# CT DISINFECTION MADE SIMPLE

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The following discussion is about CT Disinfection. It was prepared as a presentation for the Alberta Water and Wastewater Operator's Association annual conference in Banff, Alberta on March 13, 2002. It is intended to outline an easy to follow procedure that will allow operators of surface water and groundwater under the direct influence of surface water treatment plants to ensure that they are providing good disinfection to the water they treat, that they are producing the safest water possible and to demonstrate that they have done so.

The following discussion will briefly cover the 'What Is', the 'Who Uses', and the 'Why you need' CT Disinfection.

However, the main focus of the discussion will be on how to use CT Disinfection to demonstrate that you are producing good quality water from your water treatment plants.

We will review how CT Disinfection works and then work through an example.

The main goal is to demonstrate that CT Disinfection is pretty simple to use.

## *What is CT Disinfection?*

CT Disinfection is Alberta's current disinfection standard.
It's used to demonstrate the level of disinfection treatment in your water.

CT is simply the concentration of chlorine in your water times the time of contact that the chlorine has with your water.

CT = Concentration of Chlorine x Time of Contact

The concept itself is easy to understand.

## *Who needs CT Disinfection?*

Every waterworks in Alberta that uses a raw water source that is either:

(i) surface water; or
(ii) groundwater under the influence of surface water (GWI),

must disinfect the treated water to kill any pathogens that make it through the water treatment plant.

CT Disinfection demonstrates that the required disinfection is being achieved.

Alberta's disinfection standard's have evolved over the years and will continue to evolve as we learn more about water borne pathogens and how to inactivate them.

Where once the standards targeted only bacteria and viruses, using 20 minutes of chlorine contact time, we now also target Giardia, using CT disinfection, and in the near future we will target cryptosporidium as well, using ultra violet (UV) radiation.

However, right now, Alberta's disinfection standard is CT Disinfection.

All surface and GWI water systems should be using CT Disinfection to demonstrate that you are achieving sufficient water treatment to inactivate both Giardia and viruses. Disinfection with free chlorine that inactivates Giardia will usually provide enough CT to kill viruses as well. This discussion will focus on Giardia inactivation, but bare in mind the same principals apply to viruses as well.

## *Why Practice CT Disinfection?*

Practicing CT Disinfection is the safe thing to do.

CT Disinfection is the disinfection standard in Alberta.
The standard has changed because we know we can do better than just 20 minutes of chlorine contact time.

As of today, CT Disinfection is also the water treatment industry standard for disinfection. It is the best method to ensure that the water you are providing your customers is safe.

If your water has been exposed to the surface, it has also been exposed to surface contamination, whether from livestock, wild animals or other human activity.
It will most likely be biologically contaminated.

If you can show that you have provided a safe level of treatment,
then you can demonstrate that you have been duly diligent in performing your duty.

CT disinfection protects your water, and by protecting your water, you are also protecting yourself. And whether you like it or not, you need to protect yourself too.

## *How to Use CT Disinfection*

Let's start with the basics.

$$CT = \text{Concentration} \times \text{Time}$$

CT is the concentration of chlorine in your water times the time the water is in contact with that chlorine.

To use CT to demonstrate that you have sufficient water treatment, you need to do the following three things.

1. Determine how much CT you need.
2. Determine how much CT you have achieved.
3. Ensure CT achieved is more than CT required.

Using CT Disinfection is a straightforward three step process.
So let's look at these steps.

## *How to Determine the Required CT ($CT_{required}$)*

Water treatment can be broken into two phases:

1. the water treatment plant; and
2. the disinfection.

CT Disinfection focuses on the second phase, but let's focus for a moment on the entire process.

Today's water treatment standards are based on the removal of Giardia from raw water. Giardia removal requirements for the entire water treatment process are based on the quality of the raw water. Therefore, an operator must test the raw water for Giardia to know the water treatment requirements.

The water quality target for treated potable water is no more than one Giardia cyst per 100,000 litres of water.

Treated Water Giardia Target $\leq$ 1 cyst / 100,000 L

The required treatment then, is the difference between the existing Giardia concentration in the raw water and the treatment target Giardia concentration for treated water. But even for pristine water, the absolute minimum Giardia inactivation requirement is 3.0 Log.

But what does that mean, "3 Log inactivation"?

Let's look at an example.

Typically, Giardia sampling requires 1000 litres to be passed through a special filter. The filter is sent to an accredited lab for analysis.

If for example, your raw water has 100 cysts in a 1000 litre sample, this is the same as saying the sample has 10,000 cysts/100,000 litre. We have just multiplied the 100 cysts and the 1,000 litres each by 100. We have done this in order to compare the concentration of Giardia in the raw water sample with the treated water target.

We know our treated water Giardia target is less than 1 cyst / 100,000 L, therefore we must reduce the Giardia concentration in the raw water by 10,000 times in order to meet the treated water Giardia target.

Another way to express this 10,000 times reduction is by counting the zero's, in this case 10,000 has 4 zero's ($10,000 = 10^4$). Therefore we need 4 Log reduction.

This can also be stated as 99.99% reduction. Again count the 9's. 4 Log is expressed with four nines, 99.99%. Two Log removal would be 99%; three Log 99.9%.

But, as operators you do not need to worry about this math. You do the sampling, you get the Giardia analysis done, and we folks at Alberta Environment will be more than happy to work with you to determine how many Log removals of Giardia are required.

The required level of Giardia reduction is summarized in Table 1, based on quarterly samples of Giardia concentrations in the raw water entering the water treatment plant.

**Table 1: LEVEL OF GIARDIA REDUCTION**

| Raw Water Giardia Levels* | Recommended Giardia Log Reduction |
|---|---|
| < 1 cyst/100 L | 3-log |
| 1 cyst/100 L - 10 cysts/100 L | 3-log - 4-log |
| 10 cysts/100 L - 100 cysts/100 L | 4-log - 5-log |
| > 100 cysts/100 L | > 5-log |

*Use geometric means of data to determine raw water Giardia levels for compliance.

*Table 4-1 from The Standards and Guidelines for Municipal Water, Wastewater and Storm Drainage Systems, AENV 1997*

A list of Alberta Environments Municipal Approvals contacts is included at the end of this discussion. Any one of these contacts will help you determine the required disinfection to meet your overall treatment requirement.

## *How to Achieve Required Giardia Log Inactivation*

The obvious next question is, "How do we achieve this required Log inactivation of Giardia?"

As we already saw, there are two phases to water treatment:

1. the water treatment plant; and
2. the disinfection.

If your water treatment plant is treating water in accordance with Alberta Environment's 1997 water treatment plant performance standards, then you will be given credit for an appropriate level of Giardia reduction. For a conventional water treatment plant, you would receive 2.5 Log credits for Giardia reduction, if your treatment meets the 1997 performance standard. The water treatment plant performance standards that must be met in order to receive Giardia inactivation credits are listed in Section 2.2 of Alberta Environment's 1997 *Standards and Guidelines for Municipal Water Wastewater and Storm Drainage Facilities.*

But, as mentioned previously, the minimum over all treatment requirement, even in a pristine water source is 3.0 Log reduction of Giardia. The balance of the Giardia inactivation treatment requirements must be made up by disinfection. This is where CT Disinfection is used.

**Example:**

Let's look at an example of the water treatment requirements for a raw water source with 10,000 cysts per 100,000 litres.

Since this is equal to 10 cysts per 100 litres, we see from Table 1 that the total treatment requirement would be at least 4.0 Log inactivation of Giardia cysts. If a conventional water treatment plant with coagulation, flocculation, sedimentation and filtration is treating the water and meeting the 1997 performance standards, a 2.5 Log credit is given for Giardia inactivation at the water treatment plant.

The remaining 1.5 Log Giardia inactivation requirement must be achieved by disinfection.

## *Step 1: Determining the Required CT ($CT_{required}$)*

The first step in using CT Disinfection is to determine the required CT ($CT_{required}$) to demonstrate that enough disinfection is occurring.

Chlorine's effectiveness to inactivate Giardia cysts is dependent on temperature, pH, concentration of chlorine and time of contact.

To determine $CT_{required}$ we need to know:

1. The **minimum temperature** of the water during disinfection. The minimum temperature of the water in the chlorine contact chamber must be monitored. Minimum temperature is used because chlorine's ability to disinfect becomes less with lower temperatures. By using the lowest temperature of the water when determining $CT_{required}$, we know that the disinfection that occurred was at least as good as the lowest temperature allowed.

2. The **maximum pH** of the water during disinfection. The maximum pH of the water in the chlorine contact chamber must be monitored.
   Chlorine's ability to disinfect becomes less as pH increases. By using the maximum pH when determining $CT_{required}$, we know that the disinfection that occurred was at least as good as the disinfection that occurs at the maximum pH.

3. The **minimum chlorine residual** in the water during disinfection. The minimum chlorine residual in the water must be monitored at the end of the disinfection chamber.
   We know that higher chlorine dosages disinfects better.
   The lowest chlorine residual is used because the water in the chlorine contact chamber has been exposed to at least that concentration of chlorine.

4 The **<u>required Log reduction of Giardia by disinfection</u>** must also be known.
As discussed previously, the required Log reduction by disinfection is based on the raw water Giardia concentration with allowances for the treatment at the water treatment plant.

With this information, we use Giardia CT tables to determine the $CT_{required}$.

## *CT required Tables*

An example of a $CT_{required}$ table for inactivation of Giardia is included on the following page. A full set of $CT_{required}$ tables are found in Appendix A of the *Standards and Guidelines for Municipal Water, Wastewater and Storm Drainage Systems, AENV 1997.* Hard copies of this document can be purchased from the Queen's Printer in either Calgary or Edmonton.

As well, you can download this document from the Internet at the following website. The CT tables are located in Chapter 10 in the downloaded electronic format.

http://www3.gov.ab.ca/env/waste/muniwwater/stormdrainage.html

The CT Tables are used as follows:

1 Make sure you are using the **correct table**. The tables are specific to the target organism and the type of disinfectant. Most likely you will use the **Giardia inactivation table** for **free chlorine**. Most surface and GWI water treatment plants disinfect with free chlorine. Free chlorine is more than ten times better at inactivating Giardia than chloramines.

2 The tables are also temperature specific. You must use the table that corresponds to your **measured minimum temperature**.

3 The tables are divided into pH sections. Locate the section of the table that corresponds to your **measured maximum pH**.

4 Within the appropriate pH section, locate the column for your **required disinfection Log inactivation** for Giardia.

5 Within the appropriate pH section, locate the row for your measured **minimum free chlorine residual** concentration on the left side of the table.

6 Read the **$CT_{required}$** value from the table where the chlorine residual row meets the required Log inactivation column.

CT VALUES FOR INACTIVATION OF GIARDIA CYSTS BY FREE CHLORINE AT 5°C

| Chlorine Concentration (mg/L) | pH < = 6 Log Inactivations | | | | | | pH = 6.5 Log Inactivations | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0.5 | 1.0 | 1.5 | 2.0 | 2.5 | 3.0 | 0.5 | 1.0 | 1.5 | 2.0 | 2.5 | 3.0 |
| < = 0.4 | 16 | 32 | 49 | 65 | 81 | 97 | 20 | 39 | 59 | 78 | 98 | 117 |
| 0.6 | 17 | 33 | 50 | 67 | 83 | 100 | 20 | 40 | 60 | 80 | 100 | 120 |
| 0.8 | 17 | 34 | 52 | 69 | 86 | 103 | 20 | 41 | 61 | 81 | 102 | 122 |
| 1 | 18 | 35 | 53 | 70 | 88 | 105 | 21 | 42 | 63 | 83 | 104 | 125 |
| 1.2 | 18 | 36 | 54 | 71 | 89 | 107 | 21 | 42 | 64 | 85 | 106 | 127 |
| 1.4 | 18 | 36 | 55 | 73 | 91 | 109 | 22 | 43 | 65 | 87 | 108 | 130 |
| 1.6 | 19 | 37 | 56 | 74 | 93 | 111 | 22 | 44 | 66 | 88 | 110 | 132 |
| 1.8 | 19 | 38 | 57 | 76 | 95 | 114 | 23 | 45 | 68 | 90 | 113 | 135 |
| 2 | 19 | 39 | 58 | 77 | 97 | 116 | 23 | 46 | 69 | 92 | 115 | 138 |
| 2.2 | 20 | 39 | 59 | 79 | 98 | 118 | 23 | 47 | 70 | 93 | 117 | 140 |
| 2.4 | 20 | 40 | 60 | 80 | 100 | 120 | 24 | 48 | 72 | 95 | 119 | 143 |
| 2.6 | 20 | 41 | 61 | 81 | 102 | 122 | 24 | 49 | 73 | 97 | 122 | 146 |
| 2.8 | 21 | 41 | 62 | 83 | 103 | 124 | 25 | 49 | 74 | 99 | 123 | 148 |
| 3 | 21 | 42 | 63 | 84 | 106 | 126 | 25 | 50 | 76 | 101 | 126 | 151 |

| Chlorine Concentration (mg/L) | pH = 7.0 Log Inactivations | | | | | | pH = 7.5 Log Inactivations | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0.5 | 1.0 | 1.5 | 2.0 | 2.5 | 3.0 | 0.5 | 1.0 | 1.5 | 2.0 | 2.5 | 3.0 |
| < = 0.4 | 23 | 46 | 70 | 93 | 116 | 139 | 28 | 55 | 83 | 111 | 138 | 166 |
| 0.6 | 24 | 48 | 72 | 95 | 119 | 143 | 29 | 57 | 86 | 114 | 143 | 171 |
| 0.8 | 24 | 49 | 73 | 97 | 122 | 146 | 29 | 58 | 88 | 117 | 146 | 175 |
| 1 | 25 | 50 | 75 | 99 | 124 | 149 | 30 | 60 | 90 | 119 | 149 | 179 |
| 1.2 | 25 | 51 | 76 | 101 | 127 | 152 | 31 | 61 | 92 | 122 | 153 | 183 |
| 1.4 | 26 | 52 | 78 | 103 | 129 | 155 | 31 | 62 | 94 | 125 | 156 | 187 |
| 1.6 | 26 | 53 | 79 | 105 | 132 | 158 | 32 | 64 | 96 | 128 | 160 | 192 |
| 1.8 | 27 | 54 | 81 | 108 | 135 | 162 | 33 | 65 | 98 | 131 | 163 | 196 |
| 2 | 28 | 55 | 83 | 110 | 138 | 165 | 33 | 67 | 100 | 133 | 167 | 200 |
| 2.2 | 28 | 56 | 85 | 113 | 141 | 169 | 34 | 68 | 102 | 136 | 170 | 204 |
| 2.4 | 29 | 57 | 86 | 115 | 143 | 172 | 35 | 70 | 105 | 139 | 174 | 209 |
| 2.6 | 29 | 58 | 88 | 117 | 146 | 175 | 36 | 71 | 107 | 142 | 178 | 213 |
| 2.8 | 30 | 59 | 89 | 119 | 148 | 178 | 36 | 72 | 109 | 145 | 181 | 217 |
| 3 | 30 | 61 | 91 | 121 | 152 | 182 | 37 | 74 | 111 | 147 | 184 | 221 |

| Chlorine Concentration (mg/L) | pH = 8.0 Log Inactivations | | | | | | pH = 8.5 Log Inactivations | | | | | | pH < = 9.0 Log Inactivations | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0.5 | 1.0 | 1.5 | 2.0 | 2.5 | 3.0 | 0.5 | 1.0 | 1.5 | 2.0 | 2.5 | 3.0 | 0.5 | 1.0 | 1.5 | 2.0 | 2.5 | 3.0 |
| < = 0.4 | 33 | 66 | 99 | 132 | 165 | 198 | 39 | 79 | 118 | 157 | 197 | 236 | 47 | 93 | 140 | 186 | 233 | 279 |
| 0.6 | 34 | 68 | 102 | 136 | 170 | 204 | 41 | 81 | 122 | 163 | 203 | 244 | 49 | 97 | 146 | 194 | 243 | 291 |
| 0.8 | 35 | 70 | 105 | 140 | 175 | 210 | 42 | 84 | 126 | 168 | 210 | 252 | 50 | 100 | 151 | 201 | 251 | 301 |
| 1 | 36 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | 43 | 87 | 130 | 173 | 217 | 260 | 52 | 104 | 156 | 208 | 260 | 312 |
| 1.2 | 37 | 74 | [illegible] | [illegible] | [illegible] | [illegible] | 45 | 89 | 134 | 178 | 223 | 267 | 53 | 107 | 160 | 213 | 267 | 320 |
| 1.4 | 38 | 76 | [illegible] | [illegible] | [illegible] | [illegible] | 46 | 91 | 137 | 183 | 228 | 274 | 55 | 110 | 165 | 219 | 274 | 329 |
| 1.6 | 39 | 77 | [illegible] | [illegible] | [illegible] | [illegible] | 47 | 94 | 141 | 187 | 234 | 281 | 56 | 112 | 169 | 225 | 281 | 337 |
| 1.8 | 40 | 79 | [illegible] | [illegible] | [illegible] | [illegible] | 48 | 96 | 144 | 191 | 239 | 287 | 58 | 115 | 173 | 230 | 288 | 345 |
| 2 | 41 | 81 | [illegible] | [illegible] | [illegible] | [illegible] | 49 | 98 | 147 | 196 | 245 | 294 | 59 | 118 | 177 | 235 | 294 | 353 |
| 2.2 | 41 | 83 | 124 | 165 | 207 | 248 | 50 | 100 | 150 | 200 | 250 | 300 | 60 | 120 | 181 | 241 | 301 | 361 |
| 2.4 | 42 | 84 | 127 | 169 | 211 | 253 | 51 | 102 | 153 | 204 | 255 | 306 | 61 | 123 | 184 | 245 | 307 | 368 |
| 2.6 | 43 | 86 | 129 | 172 | 215 | 258 | 52 | 104 | 156 | 208 | 260 | 312 | 63 | 125 | 188 | 250 | 313 | 375 |
| 2.8 | 44 | 88 | 132 | 175 | 219 | 263 | 53 | 106 | 159 | 212 | 265 | 318 | 64 | 127 | 191 | 255 | 318 | 382 |
| 3 | 45 | 89 | 134 | 179 | 223 | 268 | 54 | 108 | 162 | 216 | 270 | 324 | 65 | 130 | 195 | 259 | 324 | 389 |

CT $_{required}$

*Table A-2 from The Standards and Guidelines for Municipal Water, Wastewater and Storm Drainage Systems, AENV 1997*

CT $_{required}$ is read directly from the table.

Using these CT tables is straight forward. It will become a routine procedure once you've done it a few times.

The CT $_{required}$ tables are temperature specific for water temperatures at 5°C increments. If your temperature falls between two temperatures for which tables exist, for example 8°C, then you need to determine the CT $_{required}$ by one of the following methods:

1. Determine the CT $_{required}$ at both 5°C and 10°C from the corresponding tables and estimate the CT $_{required}$ value for 8°C using the CT $_{required}$ values for 5°C and 10°C; or

2. Use the CT $_{required}$ table that exists for the next **lower temperature**. To determine CT $_{required}$ for 8°C we could use the CT $_{required}$ value for 5°C. This will produce a value that is conservative (i.e. higher) and adds an extra measure of safety.

Similarly, the pH sections within each table are in 0.5 pH unit increments. To determine the CT $_{required}$ value for a pH that does not correspond to one of the given pH sections, the CT $_{required}$ value can be estimated using the pH sections higher and lower than your measured pH or by using the CT $_{required}$ value at the next **higher pH** section.

## *Step 2: Determining the Actual CT (CT $_{achieved}$)*

The second step to using CT Disinfection is determining the actual CT we are achieving with disinfection.

Remember that CT equals concentration times time.

$$CT_{\textbf{achieved}} = \text{Concentration x Time}$$

To determine CT $_{achieved}$, we need to know the actual minimum chlorine concentration and the actual time that the water is in contact with the chlorine.

Multiplying these together gives us the actual CT $_{achieved}$ at the time the parameters were measured.

But, we want to know the **Minimum CT $_{achieved}$** every day.

Therefore we need to use the **Minimum Chlorine Residual** that occurs each day. This is the same minimum chlorine residual concentration that we used to determine $CT_{required}$. It will be measured at the outlet of the chlorine contact chamber in mg/L. To determine the minimum chlorine residual in a 24 hour period, the chlorine residual must be measured throughout that 24 hour period. Collecting a single grab sample once per day in no way indicates that the chlorine residual did not vary to a lower concentration since the last sample was collected the previous day.

One of the important recommendations from the **Walkerton Inquiry** was that **<u>every surface water or GWI water treatment plant should have on-line chlorine analyzers.</u>**

If you don't have one, due diligence would require that you get one. Not only will you be able to ensure your water is safe 24 hours a day, in the event that something does go wrong in your system, you can identify whether or not it was due to disinfection.

The **Minimum Chlorine Residual** is therefore the lowest chlorine residual monitored each day.

We also need to know the **Actual Time** that water is in contact with the chlorine.
**This is where it gets a little tricky**, so this is where you need to **pay close attention.**

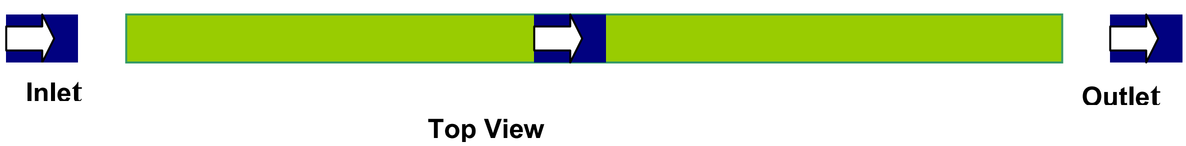
## *Determining Actual Contact Time*

Consider for a minute a length of pipe as illustrated in Figure 1.

If a litre of water passes through the pipe, it comes out the other end as a litre of water. There is **No Mixing** and **No Short-Circuiting.** Water travels through the pipe as a unit.

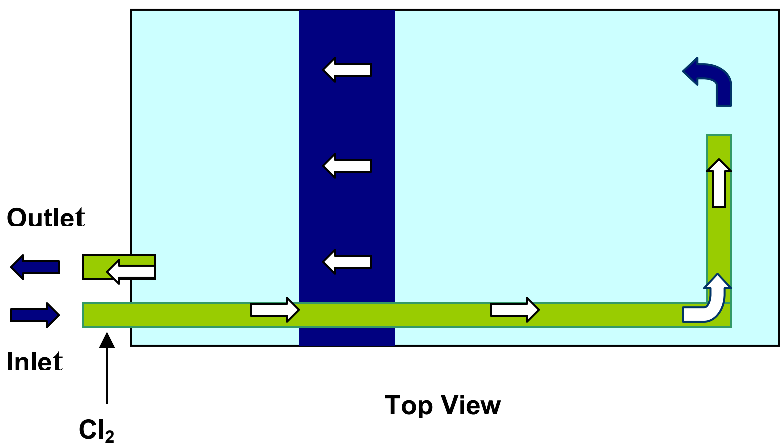
All the water travels at an '**Average Velocity'** through the pipe.

**Figure 1: Water Pipeline with No Mixing and No Short Circuiting ($F_{SC}$ = 1.0)**




Now consider a water reservoir as illustrated in Figure 2.

**Figure 2: Water Reservoir with No Mixing and No Short Circuiting ($F_{SC}$ = 1.0)**

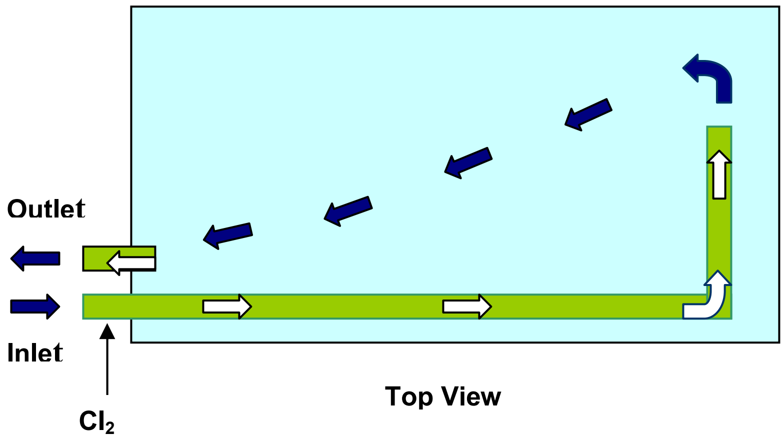



If all the water travelled through the reservoir at an average velocity, the water would travel into the reservoir through the inlet pipe and across the reservoir as a single unit, at an average velocity. There would be **No Mixing** and **No Short-Circuiting**.

But this is **not what really happens**. At least not for a reservoir where there is only maximum separation of the inlet and outlet pipes, but no baffles to reduce short circuiting between the inlet and outlet pipes.

What really happens is that water will flow into the reservoir through the inlet pipe, then across the reservoir as illustrated in Figure 3, not at the average velocity as a single unit, but with some degree of **Mixing** and **Short-Circuiting**. Due to hydraulic and temperature gradients, some water will follow a direct path, right to the outlet pipe.

**Figure 3: Water Reservoir with Mixing and Short Circuiting ($F_{SC}$ = 0.1)**




When determining the **time of contact** of the chlorine with the water in the chlorine contact chamber, we therefore must account for **short-circuiting**.

To do this, we use a time parameter, which we call $T_{10}$, the time it takes for 10 % of the water to pass through the reservoir.

Mathematically we say:

$$T_{10} = F_{SC} \times T_{MIN}$$

$T_{10}$ equals a short-circuiting factor ($F_{SC}$) times the minimum time it takes a unit of water to travel through the reservoir at the average speed if no mixing or short circuiting occurred ($T_{MIN}$), as was the case in the length of pipe that was discussed.

The short-circuiting factor will vary with different chlorine contact chamber configurations from 0.1 to 1.0. 0.1 for poorly baffled reservoirs, as illustrated in Figure 3 to 1.0 in the case of a pipe, as illustrated in Figure 1.

The short circuiting factor ($F_{SC}$) is also called the baffling factor or the **$T_{10}$/T ratio** in CT Disinfection literature.

The short-circuiting factor is determined either by tracer tests of the actual reservoir, or it will be assigned, based on tracer tests for similarly configured reservoirs. Typical short circuiting (i.e. baffling) factors are found in Table 4.3 of Alberta Environment's 1997 *Standards and Guidelines for Municipal Water Wastewater and Storm Drainage Facilities.* This table is shown here as Table 3.

**Table 3: TYPICAL BAFFLING CONDITIONS**

| Baffling Condition | $T_{10}/T$ Ratio | Baffling Description |
|---|---|---|
| Unbaffled (mixed flow) | 0.1 | None, 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 <u>or</u> 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 |

*Table 4-3 from The Standards and Guidelines for Municipal Water, Wastewater and Storm Drainage Systems, AENV 1997*

$T_{MIN}$ is the minimum time that the average unit of water is in the reservoir, or if you will, the minimum contact time on any day.

$$T_{MIN} = \frac{\text{minimum volume of water in the reservoir } (m^3)}{\text{maximum hourly flow rate } (m^3/\text{min})}$$

I indicated previously that the T in CT is where it gets a little tricky.

$\mathbf{T_{MIN}}$ is the key concept to grasp.

Let's look at the top of the $T_{MIN}$ equation:

**'minimum volume of water in the reservoir ($m^3$)'**

We know that water levels in your disinfection reservoir will fluctuate throughout the day. Everything else being equal, when the level of water in the reservoir is at its lowest point, (i.e. when you have your minimum volume of water in storage) the water will spend the least amount of time in the reservoir and you will therefore have the least amount of time available for chlorine contact.

Similarly, for the bottom of the $T_{MIN}$ equation:

**'maximum hourly flow rate ($m^3$/min)' (from the reservoir)**

Everything else being equal, when the flow rate from the disinfection reservoir is at it's highest, the water will spend the least amount of time in the reservoir and you will have the least amount of time available for chlorine contact.

Combining these two scenarios, we get:

$$T_{MIN} = \frac{\text{minimum volume of water in the reservoir } (m^3)}{\text{maximum hourly flow rate } (m^3/min)}$$

Substituting our details into the CT equation, we get the full $CT_{achieved}$ equation:

$$\boxed{CT_{achieved} = \text{Conc. of } Cl_2 \times F_{SC} \times \frac{\text{minimum volume of water in the reservoir } (m^3)}{\text{maximum hourly flow rate } (m^3/min)}}$$

## *Step 3: Comparing CT Values*

The third and final step is to compare $CT_{acheived}$ to $CT_{required}$ to determine if we meet the disinfection requirement.

If not, we need to determine why not, and take the appropriate actions to ensure CT disinfection requirements are met.

## *Summary of Required Steps Used in CT Disinfection*

Let's quickly review the three steps used in CT Disinfection.

Step 1: Determine $CT_{required}$ using the correct CT Table.

Step 2: Calculate $CT_{achieved}$ using the formula.

Step 3: Compare $CT_{achieved}$ to $CT_{required}$.

- If $CT_{acheived} \geq CT_{required}$, then you will have met your disinfection requirement.
- If not, you must take the appropriate actions to ensure CT Disinfection requirements are met.

## *Summary of Required Information to Use CT Disinfection*

Let's do a quick review of the required information to use CT Disinfection.

1 The **required Giardia inactivation by disinfection** will be determined in conjunction with Alberta Environment based on the Giardia concentration in your raw water and the configuration and treatment of your water treatment plant.

2 The **short circuiting or baffling factor ($F_{SC}$)** of your chlorine contact chamber (i.e. clearwell or disinfection reservoir) will be assigned in conjunction with Alberta Environment, based on tracer studies done on your reservoir or by comparing your reservoir configuration with other similarly configured reservoirs with known short circuiting factors. Table 4.3 of Alberta Environment's 1997 *Standards and*

*Guidelines for Municipal Water Wastewater and Storm Drainage Facilities* provides typical baffling factors.

3 The **maximum flow rate through your chlorine contact chamber** will either be known from previous determination of the flow rate or the maximum flow rate must be monitored each day.

4 The **minimum storage within the chlorine contact chamber** will either be known, for example the volume in storage at distribution pump shut off, or if the system is operated with a fluctuating water level well above the minimum, the minimum volume in storage must be monitored each day.

5 The **minimum temperature** of your water during chlorine contact must be monitored each day. The need for online monitoring equipment will vary depending on the daily temperature fluctuation range.

6 The **maximum pH** of your water during chlorine contact must be monitored each day. The need for online monitoring equipment will very depending on the daily pH fluctuation range.

7 The **minimum free chlorine residual** of your water during chlorine contact must be determined by monitoring your chlorine residual throughout each day with an online chlorine analyzer at the outlet of the chlorine contact chamber.

## *Example CT Disinfection Calculation*

Let's work through an example:

This example is for a small water system in a small Provincial Park.
However, the procedures are directly applicable to any sized water treatment system.
The system has a poorly baffled reservoir.

### Data:

Short Circuiting Factor, $F_{SC}$ = 0.10
Minimum water temperature = 5° C
maximum pH of water = 8.0
required Giardia Log inactivation by disinfection = 0.5 Log
minimum free chlorine residual concentration = 0.8 mg/L
total reservoir volume = 20 $m^3$
minimum reservoir storage at pump shut off = 5 $m^3$
maximum pumping rate from the reservoir = 0.05 $m^3$/min

## Step 1: Determine CT $_{required}$

Use Table A-2 in the Standards and Guidelines for Giardia Inactivation at 5° C. Locate the pH 8 section. Within the pH = 8.0 section find the Log inactivation 0.5 column and the chlorine concentration 0.8 mg/L row.
We read the required CT from the table $CT_{required}$ = 35 mg·min/L

## Step 2: Determine CT $_{achieved}$

To determine $CT_{achieved}$ we use our formula:

$$CT_{achieved} = \text{Conc. of } Cl_2 \times F_{SC} \times \frac{\text{minimum volume of water in the reservoir } (m^3)}{\text{maximum hourly flow rate } (m^3/\text{min})}$$

We plug in our data values:

1. Monitored chlorine residual at the contact chambers outlet, 0.8 mg/L;
2. Our known short circuiting factor, $F_{SC} = 0.1$;
3. Our minimum volume of water in storage, in our case that's where the distribution pumps are set to shut down, 5 $m^3$; and,
4. the maximum pumping rate from the contact chamber, 0.05 $m^3$/min.

$$CT_{achieved} = 0.8 \text{ mg/L} \times 0.10 \times \frac{5\ (m^3)}{0.05\ (m^3/\text{min})}$$

We do the math, and calculate $CT_{achieved}$ = 8 mg·min/L

## Step 3: Compare CT Values

Now we compare CT $_{acheived}$ to CT $_{required}$

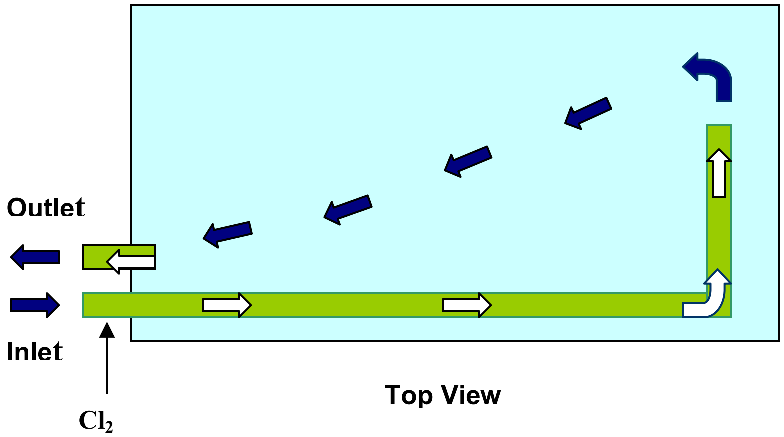
Clearly, $CT_{acheived}$ (8) is less than CT $_{required}$ (35)

This means that we **do not achieve** the required disinfection.

So we must change the operation to improve CT $_{acheived}$ to ensure the required disinfection is met. The first impulse might be to increase the chlorine dosage. However, the dosage would have to be increased to extremely high levels to achieve the required Giardia inactivation.

So let's look at the configuration of the disinfection chamber illustrated in Figure 4.

**Figure 4: Water Reservoir with Mixing and Short Circuiting ($F_{SC}$ = 0.1)**

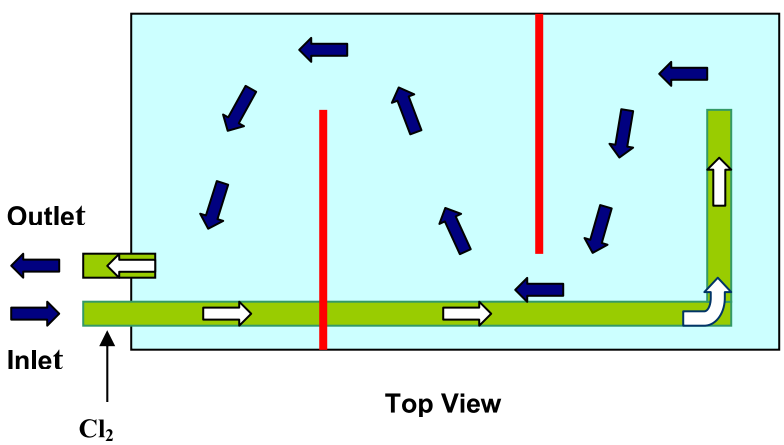



The only thing we have going for us in this reservoir with respect to disinfection, is the maximum separation of the inlet and outlet pipes. With this configuration we know that there is significant short-circuiting and mixing of the water in our reservoir.

This is reflected in the use of a very poor short circuiting factor, $F_{SC}$ = 0.1.

If we add two baffles to the reservoir as illustrated in Figure 5, we elongate the flow path and reduce the potential for short circuiting. This is reflected by an improved (i.e. larger) short circuiting factor. In this case, adding two baffles could get us a three fold increase in the short circuiting factor ($F_{SC}$) to 0.3. This is equivalent to increasing the time of chlorine contact three times.

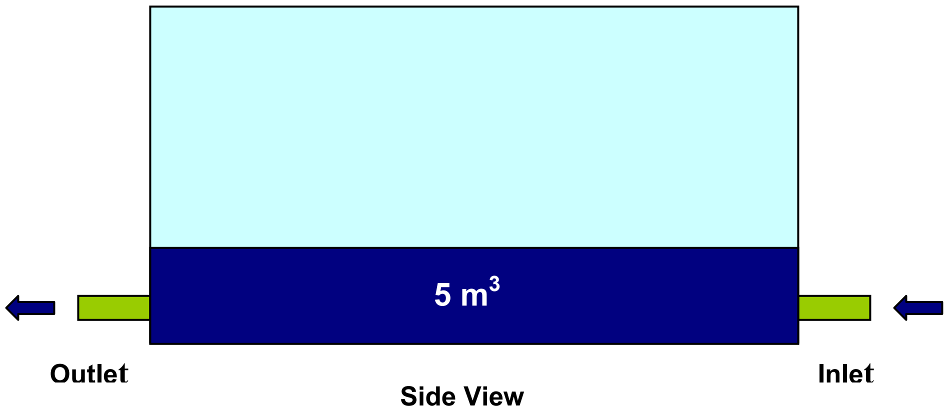
**Figure 5: Water Reservoir with Two Baffles Reduced Short Circuiting ($F_{SC}$ = 0.3)**




Adding baffles can be done at a reasonable cost by hanging sheets of plastic from stainless steel hangers and using stainless steel angle iron to hold the plastic tight to the wall and floor. It is very important that the plastic is approved for use in a potable water situation. NSF certification is required on the plastic, but these products are available.

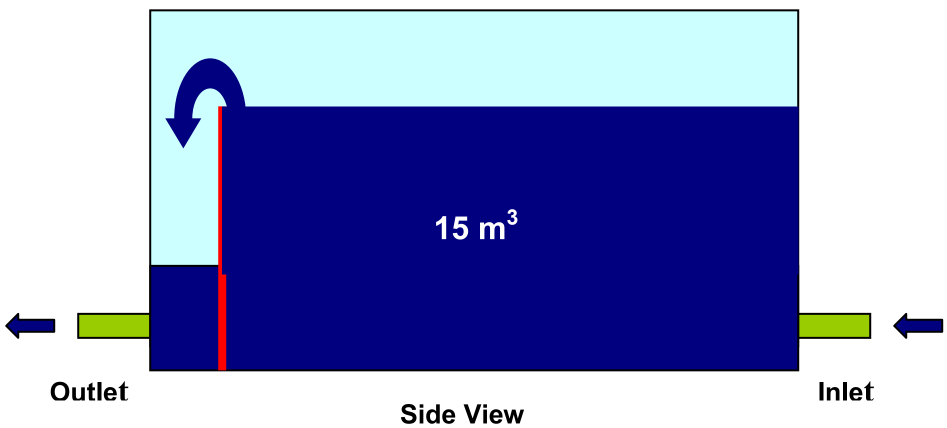
Next let's look at the minimum volume of water in storage in the reservoir. We have potentially 20 $m^3$ of storage available. Current practice is to operate the reservoir with the distribution pumps kicking out when the volume of water in storage drops to 5 $m^3$. This practice is illustrated in Figure 6.

**Figure 6: Water Reservoir with Minimum Volume of Water in Storage = 5$m^3$**




Increasing the minimum volume of water in storage to 15 $m^3$, increases the minimum contact time three fold. We can do this by resetting our flyght bulbs so that the distribution pumps kick out when the water in storage drops to 15 $m^3$, or we can install a weir that holds back at least 15 $m^3$ at all times as illustrated in Figure 7.

**Figure 7: Water Reservoir with Minimum Volume of Water in Storage = 15$m^3$**




To recap our system modifications to increase chlorine contact time:

1. we increased the flow path and thereby reduced short circuiting; and,
2. we increased the minimum volume of water in storage in the disinfection reservoir.

Both modifications increased the chlorine contact time in the disinfection reservoir.

Now we want to recalculate $CT_{achieved}$ and compare the new $CT_{acheived}$ to $CT_{required}$ to determine if these modifications will improve the disinfection enough to meet the Giardia reduction requirement.

## Repeat Step 2: Determine the revised CT $_{achieved}$

Plugging in our revised data we calculate:

$$CT_{achieved} = C \times F_{SC} \times \frac{\text{minimum volume of water } (m^3)}{\text{maximum flow rate } (m^3/\text{min})}$$

$$CT_{achieved} = 0.8 \text{ mg/L} \times 0.3 \times \frac{15\ (m^3)}{.05\ (m^3/\text{min})}$$

$$CT_{achieved} = 72 \text{ mg·min/L}$$

## Step 3: Compare CT Values

Comparing the revised $CT_{acheived}$ to $CT_{acheived}$ we find:

$CT_{acheived}$ (72) exceeds $CT_{req'd}$ (35)

So we now meet the required disinfection for Giardia inactivation

That is all there is to this discussion of CT disinfection.

## Evaluating Your Own Disinfection System

Now as operators, you need to take a hard look at your waterworks systems to determine how well you are doing with your own disinfection.

- Do you meet the CT disinfection standard?
- Are you providing the safest water possible?
- Are you protecting yourself by practicing due diligence?

***If you answer “No” to any of these questions, you need to make some changes at your waterworks.***

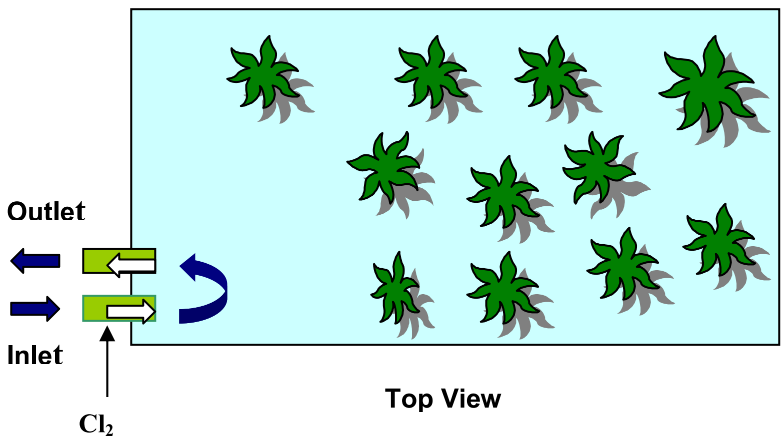
## *Reservoir configurations*

Let's take a look at some basic reservoir configurations.

A reservoir's configuration affects the flow of water through the reservoir. The degree of short circuiting within the reservoir is for the most part dependent on the reservoir's configuration.

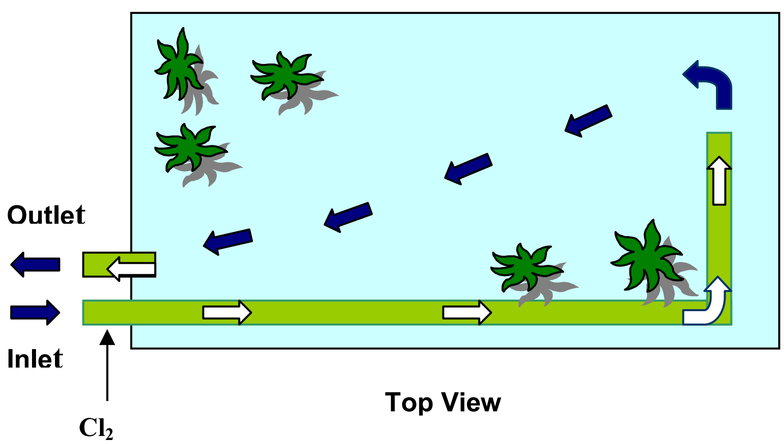
There are likely still a few reservoirs in Alberta that have almost no separation between the inlet and outlet pipes. This scenario is illustrated in Figure 8. These reservoirs have virtually no chlorine contact time. Much of the water within the reservoir does not turn over (i.e. it is not replaced with fresher water) and the water may become stagnant, with no chlorine. In addition to the risk from insufficient disinfection, the inability to turn over the water in the reservoir with fresh water, increases the potential for aquatic floral and fauna growths.

**Figure 8: Water Reservoir with Mixing and Short Circuiting ($F_{SC}$ << 0.1)**



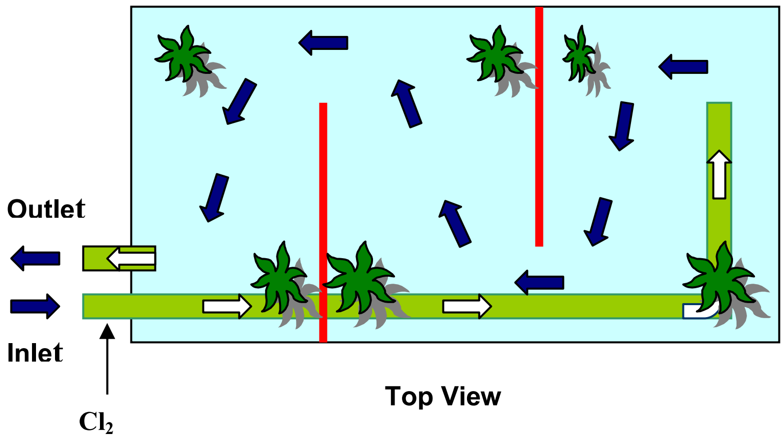

As an absolute minimum, the distance from the inlet to the outlet pipes should be maximized as illustrated in Figure 9. Although short circuiting is still significant, this configuration is a big improvement over the adjacent inlet and outlet pipe scenario.

**Figure 9: Water Reservoir with Mixing and Short Circuiting ($F_{SC}$ = 0.1)**



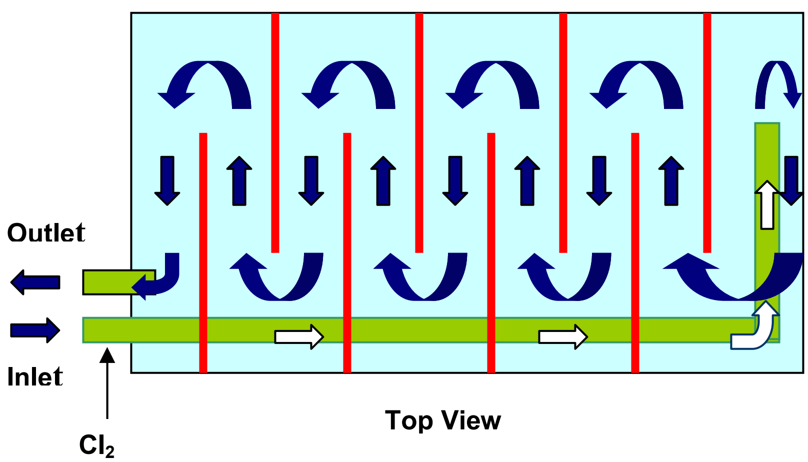
Installation of baffles within the reservoir will elongate the flow path and reduce the potential for short circuiting as demonstrated by our previous example and illustrated here as Figure 10. The baffles also ensure chlorinated water is distributed throughout a greater portion of the reservoir. However, with only two baffles there will likely be some areas where water becomes stagnant due to a lack of water turn over with chlorinated water.

**Figure 10: Water Reservoir with Two Baffles Reduced Short Circuiting ($F_{SC}$ = 0.3)**




Installation of a multiple baffles within a disinfection reservoir greatly lengthens the flow path. Figure 11 shows a reservoir configuration with 8 curtain type baffles. The short circuiting factor for this type of configuration would likely exceed 0.7. Tracer tests of the reservoir would be required to determine the actual short circuiting factor. The likelihood of any stagnant water existing with this configuration would be minimal. Flow through a reservoir with this configuration is approaching the scenario of flow through a pipe that we observed in Figure 1.

**Figure 11: Water Reservoir with Multiple Baffles with Minimal Short Circuiting ($F_{SC}$ = $0.7^{+}$)**




The addition of baffles has increased the chlorine contact time by at least seven times over the configuration in Figure 9, where only maximum separation of the inlet and outlet pipes existed. This is equivalent to increasing the size of the Figure 9 reservoir by seven times at a fraction of the cost.

## *Final Note*

I've included a list of contacts at Alberta Environment for all the municipal approvals coordinators throughout the province.

If you need help with understanding CT, or if you are setting Giardia reduction requirements or short circuiting factors for your chlorine contact reservoirs, call us. We want to ensure that you are heading in the right direction with your move to CT Disinfection. Simple modifications to your system may be all that is needed to meet the current disinfection standard, CT disinfection.

You owe it to your customers, your employers and yourself to produce the safest water possible. If you are not using CT Disinfection, you are not doing all you can and are not practicing due diligence.

You are an important public health professional. Practicing CT disinfection, in conjunction with a well operated and monitored surface water or GWI water treatment plant, allows you to produce the safest water possible and also to demonstrate that you have done so.

## *ALBERTA ENVIRONMENT CONTACTS*

## *MUNICIPAL APPROVAL COORDINATORS*

| REGION | NAME & LOCATION | PHONE | FAX |
|---|---|---|---|
| **Southern Region- Calgary Office** | Frank Lotz, P. Eng. | (403) 297-8279 | 297-5944 |
| | Brock Rush, P. Eng. | (403) 297-7884 | 297-5944 |
| | Craig Reich, A. Sc. T. | (403) 297-7887 | 297-5944 |
| **Southern Region- Lethbridge Office** | Ben Lichtenwald, EIT | (403) 382-4450 | 382-4428 |
| | Wayne Williams,CET | (403) 382-4009 | 382-4428 |
| **Northern Region- Edmonton Office (Twin Atria)** | Asoke Weerasinghe, P. Eng. | (780) 427-8270 | 427-7824 |
| | Nicola Harper, EIT | (780) 422-6643 | 427-7824 |
| | Terry McGinn | (780) 427-8146 | 427-7824 |
| **Northern Region Grande Prairie/Peace River Office** | George Neurohr, P. Eng. | (780) 538-8053 | 538-5336 |
| | David Curran, EIT | (780) 624-6417 | 624-6542 |
| **Central Region Red Deer Office** | Steve Johnson, P. Eng. | (403) 340-7739 | 340-5022 |
| | Win Tun, EIT | (403) 340-7742 | 340-5022 |
| | Alvin Beier, RET | (403) 340-5568 | 340-5022 |
| **Central Region Stony Plain Office** | Randy Lewis, P. Eng. | (780) 963-6131/267 | 963-4651 |
| | Renato Chiarella, P. Eng. | (780) 963-6131/266 | 963-4651 |
| | David Dowhaniuk | (780) 963-6131/265 | 963-4651 |