filtration credits towards meeting the treatment requirements:

2.5-log reduction for *Cryptosporidium*;

2.5-log reduction for *Giardia*;

1.0-log reduction for viruses.

Based on the above, log inactivation (disinfection) must provide the following log reduction:

Cryptosporidium		3.0-log reduction required
	Subtract	2.5-log filtration credit
	Equals	**0.5-log** inactivation credit needed
Giardia		3.0-log reduction required
	Subtract	2.5-log filtration credit
	Equals	**0.5-log** inactivation credit needed
Viruses		4.0-log reduction required
	Subtract	1.0-log filtration credit
	Equals	**3.0-log** inactivation credit needed

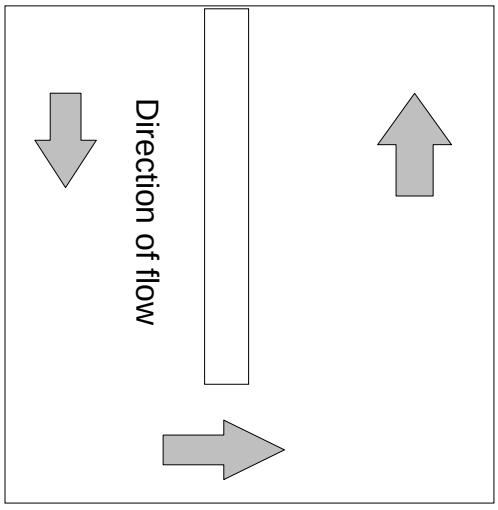
Treatment Deficiency #1

Because this facility has a shortfall in log removal credits for *Cryptosporidium*, an alternate disinfectant such as UV, chlorine dioxide or ozone will be required to meet treatment requirements.

In this example, UV is selected. The UV unit has a minimum dose of 40 mJ/cm^2. This is sufficient to receive a 4-log inactivation credit for *Cryptosporidium* and *Giardia* (see IT tables in Appendix D) which meets the above shortfalls. UV is only assigned a 0.5-log inactivation credit for viruses based on adenovirus. As such, 2.5-log inactivation is required by chlorine.

Disinfection Credits (Log Inactivation)

The contact chamber has the following configuration:



Contact Chamber Specifications:

Volume:	270 cubic metres
Max. Flow:	4.1 MLD
Dimensions:	9.1 m x 10 m x 3 m
Baffling:	Single Baffle
Min. Temperature:	5^{o}C
Highest pH:	7.6

This facility uses free chlorine for primary disinfection. In the winter, the facility has a minimum of 1.0 mg/L free chlorine residual leaving the contact chamber.

Based on the configuration of the contact chamber the length to width ratio is 2:1, which is poor. A baffling factor of 0.3 can be used.

Tank low level occurs when the tank is 70% full.

CT Calculation

Volume of chamber: 270 cubic metres = 270 000 L = 0.27 ML x 0.7 (low level) = 0.189ML

Contact time$_{actual}$: Volume ÷ Max. Flow = 0.189 ML ÷ 4.1 MLD = 0.0461 days x 24hours per day x 60 minutes per hour = 66.4 minutes

CT_{actual}: Concentration of disinfectant x contact time x baffling factor = 1.0 mg/L x 66.4 minutes x 0.3 = 19.9 mg.min/L

$CT_{required}$ (*Giardia*): UV disinfection is providing 4.0-log inactivation for *Cryptosporidium* and *Giardia*.

Adequate for 0.5-log *Giardia*? Yes

$CT_{required}$ (Viruses): Referring to the CT tables in Appendix D, 8 mg.min/L provides 4-log inactivation of viruses at 5°C, pH 6-9

Adequate for viruses? $CT_{actual} \div CT_{required} = 19.9 \div 8 = 2.49$ (greater than 1)
Therefore adequate

Conclusion

This facility will require the installation of an alternate disinfectant, in this example UV, to provide sufficient disinfection for Cryptosporidium and Giardia inactivation. Chemical disinfection will also be required to provide adequate disinfection for virus inactivation based on adenovirus.

EXAMPLE 2

Source Water - Surface Water

The source water is surface water from a lake.

Treatment Requirements

Based on source water conditions, the treatment requirements are set at:

- 3.0-log reduction for *Cryptosporidium* and *Giardia*;
- 4.0-log reduction for viruses.

Filtration Credits (Log Removal)

The treatment facility is a conventional filtration plant. Individual filter effluent turbidity was reviewed and meets the limits of 0.2 NTU 95% of the time. Therefore, this facility receives the following filtration credits towards meeting the treatment requirements:

- 3.0-log reduction for *Cryptosporidium*;
- 3.0-log reduction for *Giardia*;
- 2.0-log reduction for viruses.

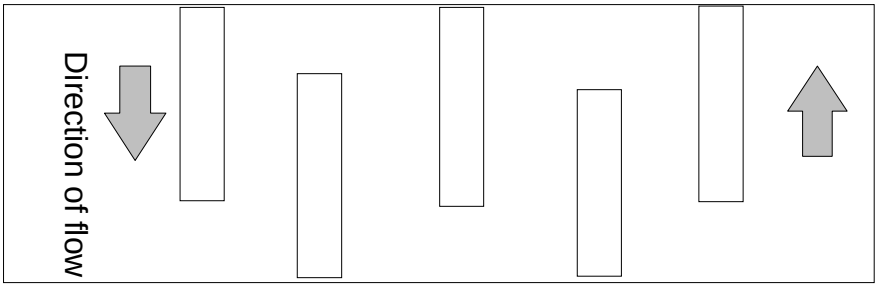
Based on the above, log inactivation (disinfection) must provide the following log reduction:

Cryptosporidium		3.0-log reduction required
	Subtract	3.0-log filtration credit
	Equals	**0.0-log** inactivation credit needed
Giardia		3.0-log reduction required
	Subtract	3.0-log filtration credit
	Equals	**0.0-log** inactivation credit needed
Viruses		4.0-log reduction required
	Subtract	2.0-log filtration credit
	Equals	**2.0-log** inactivation credit needed

There is no shortfall in log removal credits for *Cryptosporidium* in this example.

Disinfection Credits (Log Inactivation)

The contact chamber has the following configuration:



Contact Chamber Specifications:	
Volume:	303 cubic metres
Max. Flow:	3.1 MLD
Dimensions:	5.1 m x 20 m x 3 m
Baffling:	Five Baffles
Min. Temperature:	7°CHighest pH:7.3

This facility uses free chlorine for primary disinfection. In the winter, the facility has a minimum of 0.4 mg/L free chlorine residual leaving the contact chamber.

Based on the configuration of the contact chamber the length to width ratio is 4:1, and multiple baffles, which is good. A baffling factor of 0.7 can be used.

Tank low level occurs when the tank is 85% full.

CT Calculation

Volume of chamber: 303 cubic metres = 303 000 L = 0.303 ML x 0.85 (low level) = 0.258 ML

Contact time$_{actual}$: Volume ÷ Max. Flow = 0.258 ML ÷ 3.1 MLD = 0.0832 days x 24 hours per day x 60 minutes per hour = 119.8 minutes

CT_{actual}: Concentration of disinfectant x contact time x baffling factor =0.4 mg/L x 119.8 minutes x 0.7 = 33.5

Adequate for 0.5-log *Giardia*? Referring to CT Tables in Appendix D:

CT at 5°C and pH 7.0 = 23

CT at 5°C and pH 7.5 = 28

CT at 10°C and pH 7.0 = 18

CT at 10° and pH 7.5 = 21

Therefore:

CT at 7°C and pH 7.3 = 21.6 mg.min/L

$CT_{actual} \div CT_{required}$ = 33.5 ÷ 21.6 = 1.55 (greater than 1)

Therefore adequate

$CT_{required}$ (Viruses): Referring to CT tables in Appendix D,

8.0 mg.min/L provides 4.0-log inactivation of viruses

Adequate for viruses? $CT_{actual} \div CT_{required}$ = 33.5 ÷ 8.0 = 4.19 (greater than 1)

Therefore adequate

Conclusion

This facility adequately removes and inactivates *Cryptosporidium*, *Giardia* and *viruses* and meets Nova Scotia's Drinking Water Treatment Standards.

EXAMPLE 3

Source Water - High Risk GUDI Source

This example demonstrates the requirements for groundwater under the direct influence of surface water. The results from the GUDI protocol indicate that the drilled wells serving the facility have been classified as GUDI – High Risk. This classification has been accepted in writing by a Department Regional Hydrogeologist.

Treatment Requirements

Since the facility has been classified as GUDI – High Risk, the facility requires engineered filtration for pathogen reduction. The treatment requirements for this facility are:

- 3 - Log reduction for *Cryptosporidium* and *Giardia*;
- 4 - Log reduction for viruses.

Filtration Credits (Log Removal)

The facility has a micro-filtration (MF) membrane system with pre-coagulation. Individual filter effluent turbidity was reviewed and meets the limits of 0.1 NTU 99% of the time. Direct integrity testing indicates that the membrane provides 3.14-log removal for protozoa (e.g. *Cryptosporidium* oocysts and *Giardia* cysts). The system receives no credits for the removal for viruses. Therefore, this facility receives the following filtration credits towards meeting the treatment requirements:

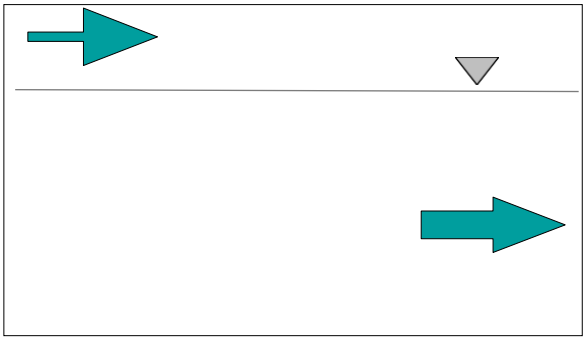
- 3.14-log reduction for *Cryptosporidium*;
- 3.14-log reduction for *Giardia*;
- 0.0-log reduction for viruses.

Based on the above, log inactivation must provide the following log reduction:

Cryptosporidium		3.00-log reduction required
	Subtract	3.14-log filtration credit
	Equals	**0.0-log** inactivation credit needed
Giardia		3.00-log reduction required
	Subtract	3.14-log filtration credit
	Equals	**0.0-log** inactivation credit needed
Viruses		4.0-log reduction required
	Subtract	0.0-log filtration credit
	Equals	**4.0-log** inactivation credit needed

There is no shortfall in log removal credits for *Cryptosporidium* in this example.

The contact chamber has the following configuration:



Contact Chamber Specifications:

Volume:	750 cubic metres
Max. Flow:	12.5 MLD
Dimensions:	5.1 m x 20 m x 3 mBaffling:no baffles, inlet at top of basin, outletat bottom of basin
Min. Temperature:	5°CHighest pH:7.5

The facility uses free chlorine. In the winter, the facility has a minimum of 1.2 mg/ L free chlorine leaving the contact chamber.

Based on the configuration of the contact chamber, there is no baffling with poor mixing. A baffling factor of 0.1 can be used.

Tank low level occurs when the tank is 85% full.

CT Calculation

Volume of chamber: 750 cubic metres = 750 000 L = 0.750 ML x 0.85 (low level) = 0.6375 ML

Contact time$_{actual}$: Volume ÷ Max. Flow = 0.6375 ML ÷ 12.5 MLD = 0.051 days x 24 hours per day x 60 minutes per hour = 73.4 minutes

CT$_{actual}$: Concentration of disinfectant x contact time x baffling factor = 1.2 mg/L x 73.4 minutes x 0.1 = 8.81 mg.min/L

CT$_{required}$ (*Giardia*): Referring to the CT tables in Appendix D, for 0.5-log inactivation of *Giardia* at 5°C and pH 7.5,

CT = 28 mg.min/L

Adequate for 0.5-log *Giardia*?

$CT_{actual} \div CT_{required} = 8.81 \div 28 = 0.31$ (less than 1)

Therefore <u>not</u> adequate

CT$_{required}$ (Viruses): Referring to the CT tables in Appendix D, 8 mg.min/L provides 4.0-log inactivation of viruses at 5°C, pH 6-9

Adequate for viruses? $CT_{actual} \div CT_{required} = 8.81 \div 8 = 1.1$ (greater than 1)
Therefore adequate

Conclusion

The current configuration of the contact chamber is <u>not</u> sufficient to provide 0.5-log inactivation for *Giardia*.The contact chamber can be increased in size, the baffling improved, the chlorine residual increased or UV disinfection can be added.

EXAMPLE 4

Source Water - Medium Risk GUDI Source

This example demonstrates the requirements for groundwater under the direct influence of surface water. The results from the GUDI protocol indicate that the drilled wells serving the facility have been classified as GUDI – Medium Risk. This classification has been accepted in writing by a Department Regional Hydrogeologist.

Treatment Requirements

Since the facility has been classified as a GUDI – Medium Risk, the treatment requirements for this facility are:

- 3 - Log reduction for *Cryptosporidium* and *Giardia*;
- 4 - Log reduction for viruses.

Filtration Credits (Log Removal)

A medium risk GUDI facility is eligible for a 1.0-log natural filtration credit for protozoa if the *Guidelines for the Determination of Natural Filtration Log Removal for Protozoa* are followed (see Appendix B) and a Department Regional Hydrogeologist accepts the determination in writing. This process has been completed and accepted by the Department.

Therefore, this facility receives the following filtration credits towards meeting the treatment requirements:

- 1.0-log reduction for *Cryptosporidium*;
- 1.0-log reduction for *Giardia*;
- 0.0-log reduction for viruses.

Based on the above, log inactivation must provide the following log reduction:

Cryptosporidium		3.0-log reduction required
	Subtract	1.0-log filtration credit
	Equals	**2.0-log** inactivation credit needed
Giardia		3.00-log reduction required
	Subtract	1.0-log filtration credit
	Equals	**2.0-log** inactivation credit needed
Viruses		4.0-log reduction required
	Subtract	0.0-log filtration credit
	Equals	**4.0-log** inactivation credit needed

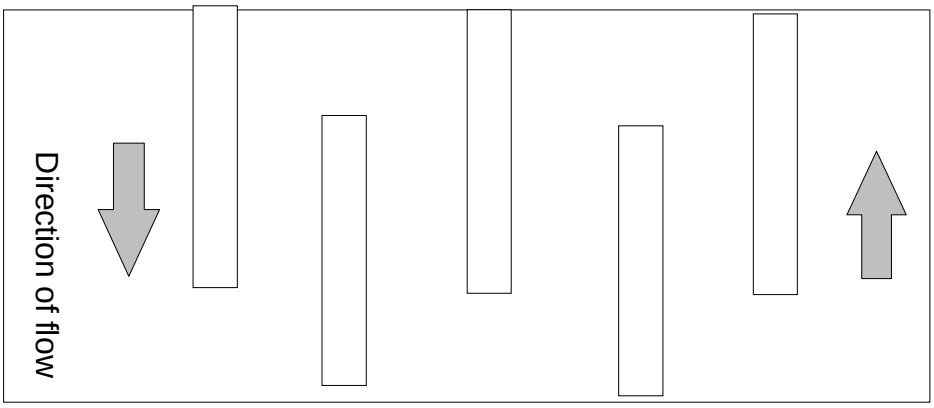
Treatment Deficiency #1

Because this facility has a shortfall in log removal credits for *Cryptosporidium*, an alternate disinfectant such as UV, chlorine dioxide or ozone will be required to meet treatment requirements.

In this example, UV is selected. The UV provides a minimum dose of40 mJ/cm^2. This is sufficient to receive a 4-log inactivation credit for *Cryptosporidium* and *Giardia* (see IT tables in Appendix D) which meets the above shortfalls. UV is only assigned a 0.5-log inactivation credit for viruses based on adenovirus. As such, 3.5-log inactivation for viruses must be addressed. In this example, chlorine is selected to inactivate viruses.

Disinfection Credits (Log Inactivation)

The contact chamber has the following configuration:



Contact Chamber Specifications:

Volume:	450 cubic metres
Max. Flow:	4.5 MLD
Dimensions:	5 m x 30 m x 3 m
Baffling:	Five BafflesMin. Temperature: 10^{o}C Highest pH:7.5

The facility uses free chlorine for virus disinfection. The facility has a minimum of 0.5 mg/L free chlorine residual leaving the contact chamber.

Based on the configuration of the contact chamber the length to width ratio is 4:1, and has multiple baffles, which is good. A baffling factor of 0.7 can be used.

The tank is configured such that it is always full (e.g. outlet weir controls water level).

CT Calculation

Volume of chamber: 450 cubic metres = 450 000 L = 0.450 ML x 1 (low level) = 0.450 ML

Contact time$_{actual}$: Volume ÷ Max. Flow = 0.450 ML ÷ 4.5 MLD = 0.1 days x 24 hours per day x 60 minutes per hour = 144 minutes

CT_{actual}: Concentration of disinfectant x contact time x baffling factor = 0.5 mg/L x 144 minutes x 0.7 = 50.4

$CT_{required}$ (*Giardia*): UV disinfection is providing 4.0-log inactivation for *Cryptosporidium* and *Giardia*.

Adequate for 0.5-log *Giardia*? Yes

$CT_{required}$ (Viruses): Referring to the CT tables in Appendix D, 6 mg·min/L provides 4.0-log inactivation of viruses at 10°C, pH 6-9

Adequate for viruses?

$CT_{actual} \div CT_{required} = 50.4 \div 6 = 8.4$ (greater than 1)
Therefore adequate

Conclusion

This facility will require the installation of an alternate disinfectant, in this example UV, to provide sufficient disinfection for *Cryptosporidium* and *Giardia* inactivation. Chemical disinfection will also be required to provide adequate disinfection for virus inactivation.

EXAMPLE 5

Source Water - Non-GUDI

This example demonstrates the requirements for a non-GUDI source. The results from the GUDI protocol indicate that the drilled wells serving the facility have been classified as non-GUDI. This classification has been accepted in writing by a Department Regional Hydrogeologist.

Treatment Requirements

Since the facility has been classified as non-GUDI, the treatment requirements for this facility are:

- 4 - Log reduction for viruses.

Treatment Adequacy

A non-GUDI facility does not require engineered filtration for pathogen reduction. Therefore, only disinfection is required for the 4-log inactivation of viruses. The Approval Holder has two choices for primary disinfection: chemical disinfection only or UV and chemical disinfection.

The facility well field is located 2.1 km from the first customer with a 12 " ductile iron watermain, which provides plug flow. The baffling factor for the water main is 1. The maximum flow in the system is 4.5 MLD.

The minimum water temperature is 5^0 C.

With chemical disinfection only the utility ensures that the minimum free chlorine concentration at the first customer is 0.4 mg/L.

This facility is considering UV as an added barrier for disinfection, but wanted to compare the two choices before making the final selection.

Option 1: Chemical disinfection only

Volume of the chamber

= Length of water main x cross-sectional area

= 2100 m x 0.073 sq. m = 153 cu. m = 0.153 ML

Contact time$_{actual}$

= Volume/Max. Flow = 0.153 ML /4.5 MLD = 0.034 days x 24 hours per day x 60 minutes per hour = 49.0 min.

CT_{actual} = Concentration of disinfectant x contact time x baffling factor

CT_{actual} = 0.4 mg/L x 49.0 min x 1.0

CT_{actual} = 19.6 mg min/L

$CT_{required}$ (viruses):

Referring to CT Tables in Appendix D, 8 mg·min/L provides 4.0-log inactivation at 5^0 C, pH 6-9

Adequate for viruses?

CT= CT_{actual} ÷ $CT_{required}$ = 19.6 ÷ 8 = 2.45 (greater than 1)

Therefore adequate

Option 2: UV with chemical disinfection

UV will only provide 0.5-log inactivation for viruses based on adenovirus so chemical disinfection will be required for 3.5-log inactivation of viruses. Given that the chemical disinfection would provide most of the inactivation the Approval Holder reduced the free chlorine concentration to 0.3 mg /L as a cost saving measure.

CT_{actual} = Concentration of disinfectant x contact time x baffling factor

CT_{actual} = 0.3 mg/L x 49.0 min x 1.0

CT_{actual} = 14.7 mg-min/L

CT = CT_{actual} ÷ $CT_{required}$ = 14.7 ÷ 8 = 1.84 (greater than 1)

Adequate for viruses? The CT is greater than one, therefore, it is adequate.

Conclusion

Both options are sufficient for disinfection. Since the facility only obtains a 0.5-log reduction credit for viruses for the UV unit based on adenovirus, the Approval Holder must evaluate the additional capital and operating costs of the UV unit, reduced cost of chlorine addition and risk benefit.

EXAMPLE 6

Source Water - Low Risk GUDI Source

This example demonstrates the requirements for groundwater under the direct influence of surface water. The results from the GUDI protocol indicate that the drilled wells serving the facility have been classified as GUDI – Low Risk. This classification has been accepted in writing by the Department Regional Hydrogeologist.

Treatment Requirements

Since the facility has been classified as a GUDI – Low Risk, the treatment requirements for this facility are:

- 3 - Log reduction for *Cryptosporidium* and *Giardia*;
- 4 - Log reduction for viruses.

Filtration Credits (Log Removal)

A low risk GUDI facility is eligible for a 3.0-log natural filtration credit for protozoa if the *Guidelines for the Determination of Natural Filtration Log Removal for Protozoa* are followed (see Appendix B) and the Department's Regional Hydrogeologist accepts the determinationin writing. This process has been completed and accepted by the Department.

Therefore, this facility receives the following filtration credits towards meeting the treatmentrequirements:

- 3.0-log reduction for *Cryptosporidium*;
- 3.0-log reduction for *Giardia*;
- 0.0-log reduction for viruses.

Based on the above, log inactivation must provide the following log reduction:

Cryptosporidium		3.0-log reduction required
	Subtract	3.0-log filtration credit
	Equals	**0.0-log** inactivation credit needed
Giardia		3.0-log reduction required
	Subtract	3.0-log filtration credit
	Equals	**0.0-log** inactivation credit needed
Viruses		4.0-log reduction required
	Subtract	0.0-log filtration credit
	Equals	**4.0-log** inactivation credit needed

Treatment Adequacy

A low-risk GUDI source does not require engineered filtration for pathogen reduction. Therefore, only disinfection is required for the 4-log inactivation of viruses. The facility has two choices for primary disinfection: chemical disinfection only or UV and chemical disinfection. The facility chooses chemical disinfection only through the use of free chlorine.

The facility well field is located 2.1 km from the first customer with a 12" ductile iron water main, which provides plug flow. The baffling factor for the water main is 1. The maximum flow in the system is 4.5 MLD.

The minimum water temperature is 5^0 C.

With chemical disinfection only the utility ensures that the minimum free chlorine concentration at the first customer is 0.4 mg/L.

Volume of the chamber

= Length of water main x cross-sectional area
= 2100 m x 0.073 sq. m = 153 cu. m = 0.153 ML

Contact time$_{actual}$

= Volume/Max. Flow = 0.153 ML /4.5 MLD = 0.034 days x 24 hours per day x 60 minutes per hour = 49.0 min

CT Calculation

CT_{actual} = Concentration of disinfectant x contact time x baffling factor

CT_{actual} = 0.4 mg / L x 49.0 min x 1.0

CT_{actual} = 19.6 mg min/L

$CT_{required}$ (viruses):

Referring to CT Tables in Appendix D, 8 mg·min/L provides 4.0-log inactivation at 5^0 C, pH 6-9

Adequate for viruses?

CT= $CT_{actual} \div CT_{required}$ = 19.6 ÷ 8 = 2.45 (greater than 1)
Therefore adequate

Conclusion

With the Department accepted natural filtration log credit and chemical disinfection this facility adequately removes and inactivates *Cryptosporidium*, *Giardia* and viruses and meets Nova Scotia's Drinking Water Treatment Standards.