CT TEMPLATE INSTRUCTION MANUAL

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PREFACE

This publication contains instructions for completing the original and revised CT studies using the Automated CT Study Template (the Template). All public water systems (PWSs) must ensure that the water they produce is safe to drink. These systems must inactivate any pathogens not removed by the treatment process. The efficacy of pathogen inactivation is determined by measuring the amount of disinfectant in the water and the amount of time that it is in contact with the pathogens. A CT study is a formal determination of the disinfectant concentrations and the effective contact time provided by a given treatment plant. The Template will ease the completion of original and revised CT studies and expedite the approval process.

"We" and "You" in This Guide
-"We", as used in this guide refers to the Texas Commission on Environmental Quality(TCEQ)
 - specifically the Public Drinking Water Section of the TCEQ's Water Supply
   Division.

In this guide, "you" means the person who signs the CT study. This person may be a licensed waterworks operator, a licensed professional engineer, or any other individual who has been authorized by the water system to submit their CT study.

The specific requirements for completing CT studies can be found in 30 TAC §290.110(c)(1)(B).

You can find links to the Secretary of State's official version of these rules on the TCEQ web site, www.tceq.state.tx.us. From the home page, click on "Rules", and then use the links to view the rules online. The official version of these rules was published in the Texas Register on May 10, 2002.

Other Applicable Rules
Public water systems should be aware of additional rules about drinking water found in other parts of the Texas regulations. A public water system must comply with all the applicable requirements. Some examples of additional rules, and their locations, are given below:

30 TAC §290, Subchapter D: rules and regulations for public water systems related to requirements for water treatment plant design, operation, and maintenance. If you have questions about Subchapter D, contact the TCEQ Public Drinking Water Section at (512) 239-4691.

30 TAC §290, Subchapter F: Drinking water Standards Governing Drinking Water Quality and Reporting Requirements for Public Water Supply Systems. Subchapter F covers the requirements regarding harmful or potentially harmful constituents for water systems that supply potable water to the citizens of Texas. If you have questions about Subchapter D, contact the TCEQ Public Drinking Water Section at (512) 239-4691.

30 TAC §291: Utility Regulations. Rules and regulations for water utilities related to requirements for rates, capacity development, and Certificates of Convenience and Necessity for utilities. Contact the Utilities Technical Review Team at (512) 239-4691 if you have questions about these rules.

30 TAC §293: Water Districts. Governs the creation, supervision and dissolution of all general and special law districts subject to and within the applicable limits of the jurisdiction of the commission. Contact the Utilities Technical Review Team at (512) 239-4691 if you have questions about §293 rules.

30 TAC §30, Subchapters A and K: Occupational Licenses and Registration. Contains the administrative requirements and administrative procedures for certification of water works operators. TCEQ's Operator Certification Team, at (512) 239-6165 can answer questions about these rules.

If you have questions about the rules in this instruction manual, contact the TCEQ Public Drinking Water Section Technical Review & Oversight Team at (512) 239-4691.

If you are required to submit plans for review, please contact in the Utilities Technical Review Team at (512) 239-6953.

This instruction manual does not take the place of the full, official TCEQ rules. The document is intended only as a general explanation about selected parts of 30 TAC Chapter 290 (or any other TCEQ rules that might be referred to.)

GLOSSARY

baffling characteristics: The design features of a disinfection contact basin that determine how effectively the basin prevents water from passing through it before being adequately disinfected.

cell: A spot on the spreadsheet where data can be recorded. It is the intersection of a specific row and column. For example, the first cell in a spreadsheet is cell "A1" and is located at the point where column "A" and row "1" intersect.

comment box: A note that is attached to a single cell in a spreadsheet. In the case of the Template, the comment box contains useful information to help you enter the proper data in the cell.

clearwell: A storage unit, usually located at the plant site, that contains treated water before it is pumped to the distribution system. Some plants refer to their clearwells as "ground storage tanks."

CT: The result when the disinfection concentration at the end of a disinfection zone, C is multiplied by the contact time, T_{10}, within the disinfection zone.

disinfection zone: A segment of the treatment process where disinfection occurs. A disinfection zone contains one or more treatment units and the associated piping. A disinfection zone is defined as that section of the plant starting at a disinfectant injection or monitoring point, and ending at the subsequent disinfectant injection or monitoring point. Every disinfectant injection point is the start of a new disinfection zone, even if it is not always used. Every injection point must have an associated monitoring point. However, a plant may have only one disinfectant point and choose to monitor at more than one point, creating multiple disinfection zones.

distribution system: The system of pipes that delivers treated water to customers. Typically, the distribution system does not begin until the water leaves the grounds of the treatment plant.

effluent: The point where water leaving a treatment unit, such as a filter.

finished water: The water leaving a treatment plant; water that has passed through all of the treatment units. Finished water is sometimes also called treated water.

Interim Enhanced Surface Water Treatment Rule (IESWTR): The first federal regulation to require surface water treatment plants to begin producing treated water with a turbidity level of 0.3 NTU or less and to impose individual filter effluent (IFE) monitoring requirements on these plants.

inactivation ratio (IR): The method used to determine if a surface water treatment plant has met the daily minimum disinfection requirements. The value of IR is determined by dividing the value of CT actually achieved by the treatment plant by that of CT required to achieve the desired level of pathogen inactivation (see Section 5.4). An inactivation ratio of 1.0 or above for both virus and *Giardia* is required to meet the disinfection requirements.

influent: The point where water enters a treatment unit, such as a filter.

macros: A small computer program that automatically performs specific tasks. There are several macros in the Template spreadsheet that do things like circling empty cells that should contain data.

monitoring requirement: A test that must be run in order to meet minimum state and federal standards. For example, some of the monitoring requirements include tests for water temperature, and disinfectant residuals.

protected cell: A cell in the spreadsheet where you cannot enter data.

raw water: The untreated water entering a treatment plant.

settled water: The partially treated water that has passed through the sedimentation process, but not through the filtration process.

spreadsheet: An electronic file containing data that is arranged by rows and columns.

train: A series of treatment units that operate as a single unit within a treatment plant. Surface water treatment plants may contain one or more treatment trains that operate side by side. (See Figure 2-3)

treated water: The water leaving a treatment plant; water that has passed through all of the treatment units. Treated water is sometimes also called finished water.

unit process: A physical, chemical, or biological method of treatment that accomplishes a specific task. Examples of unit processes are rapid mixing, flocculation, sedimentation, and filtration. In the template, long sections of piping are considered unit processes because they provide detention time for disinfection.

worksheet: One page of a spreadsheet. The Template spreadsheet contains four worksheets.

1 INTRODUCTION

1.1 Purpose of the CT Study Instruction Manual

The purpose of this instruction manual is to help you complete original and revised CT studies for your treatment plant using the CT Template.

1.2 What Systems Can Use the New Automated CT Study Template?

The Template is primarily intended for small and medium size treatment plants. The template is designed for treatment plants with no more than 10 disinfection zones, each zone consisting of no more than 10 treatment units. If your plant does not meet these requirements, your CT study will need to be completed manually.

1.3 How Is This Instruction Manual Organized?

Table 1-1 gives a summary of the chapters in this manual and what they cover.

Table 1-1: CT Study Template Guidance Manual Chapters

Chapter	Topics
1	**Introduction** This chapter describes who is eligible to use the new Template and discusses how to use this guidance manual.
2	**CT Studies and the CT Study Approval Letter** This chapter details the concepts used in the preparation of a CT Study and the subsequent approval process. A firm understanding of the background presented here is critical to the preparation of an accurate CT Study.
3	**Describing Your Treatment Plant** This chapter presents the guidelines you will use follow in writing a narrative description and preparing a plant schematic.
4	**Describing Your Disinfection Zones** This chapter takes you through the steps involved with customizing the Template to accurately reflect the number of disinfection zones and treatment units in your treatment plant. This chapter outlines the information you must enter to characterize your disinfection process.
5	**Evaluating Your Disinfection Protocol** Chapter 5 describes the Calculator worksheet of the CT Study Template and the information you must provide to determine whether your disinfection process provides adequate disinfection.
6	**Submitting Your CT Study Report** This chapter presents the steps involved with submitting your complete CT Study Report to the TCEQ.

Chapter	Topics
Appendices	The appendices contain a variety of background information that is referenced throughout this guidance. They contain examples of CT studies completed with the Automated Template as well as example CT Study approval letters. Background information regarding the pros and cons of different disinfectants are discussed.

1.4 CT Study Template Features

If your treatment plant meets the requirements given in Section 1.2, you can complete your CT study using the Template. The electronic CT Study Template was developed using Microsoft Excel 97, but will also run on all new versions of Excel. You may download the Template from our Web site at:

www.tnrcc.state.tx.us/permitting/waterperm/pdw/pdw_pub.html

If you do not have Internet access, call the Public Drinking Water Section at (512) 239-4691 and ask them to mail you the Template and Instruction Manual.

To facilitate the CT study approval process and reduce errors, the Template has built-in functions and macros that:

1. customize the spreadsheet so that it more accurately describes your plant;
2. limit the type, kind, and values of data that you can enter in certain cells;
3. help you identify any errors or omissions that occurred when you entered the data;
4. perform the CT calculations; and
5. compile summary data.

1.5 How to Interpret the Symbols We Use in This Manual

We have included instructions and comments in the electronic spreadsheet. Once you figure out how to use the Template, those electronic comments will reduce or eliminate your dependence on this manual.

In this manual, we have highlighted the calculated cells in the Template using the symbol, ⬭ CALC . We have also used the symbols < > to designate keys on the computer keyboard; for example, <Y> means the "Y" key and <Tab> means the "Tab" key. If we need you to push two or more keys at the same time, we will use the < > + < > format. For example, <Shift> + <Tab> means to press the< Shift > and <Tab> keys at the same time. If the spreadsheet has a"button" that you need to click in, the symbol is [ ]. For example, [OK] means you should move your cursor **over the "OK" button** and click once on your left mouse button. Table 1-2 summarizes the meaning of the symbols used in this document.

Table 1-2: Meaning of Symbols Used in this Document

Symbol	Meaning
CALC	This shows a cell that you can't type in because it contains a formula for automatically calculating a value.
< >	Two pointy brackets with a grey highlight is the symbol for a key on the computer keyboard. For example, <Esc> means the Escape key.
< > + < >	Two keyboard symbols with a plus sign means you have to press the keys at the same time.
[ ]	Square brackets with a grey highlight means there is a button on the screen to click.
[WORDS IN THIS FONT]	We use words typed in this font to show where there is information you have to type in. For instance [Plant] means you should type in the name of your plant.
Heading	We use words typed in this font to show that we are talking about an area on the Template or a feature in the spreadsheet. For example, **Disinfection Process Parameters** means we are describing an area of the report that is labeled Disinfection Process Parameters.

Features of the Spreadsheet

As you work with the spreadsheet, you will find many features that make it easier for you to use. Chapters 3-5 explain the specifics of filling out the spreadsheet. Here are some general features that will help you use the spreadsheet.

Enable Macros? Yes!

When you open the Template file, a Microsoft Excel ® dialog box will pop up to let you know that the workbook you are opening contains macros. In order for the spreadsheet to run properly, you must click the [Enable Macros] button every time you open the spreadsheet. Figure 1-1 shows the screen that appears, with the [Enable Macros] button in the bottom center.
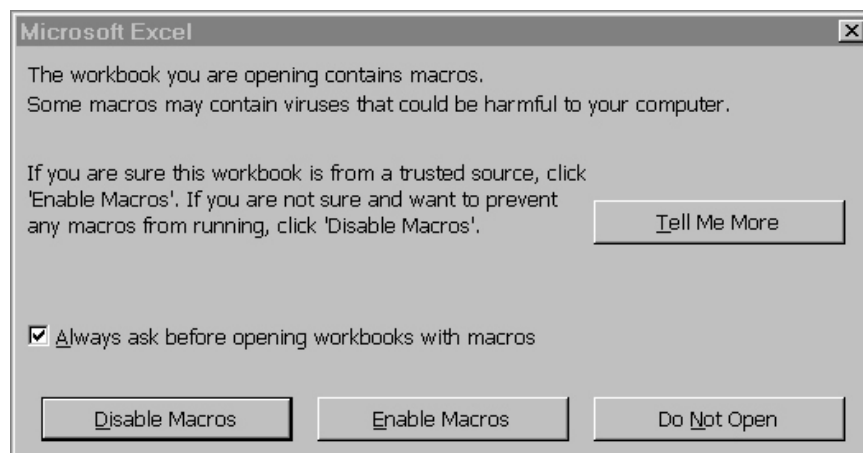
Figure 1-1: Enable Macro Dialog Box

> **WARNING ABOUT MACROS!**
> Macros are programs that will automatically execute when you open a file. Unless you are absolutely sure that you have obtained the file from a reliable source, you should be very wary about enabling a spreadsheet macro because hackers can hide computer viruses in the macro. If you have any doubts, scan the spreadsheet with an up-to-date anti-virus program.

Worksheets

An Excel spreadsheet is also called a workbook which is made up of separate worksheets. After you open the workbooks, you will find a series of tabs at the bottom of the screen. Each of these tabs identifies one of the worksheets in the workbook.
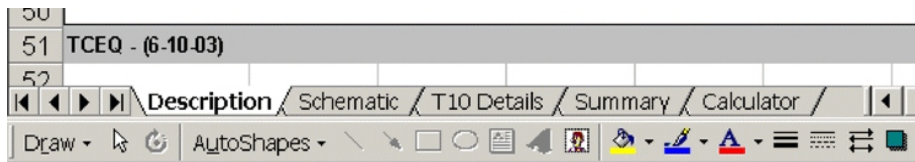
Figure 1-2: Worksheet Tabs

When you click on one of these tabs, it will take you to the worksheet named on the tab. Figure 1-2 shows the bottom of a screen open to the description worksheet (the tab is not shaded gray).

Shading

The Description Worksheet and the T10 Details Worksheet both use shading as a tool for indicating which cells you are allowed to enter data into. Cells that appear white against the gray shaded background are the cells that can be filled. Cells that are shaded grey are not available for data entry. An example illustrating the use of shading is shown in Figure 1-3 and comes from the Description worksheet.

Figure 1-3: Shading

Comments

Many of the cells in the spreadsheet have comments. You can tell if there is a comment attached to the cell if there is a little red triangle in the upper right corner of the cell. To see the comment, just move the cursor (the arrow) over a cell - a comment will appear the describes the information you need to enter.

PUBLIC WATER
SYSTEM NAME: _____

PWS Name
Enter the name of your
public water system.

Figure 1-4: Comment Boxes

Drop-Down Menus

Some cells in the spreadsheet have drop-down menus that give you the acceptable options that you can put in that cell. You can tell which cells have drop-down menus because when you move your cursor over them, a little downward-pointing arrow will appear. For example, the Month cell on the T10 Details Worksheet looks like this:

Month: _____

But when you move your cursor over it, you see the downward-pointing arrow:

Month: _____

When you click the left mouse button once on the downward-pointing arrow, the drop-down menu shown in Figure 1-5 appears.

Month:

January
February
March
April
May
June
July
August
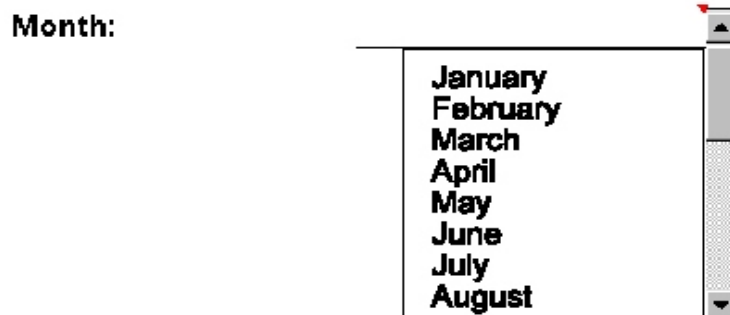
Figure 1-5: Drop-down Menu

Now, you can move your cursor over the month you want to select, click your left mouse button again (once) and the month you selected will appear in the cell:

Month: February
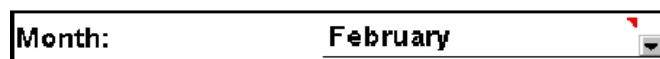
Protected Cells

Some of the cells in the spreadsheet are "protected" so that you can't type in them. You should not have any reason to try to type in a protected cell. For example, if you only have two disinfection zones, and you try to enter data for a third disinfection zone, the spreadsheet won't let you do it. Another example of a protected cell is one that has a formula for doing automatic calculations. When you click on a protected cell, you will see the following screen:

Figure 1-6: Protected Cell Warning

Just click [OK], and the box will disappear.

Viewing the Spreadsheet

You can change how big or how little the type appears on your computer screen by using the zoom function. To do this, click [View] in the Excel Menu, select [Zoom] at the bottom of the drop-down list, and select the size that you want.

1.6 How is the CT Study Template Organized?

If you look closely at the bottom of the Template, you will notice that there are five worksheets (Figure 1-2). The five worksheets are titled "Description", Schematic", "T10 Details", "Summary", and "Calculator". Table 1-3 summarizes the worksheets contained in the Template and each of their content.

Table 1-3: Contents of the Automated CT Study Template

Worksheet Title	Contents
Description	Contains a narrative description of the treatment plant layout and the disinfection protocol.
Schematic	Can be used for creation of your plant schematic using Microsoft Drawing Tools. (You may include a hand drawn sketch of your treatment processes instead of using Microsoft Drawing Tools.)
T10 Details	Contains the details of every treatment process unit including unit type, shape, dimensions, flow rates, and baffling factors. Automated calculators calculate the volume and the T_{10} for each unit and zone.
Summary	Summarizes several characteristics of each disinfection zone and the treatment units it contains. This information includes unit descriptions, volumes, flow rates, baffling factors, and T_{10} values.
Calculator	Contains macros that use plant data entered in the T10 Details Worksheet and disinfection data entered in the Calculator Worksheet to calculate the pathogen inactivation ratios achieved by your treatment plant.

Table 1-4 summarizes the sequence of steps you will follow when completing your CT Study.

Table 1-4: Sequence for Completing a CT Study Using the Template

Step	Process
0	Familiarize yourself with the background information necessary to complete a CT Study (Chapter 2). Correctly delineating disinfection zones and selecting appropriate baffling factors for each treatment unit is important for the successful completion of your CT study.
1	Identify all of the disinfection zones at your plant and all of the treatment units that you want to include in each zone.
2	Enter a narrative description that explains the details of your treatment plant layout and disinfection protocol (Section 3.2).
3	Create a plant schematic that visually depicts the information contained in the narrative description. (Section 3.3)
4	Customize your Template to accurately reflect your treatment plant layout and disinfection protocol (Sections 4.2)
5	Enter details of each treatment process unit including dimensions, flow rates, and baffling factors (Section 4.3).
6	Enter the appropriate operating conditions, allowing the spreadsheet to calculate the pathogen inactivation ratios achieved by your plant (Chapter 5)
7	Submit your completed CT study to the TCEQ (Chapter 6). You must submit a revised CT study any time you add or eliminate a treatment unit or treatment train, or make a change to your disinfection protocol.

2 CT STUDIES AND THE CT STUDY APPROVAL LETTER

2.1 Factors Influencing the Efficacy of Disinfection

A typical surface water treatment plant cannot remove all of the disease-causing organisms that might be present in the raw water. Therefore, the treatment process must include disinfection to kill or inactivate the pathogens that are not removed.

The effectiveness of the disinfection process depends on several factors. These factors include:

1. **The type of disinfectant that the plant uses.** Some disinfectants are stronger than others. The stronger disinfectants will typically require a lower dose to achieve the desired level of inactivation. However, some of the strongest disinfectants, like ozone, do not produce long-lasting residuals.

2. **The concentration of the disinfectant.** Whichever disinfectant you use at your plant, rasing the disinfectant residual generally improves the effectiveness of the disinfection process. However, while increasing the residual increases the number of organisms that you kill, it can also increase your disinfection by-product levels.

3. **The amount of time that the disinfectant is in contact with the water.** The longer that you expose a pathogen to a disinfectant, the more likely it is that you will kill it.

4. **The pH of the water.** Some disinfectants are affected by the pH of the water. Chlorine is particularly affected because it changes from its hypochlorous acid form to its less effective hypochlorite ion form as the pH rises. Chlorine dioxide, on the other hand, is less effective at lower pH levels than it is at pH levels above 7.5 pH units.

5. **The temperature of the water.** Disinfectants are less effective at lower temperatures than they are at higher temperatures. This relationship exists because chemical reactions occur more slowly at lower temperatures and because many pathogens tend to "go to sleep" when the temperature drops. This is generally not a problem unless your water temperature drops below 5° C (41°F).

Some of these factors, like residual concentration and pH, can be controlled to a great extent by the operator. Other factors, like the type of disinfectant and the contact time, are limited by the design of the treatment plant and the water demand.

2.2 The CT (Concentration x Time) Concept

The type of disinfectant that a plant uses and the pH and temperature of its water tend to remain relatively constant on a day-to-day basis. Consequently, we tend to evaluate the disinfection process using the concentration and time factors. Often, we describe the relationship between the disinfectant concentration and time using the term "CT" and the following equation:

$$concentration\ of\ disinfectant\left(mg\ /\ L\right) \times time(minutes) = CT$$

(Equation 2-1)

Basically, the less time you have to disinfect, the more disinfectant you have to apply to maintain the same CT value.

Just as turbidity levels and particle counts are used to evaluate the effectiveness of physical removal processes, **CT values** are used to assess the performance of chemical disinfection processes. The actual CT value for a disinfection zone is obtained by multiplying the actual disinfectant concentration, "C", by the time, "T", that the disinfectant was in contact with the water. The actual CT value (that is, CT_{actual}) is then compared to the CT required to achieve the desired level of pathogen inactivation (that is, $CT_{required}$). The log inactivation achieved during the disinfection process can be calculated as shown below:

$$log\ inactivations = \frac{CT_{actual}}{CT_{required}\ for\ N\text{-}log\ inactivation} \times N\text{-}\mathbf{log}$$

(Equation 2-2)

Although the overall CT concept may seem simple and straightforward, applying this approach is complicated because:

- the actual contact time available at your plant is affected by the amount of short-circuiting that occurs within your contact basins;
- the required CT varies based on:
  - the pathogen being inactivated,
  - the log inactivation level (N-log) that you are required to achieve,
  - the actual plant operating conditions, that is, the pH and
  - temperature of the water, and
- type and concentration of the disinfectant, and
- your plant may use several disinfectant application points and may even adjust the pH level during the disinfection process.

Because applying this CT approach can be difficult and time-consuming, we have incorporated a small Visual Basic computer program in the Template spreadsheet. This program uses several mathematical equations to calculate CT_{actual} based on the information you enter in your Template.

2.3 Purpose of a CT Study and CT Study Approval Letter

Every plant is required to have a CT study approval letter from the TCEQ. The purpose of the CT study approval letter is to document the fact that we have reviewed and approved your plant's CT study and its current disinfection process. See Appendix B for a sample CT letter like the one for your plant.

Every treatment plant that uses surface water or groundwater that is under the direct influence of surface water must have a current, TCEQ-approved CT study. You must request that changes be made to your CT study if you make a significant change to your disinfection practice. ***You may not make a change to your disinfection process without our prior written approval.*** Significant changes to disinfection practices include any of the following:

- changing the type of disinfectant;
- moving the point of disinfectant addition or monitoring:
- changing physical facilities in such a way the more or less effective contact time is used;
- changing the approved capacity of the plant; or
- any other change that we consider significant.

The CT study is an evaluation of your plant's disinfection process. The purpose of the CT study is to:

- identify the number of disinfection zones at your plant;
- determine the effective contact time, or T_{10} that is provided in each zone; and
- establish that the plant will be able to meet its disinfection requirements.

In order to complete your CT study, you need to understand how we evaluate the disinfection process at your plant. The critical factors we evaluate are:

- the number of disinfection zones and treatment trains at the plant;
- the maximum flow rate through each zone, and if applicable, each train;
- the baffling characteristics of each disinfectant contact unit; and
- the T_{10} time in each zone.

2.4 Disinfection Zones and Treatment Trains

A disinfection zone contains one or more unit processes and the associated piping. A disinfection zone is defined as that section of the plant starting at a disinfectant injection or monitoring pint, and ending at the subsequent disinfectant injection or monitoring point. Every disinfectant injection point is the start of a new disinfection zone, even if it is not always used. Every injection point must have an associated monitoring point. However, a plant may have only one disinfectant point and choose to monitor at more than one point, creating multiple disinfection zones.

The starting point for analyzing your disinfection process is to identify the unit processes and the disinfection injection and monitoring points. As part of the CT Study, you will be required to create a schematic drawing of your treatment plant and identify all unit processes, disinfectant injection points, and disinfectant monitoring points. A drawing, like the ones shown in Figures 2-1, 2-2, and 2-3, may help in defining disinfection zones.

Unit Processes

A unit process is a method of treatment designed to accomplish a specific task. Examples of unit processes include rapid mixing, flocculation, sedimentation, filtration, and disinfection basin. Long stretches of piping, clearwells, storage tanks, and transfer wells are considered unit processes because they provide contact time for disinfection. In Figure 2-1 there are four unit processes: flocculation, sedimentation, filtration, and a clearwell. If any of the piping between units would provide substantial detention time, it may be defined as a unit process.

Often, a single unit process contains several units in parallel. For example, granular media filters are often installed in banks of several parallel units and the flow is split between them. In this case, there is one unit process (filtration) and several units within that unit process.

Disinfection Injection and Monitoring Points

Figure 2-1 contains the schematic for a plant that has multiple chlorine injection points and uses several different types of disinfectants. The figure shows how the disinfection zones might be defined in this complex design.
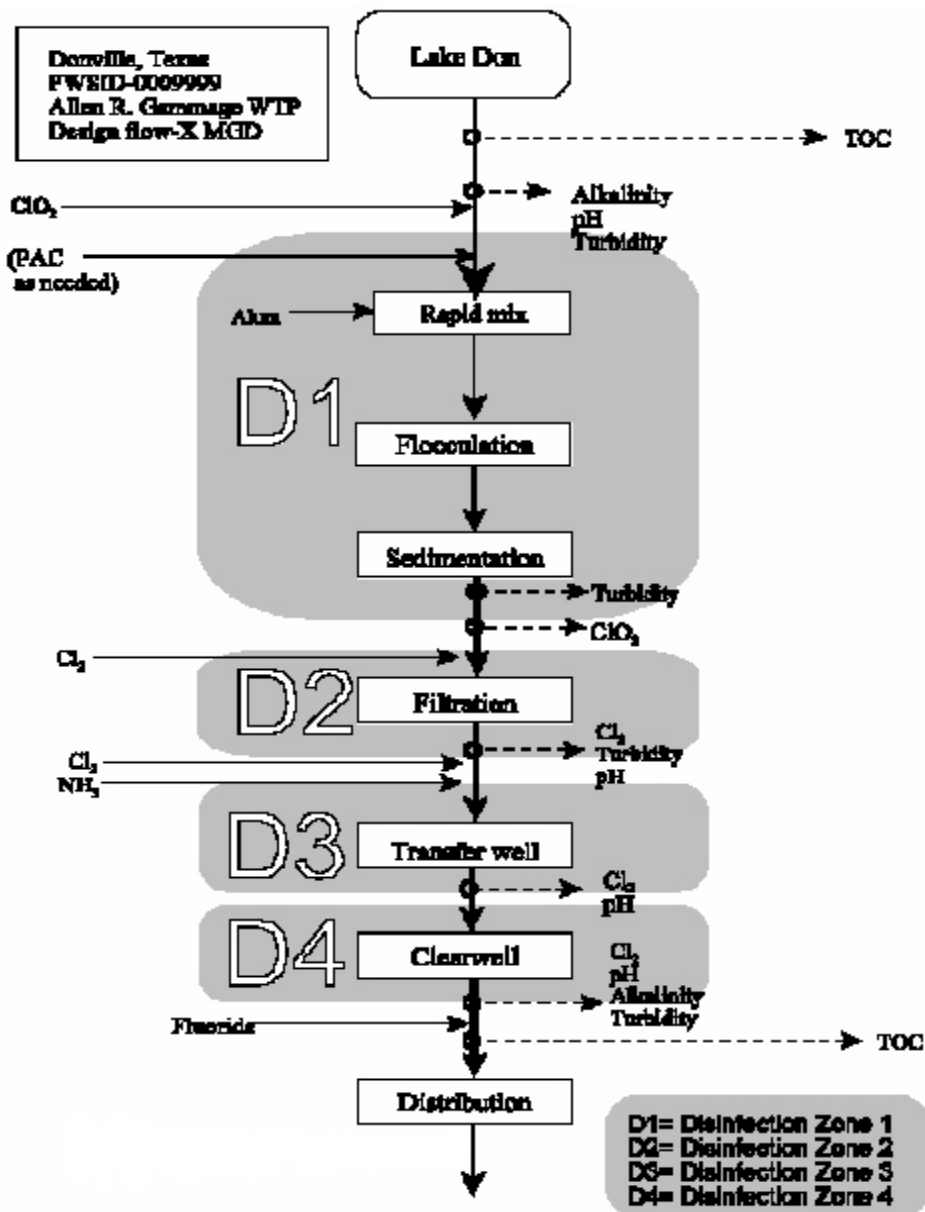
Figure 2-1: Schematic of SWTP with Multiple Disinfectant Application Points

Plants with multiple treatment trains may have parallel disinfection zones. The analysis of multiple treatment trains is not harder than the one for a single treatment train **if** the treatment trains are identical, they share a common disinfectant application point, and flow is split equally. If the treatment trains are very different, it may be more appropriate to treat the treatment trains as separate plants. Figure 2-2 shows the schematics of two treatment plants. The upper

schematic shows a plant where it would be appropriate to define two trains. The complexity of the plant in the lower schematic suggests that it may be more appropriate to redefine the facility as two plants instead of two trains.
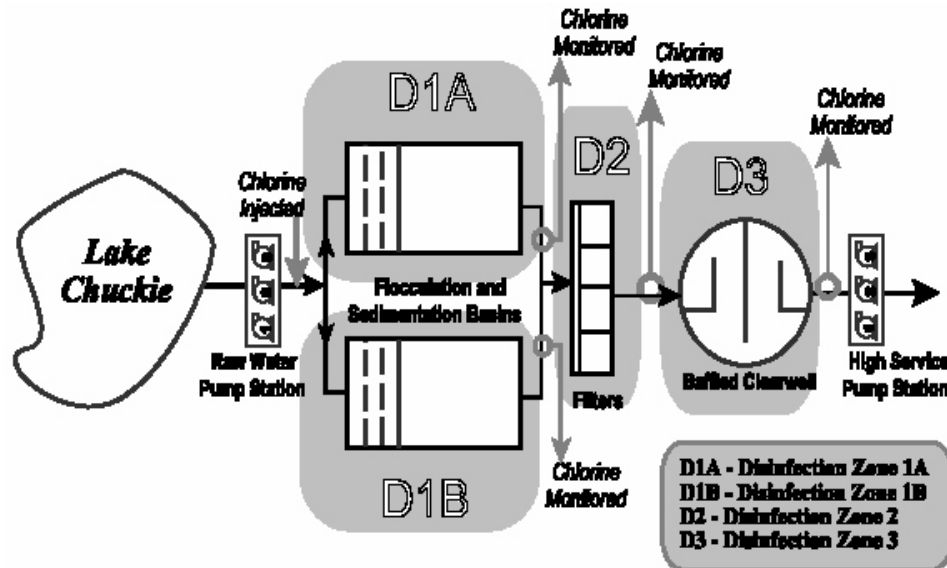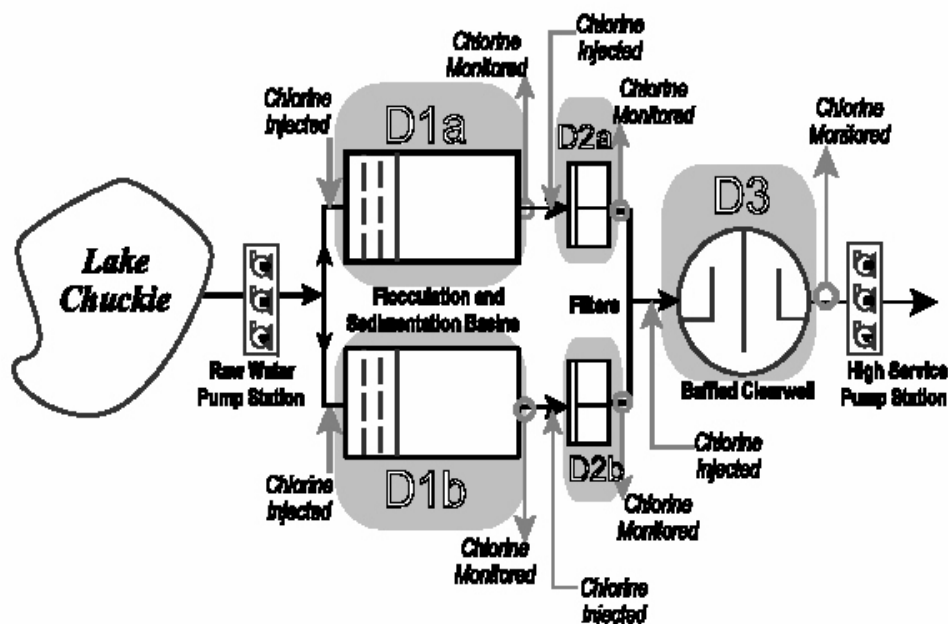
Figure 2-2: Schematic of a SWTP with Multiple Treatment Trains

Special Case for Filters

In nearly all cases, filters are designed in water treatment systems as a bank of several identical, parallel units. As such, when one or more filters are taken out of service for backwashing, the filters that remain on-line experience higher flows. The CT calculations in the Template use the maximum peak hourly flow rate through a single filter to estimate the log inactivation of pathogens. When there are multiple units in succession within a disinfection zone, the flow rate through the basin that contributes the most T_{10} time is used in the calculations. When filters are included in a disinfection zone with other treatment units, the calculated CT values can be compromised. It is beneficial in this situation, to define a separate disinfection zone that contains only filters. We can do this by having either a disinfectant injection or monitoring point immediately before the filters and a disinfectant monitoring point immediately following the filters. If your treatment system does not have filters in a separate disinfection zone, we may require that you install an additional disinfection monitoring point so that the filters are in a zone by themselves.

2.5 Effective Contact Time, T_{10}

Flow Rate

The theoretical contact time in a basin is calculated by dividing the actual volume of the basin by the flow rate through the basin. When the flow rate increases, the time the water spends in the plant decreases. You need to use the maximum flow rate through the disinfection zone when evaluating your disinfection process. This flow rate should be based on the rated capacity of your treatment plant.

The theoretical contact time is dependent only on the volume of the basin and the flow rate of the water. However, the actual contact time depends on these two factors plus the hydraulic characteristics of the basin, that is, how much short-circuiting occurs within the basin. Short-circuiting occurs when individual drops of water do not remain in a basin for the same amount of time. Short-circuiting exists to a significant degree in basins that have inadequate baffling and in basins where mixing occurs.

Baffling Factors

The effective contact time (T10) in each disinfection zone is a function of the hydraulics of the basin. The flow through a pipe or a well-baffled basin is very different from the flow throughout a storage tank or a poorly baffled basin.

The two basins shown in Figure 2-3 have the same shape and size and the only difference between them is that one is well baffled and the other is poorly-baffled. Assume that the flow rate of the water through each basin is the same and that a food-grade dye is injected at each of the inlets for one minute. In the well-baffled basin, the dyed water moves through the basin as though the water was a solid plug, that is, the dyed water that enters the basin first will leave the basin first. In the poorly-baffled basin, some of the dyed water moves through the basin faster than the rest of the water, that is, some of the dyed water that entered the basin last may exit before some of the water that entered first. As Figure 2-4 shows, in an

extreme case, much of the dyed water in a poorly baffled basin will be discharged before any of the dyed water in the well-baffled basin even reaches the outlet.
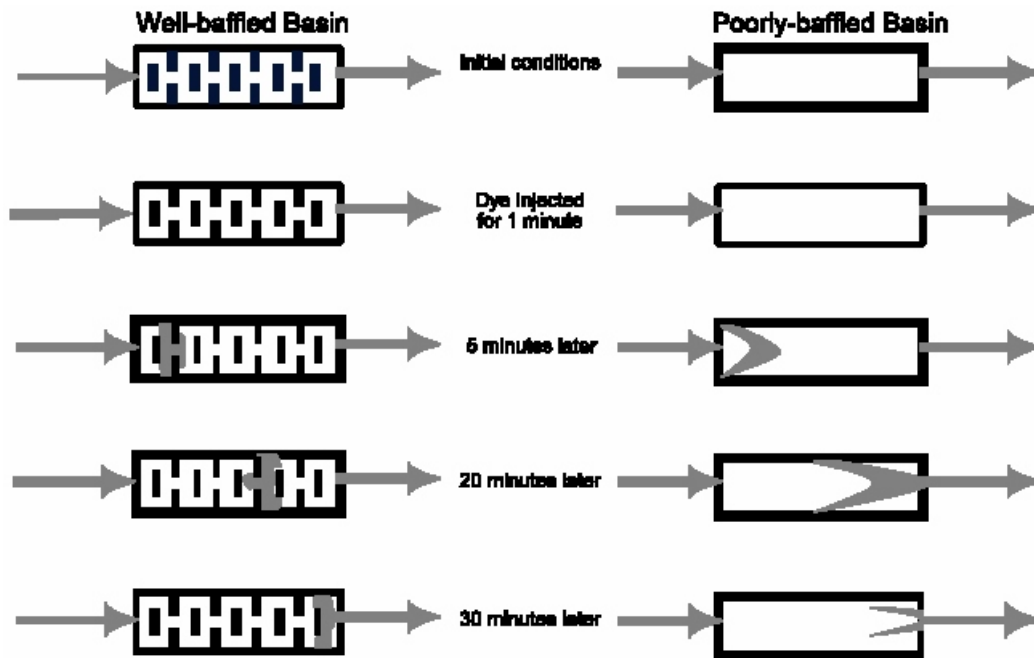
Figure 2-3: Comparison Flow Patterns in Well-Baffled and Poorly Baffled Basins

In the two treatment units shown in Figure 2-4, the longest path a particle can take through a pipeline is not that different from the shortest path. It is different for an unbaffled mixing tank. In the case of a tank, one particle may flow through directly from the influent to the effluent. This short-circuiting particle will be in contact with the disinfectant for a relatively short time.
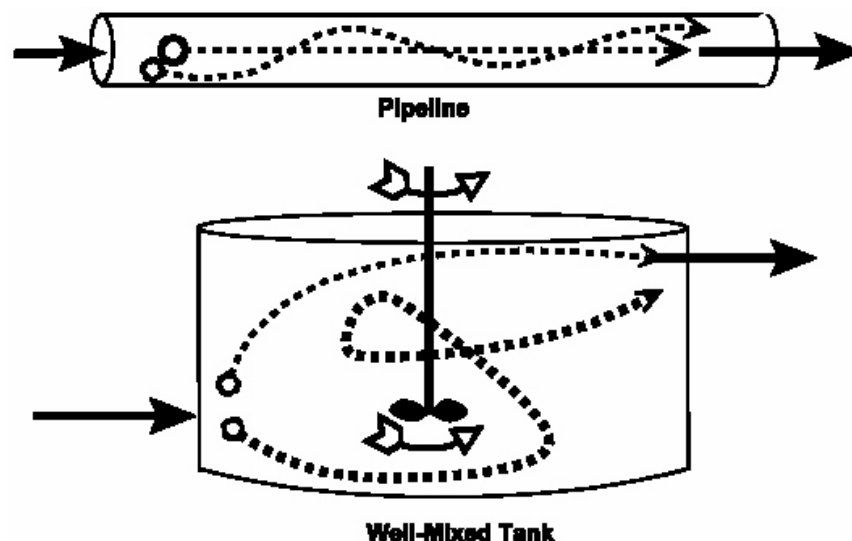
Figure 2-4: Comparison of the Flow Patterns in a Pipe and a Well-Mixed Tank

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Although basins with mixers and poor baffling exhibit high levels of short-circuiting, some short-circuiting exists in all basins. The question becomes "How much short-circuiting do we allow before we determine the actual contact time?" To answer this question, a number of research studies were conducted on pilot plants and at full-scale facilities. Based on the results of these studies and a theoretical analysis of the problem, the EPA determined that only 10% short-circuiting should be allowed when determining the actual contact time.

Under those conditions, 10% of the water would receive slightly less disinfection than desired but the rest of the water would receive more than enough disinfection to meet the objectives. Since the actual contact time is based on a 10% short-circuiting allowance, the term T_{10} **time** is used to describe the actual disinfectant contact time at your full-scale plant. It should be noted that using the T_{10} time for CT calculations is a very conservative approach: in many cases 50% of the water actually receives twice the required level of disinfection, and 10% of the water might receive as much as four times more disinfection than required.

The best way to determine the T_{10} time in a disinfectant contact basin is to run several tracer tests at different flow rates. During each of the tracer tests, you introduce a tracer, or marker, compound (such as a dye, fluoride, or other soluble material) into the water as it enters the basin. Then you run a series of tests to determine how long it takes for 10% of the tracer to reach the end of the basin. By running the tests at several different flow rates, you can determine if the hydraulic properties of the basin change as the flow rate changes.

The differences in hydraulics are described by the baffling factor (BF). The baffling factor is defined as the ratio of the effective contact time (T_{10}) to the theoretical detention time ($T_{theoretical}$). The results of the tracer studies are used to determine a baffling factor that characterizes the hydraulic short-circuiting within the treatment unit. The relationship between the baffling factor, T10, and the theoretical contact time can be expressed using the following equation:

$$Baffling\ Factor = \frac{T_{10}}{T_{theoretical}} = T_{10} \times \frac{Flow\ rate\ during\ the\ tracer\ test}{Volume\ during\ the\ tracer\ test}$$

(Equation 2-3)

The baffling factor is important because it is then used to calculate the T10 times at flow rates other than the ones used during the tracer study. The T10 can be calculated for any given operating condition using the following equation:

$$T_{10\ current} = \frac{Current\ Volume}{Current\ Flow\ Rate} \times Baffling\ Factor$$

(Equation 2-4)

Two additional assumptions are made when completing CT studies in order to significantly reduce the amount of data that you need to collect each day.

- First, we ask you to use a minimum water level when calculating the T_{10} for the treatment unit. By using a minimum volume, you ensure that the contact time under all operating conditions will be greater that the value that we are approving...and more time means more kill.

- Second, we assume that the water level never exceeds the water level we use when we approve the CT study. This assumption allows us to conclude that the flow rate into the unit is equal to the flow rate out of the unit. (If this were not true, the water level would continue to fall or start to rise.) The assumption allows us to base the detention time in the clearwell (and other variable-level contact basins) on the rate that water is being treated rather than the peak flow rate of the service or transfer pumps. While this assumption may underestimate the contact time in tanks where the water level falls rapidly (such as at plants with very small clearwells or very large service pumps), it provides a conservative estimate at most of the plants in Texas.

Although these assumptions are a minor inconvenience for systems that closely monitor the water level in their clearwells and storage tanks, they significantly simplify the CT calculation for the majority of plants because it is no longer necessary to determine the water volume in each treatment unit each time you evaluate your disinfection process. By making these assumptions, we can combine Equations 2-3 and 2-4 to obtain:

$$
\begin{aligned}
T_{10\ current} &= \frac{Current\ Volume}{Current\ Flow\ Rate} \times Baffling\ Factor \\
&= \frac{Current\ Volume}{Current\ Flow\ Rate} \times \frac{CT\ Study\ Flow\ Rate}{CTStudy\ Volume} \times T_{10\ CT\ Study} \\
&= \frac{Current\ Volume}{CTStudy\ Volume} \times \frac{CTStudy\ Flow\ Rate}{Current\ Flow\ Rate} \times T_{10,\ CT\ Study}
\end{aligned}
$$

(Equation 2-5a)

Since we have assumed that the Current Volume and the CT Study Volume are the same, the first term cancels out and you can calculate the actual T_{10} using Equation 2-5b:

$$
T_{10\ current} = \frac{CTStudy\ Flow\ Rate}{Current\ Flow\ Rate} \times T_{10\ CTStudy}
$$

(Equation 2-5b)

There are three types of baffling factors that are approved for use in your CT study:

- baffling factors obtained from a tracer study;
- manufacturer provided and TCEQ approved baffling factors; or
- theoretical baffling factors. In most cases theoretical baffling factors will be the type of baffling factors that you use.

Baffling Factors Obtained From a Tracer Study

As stated above, the most accurate way of estimating the effective contact time is by performing tracer studies on a basin or series of basins. If you have completed tracer studies on any of your basins it is possible to calculate a baffling factor from the results of the test using Equation 2-3. Since the tracer study baffling factor affects the CT study results, the tracer study data must be included when you submit your CT study for our review.

Manufacturer Approved Baffling Factors

The second type of baffling factor is manufacturer provided and TCEQ approved baffling factors. For many patented treatment processes, the manufacturer has performed extensive hydraulic testing and has published the baffling factors from the results of those tests. We recognize and accept manufacturer provided baffling factors for the treatment process units contained in Table 2-1.

Table 2-1: Manufacturer Approved Baffling Factors

Trade Name of Unit	Approved Baffling Factor
Trident®	0.7
Actiflo®	0.7
Pacer II®	0.7
Walker Claricone®	0.42

If your treatment plant uses one of the units listed in Table 2-1, the manufacturer provided baffling factors may be used in your CT study. If your plant uses a treatment process unit that is not listed, but you believe the manufacturer has performed the testing necessary for the use of a manufacturer provided baffling factor, please contact us to initiate the approval process for that unit.

Theoretical Baffling Factors

Although tracer tests are the most accurate way to determine the actual contact time, T_{10}, in a basin, tracer studies are time-consuming, expensive, and difficult to conduct. You or your engineer may choose to estimate the baffling factor (use a theoretical baffling factor) for your basins rather than conducting an actual tracer study to determine an empirical (data based) value. In fact, most of the CT studies that we review and approve use theoretical baffling factors for one or more of the treatment units.

The theoretical baffling factors that we use when reviewing CT studies are based on the design of a basin and use the data obtained from many research studies. The theoretical baffling factors that we approve are relatively conservative and may actually underestimate the T_{10} time provided in a basin. If your plant is using a theoretical baffling factor, you may be providing slightly more disinfection than you think.

Unless tracer study data or a manufacturer provided baffling factor exists, you must estimate the theoretical baffling factors for each unit of the plant in which disinfection occurs. For example, in a length of pipe there is plug flow. A tracer test in a pipe would show that all the material you put in comes out at the theoretical hydraulic detention time of the pipe. Therefore, the correct theoretical baffling factor to use for a pipe is 1.0. In a tank such as an unbaffled clearwell, some of the tracer material in a tracer test would come out almost immediately. The appropriate baffling factor for an unbaffled clearwell is 0.10, because of this short-circuiting. Using the guidelines presented in Table 2-2 and the following paragraphs, you should be able to determine the appropriate baffling factor for each unit process at your plant.

Table 2-2: Theoretical Baffling Factors

Condition	Baffling Factor	Baffling Description	Typical Unit Process
Unbaffled	0.1	None; agitated basin; single inlet; high inlet and outlet flow velocities; variable water level	Clearwell or storage tank without baffling; with no perforated inlet or outlet; and with inlet and outlet submerged
Poor	0.3	Single or multiple inlets with a 2.0 ft air gap to water surface and single or multiple unbaffled outlets; baffled inlet or outlet with 0-1 intrabasin baffling walls	Many conventional sedimentation basins; storage tanks with one or two baffles
Average	0.5	Baffled inlet or outlet with 2+ intrabasin baffling walls; baffled inlet and outlet with 0-1 baffling walls	Some (few) sedimentation basins; highly baffled flocculation basins and storage tanks with three or four baffles
Superior	0.7	Baffled inlet and outlet with 2+ intrabasin baffling walls; perforated inlet baffle, serpentine or perforated intrabasin baffles, and outlet weir	Filters; contact tanks with serpentine baffling
Plug Flow	1	Pipeline flow	Sections of pipe 10 times longer than their diameter

In addition to the baffling factors described in Table 2-2, the following theoretical baffling factors are approved for use when two or more clearwells occur in series.

Table 2-3: Baffling Factors for Clearwells in Series

Number of Clearwells in Series	Baffling Factor
2	0.2
3	0.25
4	0.3
5	0.35

Disinfection Zones and Total T_{10}

The total T_{10} for a disinfection zone is the sum of the T_{10}'s for the individual units in the zone. These individual units can include several sections of pipe, a tank or basin, or any other treatment unit that provides time for the disinfectant to work. Equation 2-6 summarizes this relationship.

$$T_{10,Zone} = \sum_{unit\,1}^{unit\,n} T_{10}\ Unit = T_{10,\,unit\,1} + T_{10,\,unit\,2} + \ldots + T_{10,\,unit\,n}$$

(Equation 2-6)

2.6 Additional Concepts

Disinfection Profiling

The Interim Enhanced Surface Water Treatment Rule (IESWTR) requires certain public water systems to evaluate their disinfection practices and work with the state to assure there are no unintended reductions in microbial protection. Public water systems that serve more than 10,000 people or have trihalomethane or haloacetic acid concentrations above specified levels are required to create a disinfection profile.

The disinfection profile is developed by compiling daily *Giardia* lamblia log inactivations computed over a period of 12 months. In addition, a disinfection profile for daily virus log inactivations must be developed for PWSs that use either chloramines or ozone for primary disinfection. The log inactivation values are calculated using daily measurements of operational data collected during peak-hour flows. The PWS must keep the disinfection profile on file to be reviewed during its Sanitary Survey.

Disinfection Benchmarking

A disinfection benchmark is an indicator of disinfection effectiveness and depends upon the inactivation of *Giardia lamblia* (or viruses). A benchmark is determined by calculating the average daily inactivation value for each of 12 consecutive months. The lowest monthly average becomes the disinfection benchmark. If the system has data from more than 1 year, it repeats this calculation for each year. The benchmark is the average of the lowest month's value for each of the years.

The calculation of a disinfection benchmark is required if you are planning on making a significant change to your disinfection protocol. Significant changes would include:

- changes to the point of disinfection:
- changes to the disinfectant(s) used at your treatment plant;
- changes to the disinfection process; and
- Any other modification we would consider significant.

The benchmark will be used by the TCEQ as a standard for evaluating the proposed changes to your disinfection protocol.

3 DESCRIBING YOUR TREATMENT PLANT

This chapter outlines the steps involved with creating your CT Study Template File, preparing and entering a narrative description of your treatment plant, and creating a plant schematic that visually summarizes the narrative description.

3.1 Preliminaries

Before completing the steps outlined in this chapter, you should be familiar with your treatment plant and disinfection process. Access to engineering drawings and daily operational data will be useful. The detailed information that will be required is outlined in Section 3.2.

Enable Macros? Yes!

When you open the Template file, a Microsoft Excel® dialog box will pop up to let you know that the workbook you are opening contains macros. In order for the spreadsheet to run properly, you must click the [Enable Macros] button every time you open the spreadsheet. Figure 3-1 shows the screen that appears, with the [Enable Macros] button in the bottom center.
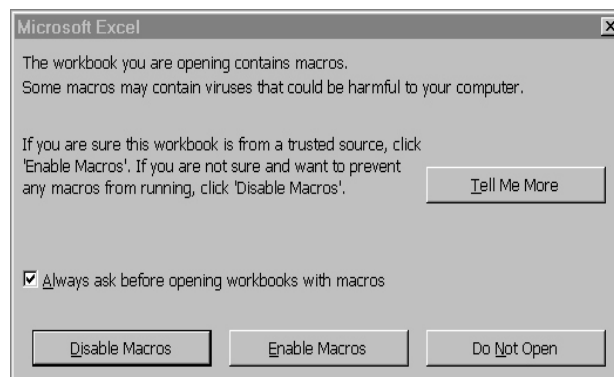
Figure 3-1: Enable Macro Dialog Box

3.2 Narrative Description

When you open the CT Study Template spreadsheet, the program automatically takes you to the top of the Description worksheet so that you can enter the name of the your water system and other information. If you have moved away from the Description worksheet without identifying your plant, activate the Description worksheet by clicking on the tab labeled "Description" at the bottom of the screen.

Identify Your Plant (on Description Worksheet)

The first thing you will need to do is identify the treatment plant for which you are completing the CT Study. At the top of each worksheet of the CT Study Template, you will find blanks for identifying your water system and your plant. However, we have locked all of these blanks except for the ones on the Description worksheet. The program was written so that when you fill out the

water system/plant information on the Description worksheet, the data will automatically be copied onto the other worksheets. Figure 3-2 shows the top of the Description worksheet.

Figure 3-2: Plant Description Section of the CT Study Template

Public Water System Name
Enter the name of your public water system.

Plant Name or Number
If your water system has more than one treatment plant, enter the name of the treatment plant for which the CT Study is being completed. You may leave this cell empty if your water system has only one treatment plant.

Special Case: Sometimes the treatment trains in a single treatment plant are markedly different. In these cases, you may need to submit a separate CT Study for each treatment train. If you think your plant should submit more than one CT Study, call the Public Drinking Water Section at (512) 239-4691 to be sure.

PWS ID No.
Enter your water system's seven-digit PWS ID number.

Month, Day, and Year
Using the drop down menus, enter the date that you prepared this CT Study.

Enter a Narrative Description
Use the text box provided to enter a written description of your treatment plant layout and disinfection protocol. An example of a narrative description is shown in Appendix A. We should be able to easily identify the following items in your description:

- name of the water system;
- name of the plant;
- source of the raw water being treated;
- plant's nominal capacity;
  - basis for the capacity (e.g., limiting unit or pump capacity);

- unit processes that make up the treatment plant;
  - how flow is split between processes and parallel treatment units; and
  - description of each unit(e.g., number of each unit type, gravity vs. pressure filter, type of clarifier and sedimentation basins);
- physical layout of each disinfection zone;
  - the treatment units contained in each zone;
  - where each zone begins; and
  - where each zone ends;
- disinfectant used in each disinfection zone;
  - location of each injection point (e.g., prior to flocculation basin in Figure 2-1);
  - location of each monitoring point (e.g., at combined effluent of sedimentation basins in Figure 2-1)
- unusual characteristics of the plant (e.g., are all treatment units used all of the time or are some used seasonally?)

WARNING ABOUT PRINTING!
If you print the Description page of the CT Study Template File, only the portion of the description that appears inside the text box will appear on the printed page. However, if you transmit your CT Study Template to the TCEQ electronically, your entire description will be transmitted, even if its length exceeds the size of the box.

Save Your CT Study Template File
Once you have entered the information that identifies your plant and you have written the narrative description, save the spreadsheet using an appropriate filename.

3.3 Plant Schematic

Once you have entered a narrative description of your treatment plant and disinfection protocol, you must translate that written description into a schematic diagram. The schematic should be a simple picture of your treatment plant that identifies all of the items described in the previous section. This schematic can be created in any way (drawn by hand, CAD, Microsoft Drawing tools, etc.) As long as it is neat and easy to follow.

The Schematic worksheet is available if you would like to create your schematic using Microsoft Drawing tools,. If you do use the Schematic worksheet, all of the pieces of your CT Study will be in one place. You are not required to use the Schematic worksheet. It is included as a convenience for those who elect to use the drawing tools to create their plant schematic.

Process Units

Every unit treatment process should be shown on the schematic using an appropriate symbol. These symbols do not need to be complicated, but should accurately represent the general shape of the basin. For example, circles should be used for circular tanks and rectangles should be used for rectangular tanks.

NOTE - LABELING TREATMENT UNITS

Each unit should be labeled using the same terminology used in the narrative description. An accurate schematic with clearly identified labels will expedite our review of your CT Study.

Flow Path

The flow path of water through your treatment plant should be indicated by arrows indicating the direction of flow. When flow is divided between parallel units, illustrate this by using a " y" or "tee" in the line. If the piping in your treatment plant contributes a significant volume and you plan on including it in the T_{10} calculations, you should label those runs of piping on the schematic.

Disinfectant Injection and Monitoring Points

Illustrate every point in the treatment plant where a disinfectant is added by drawing an arrow into the pipe or treatment process where the disinfectant is added. Label the arrows with the disinfectant that is being added. Illustrate every point in the treatment plant where a disinfectant concentration is being measured. For example, if chlorine is added into the rapid mix basin, draw an arrow labeled "CL_2" pointing into the symbol for the rapid mix basin. Draw and label disinfectant monitoring points by drawing arrows that point *away* from the pipe or treatment unit from which the measurements are taken.

It is important to clearly illustrate the disinfection injection and monitoring points on your schematic and to describe them in the narrative because these points determine the disinfection zones at your treatment plant. The details of how many disinfection zones your plant contains and the number of treatment units in each zone is critical to the completion of your CT Study using the automated template. You can use this schematic as you perform the tasks described in Chapters 4 and 5.

4 DESCRIBING YOUR DISINFECTION ZONES

In this chapter, we will go through the steps you need to complete in order to customize and fill out the CT Study Template so that it matches the plant layout and disinfection protocol you described in the narrative description and plant schematic. For help with a specific part of the CT Study Template, scan for the name of the worksheet and then for specific items within that section.

4.1 Preliminaries

Before performing the tasks described in this Chapter, you must have the following information:

- the plant rated capacity;
- the number of disinfection zones in your treatment process;
- the number of parallel treatment trains in each disinfection zone; and
- the number, type, shape, and dimensions of each treatment unit within each disinfection zone.

Section 2.4 will help you become familiar with these terms and apply them appropriately to your treatment plant.

Flow Rates

All flow rates that are entered in the CT Study Template should be based on the **plant rated capacity**.

4.2 Description

Customize the CT Study Template spreadsheet by clicking on the [Define Disinfection Zones] button on the Description worksheet. You will find this button just to the right of the text box for entering the narrative description. Figure 4-1 shows this button.

Figure 4-1: Define Disinfection Zones Button

To define the disinfection zones at your treatment plant, move your cursor over the button and click once with your left mouse button. Clicking on the control button runs the Disinfection Zone dialog box and associated macros (See Section 4.3).

The first time you use the Template spreadsheet, you will enter the data that will customize it for the number of disinfection zones and parallel treatment trains in your plan. After customizing the spreadsheet once, and saving the customized file, you can skip this step.

If you mistakenly click on the [Define Disinfection Zones] button and don't wish to make changes, click on the [Cancel] button when the **Disinfection Zones** dialog box opens. The only time that you will need to re-enter any of the disinfection zone data is if you make a mistake when initially filling out the dialog box or when something at the plant changes. The limitations of changing the disinfection zone data are described below.

Fill Out the Disinfection Zones Dialog Box

When you click on the Define Disinfection Zones button, the Disinfection Zones dialog box will prompt you for the information needed . In order for the spreadsheet to run properly, you must complete this box. As you enter data in the dialog box, you can use the <Tab> key to move to the next cell, or data entry spot, and the <Shift> + <Tab> keys to move back to the previous cell.

All of the information that you need to enter in the **Disinfection Zones** dialog box relates to the layout of your plant and your disinfection protocol. You should use Section 2.4 as a guide for delineating the disinfection zones at your plant. It may be helpful now to reference your narrative description and plant schematic.

Number of Disinfection Zones

Enter the total number of disinfection zones at your plant. The template is designed to accept a maximum of 10 disinfection zones. If your plant has more than 10 disinfection zones, you cannot use the automated template.

Number of Trains

After you enter the number of disinfection zones at your plant, hit <Enter> and the **Number of Trains** cell will pop up beside each of the zones you have at the plant. For each disinfection zone, enter the number of treatment trains in each zone. The treatment trains, if defined in the dialog box, are denoted in the spreadsheet by suffixes A, B, C, etc.

The template is designed to accept a maximum of 10 distinct disinfection zones. Each parallel treatment train is treated as a distinct disinfection zone. Therefore, if any of your disinfection zones contain parallel trains, the number of zones that you are allowed to enter is reduced.

Figure 4-2 shows an example of the Disinfection Zones dialog box as it would be completed for the example plant described in Appendix A. The entries in Figure 4-2 indicate that the plant has four disinfection zones. The figure also shows that disinfection zone D2 contains two treatment trains.

Figure 4-2: Disinfection Zones Dialog Box with Sample Data

Once you have entered the last piece of data in the Disinfection Zones dialog box, click on the [OK] button. Now, the macro will finish running and create the customized CT Study Template for your plant.

BE PATIENT!
It may take 90 to 120 seconds for this macro to finish running (or longer if you have a complex design or a slow computer). Also, the computer screen display may appear to vibrate while the macro is running. In general, it is a good idea not to click buttons or type while you are waiting for the program to calculate or run macros.

When the macro finishes running, you will be in the spreadsheet, ready to type in your plant information and data.

Save Your Customized CT Study Template File

After you have run the **Disinfection Zones** macro and entered the information on your system, we recommend that you save the customized spreadsheet using an appropriate file name. That way, you will not have to re-enter all that data each time that you open the CT Study spreadsheet.

Running CT Study Template File after You have Customized It

If you saved the customized spreadsheet, you will still need to click on the [Enable Macros] button in the Excel dialog box each time you open the spreadsheet. However, unless you need to edit the data in the Disinfection Zones dialog box, you do not need to click on the [Define Disinfection Zones] button.

Changing the Number of Disinfection Zones or Parallel Treatment Trains

The process of adding or removing disinfection zones is simple as long as you have not entered any data on the T10 Details worksheet. Just follow the steps described above and re-enter the correct values in the **Disinfection Zones** dialog box. If you have entered information on the T10 Details worksheet, adding a disinfection zone at the end of your treatment process does not create a problem. However, there are some limitations in changing the *number of* disinfection zones or *number of* parallel treatment trains within a zone.

If you have to insert a disinfection zone or parallel train between two zones that you have already defined, you will lose some data on the T10 Details worksheet and the Calculator worksheet. All of the information that you entered in the zones prior to the inserted zone will remain intact, but you will have to redefine the remaining zones and reenter the correct information for any zones that follow the new one.

4.3 T10 Details

Once you have saved your customized CT Study Template, the next step is to define and characterize the treatment units in each disinfection zone. This process uses data on the T10 Details worksheet. Figure 4-3 shows what the T10 Details worksheet looks like after you customize it with the data entered in Figure 4-2.

Figure 4-3: T10 Details Worksheet After Defining Disinfection Zones

As shown in Figure 4-3, only the first five disinfection zones have been enabled (you can tell because they are not cross-hatched). All of the unused disinfection zones have been locked and will not let you enter any data. For each disinfection zone and treatment train that you defined in the Disinfection Zones dialog box, you will need to select a disinfectant and then define the treatment units within that zone or train by entering the dimensions of each unit process.

Treatment Plant Capacity
Enter the rated capacity of your entire treatment plant in the unshaded cell at the top of the T10 Details worksheet in units of gpm.

Select Disinfectant
Each disinfection zone consists of all the treatment process units that are between a disinfectant injection point and the subsequent monitoring point *or* between two subsequent monitoring points. Only one type of disinfectant can be used in each zone.

Select the disinfectant, using the drop-down menu in the unshaded Disinfectant cell. The drop-down menu contains the following disinfectant options:

- Free Chlorine
- Chlorine Dioxide
- Ozone (Chamber 1- should only be selected for the first zone in which ozone is injected)
- Ozone (Any Chamber - may be selected for any subsequent disinfection zone that uses ozone as the disinfectant)
- Chloramines

Define Unit Processes

Directly to the right of each **Disinfectant** cell there is a [Define Unit Processes] button (Figure 4-4). Click on these buttons to activate the Disinfection Zone Units dialog box. This dialog box prompts you for the information needed to further customize the CT Study Template for your plant. To ensure that the spreadsheet operates properly, you must complete the entire box. Navigate the box by using the <Tab> key to move to the next cell, or data entry spot, and the <Shift> + <Tab> keys to move back to the previous cell.

Define Unit Processes
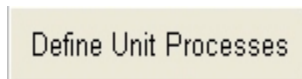
Figure 4-4: Define Unit Processes Button

To define a given treatment unit, move your cursor over the button and click once with your left mouse button. Clicking on the control button runs the Disinfection Zone Units dialog box and the associated macros (Figure 4-5). The control buttons for unused disinfection zones are inactivated. (If you have not chosen a disinfectant for this particular zone, an error message box will tell you to choose a disinfectant first.)

Figure 4-5 shows an example of the **Disinfection Zone Units** dialog box as it would be completed for the plant presented in the example in Appendix A. The entries in Figure 4-5 indicate that the plant has two unit processed in disinfection zone D1. The two unit processes are rectangular rapid mix and rectangular flocculation.

Figure 4-5: Disinfection Zone Units Dialog Box with Sample Data

All of the information that you need to enter in the **Disinfection Zone Units** dialog box is about the number of treatment units in each disinfection zone, their type, and their shape. All of this information should be documented in the design and construction plans and specifications for your plant.

Number of Unit Processes

Enter the total number of sequential unit processes in the selected disinfection zone. Examples of unit processes include piping, flocculation, sedimentation, and filtration.

WARNING ON NUMBER OF UNIT PROCESSES!
It is important that you do not enter the number of each type of unit here. For example, if a disinfection zone consisted of four parallel sedimentation basins, you would enter [1] to represent the sedimentation unit process, not the number of parallel basins. Only sequential unit processes are to be entered in this box. The number of parallel units of each type will be entered elsewhere.

The CT Study Template has been designed to accept a maximum of 10 units in each disinfection zone. If your treatment plant has disinfection zones with more than 10 unit processes, you will not be able to use the Template.

Unit Type

After you enter the number of unit processes in the disinfection zone, hit <Enter> and the **Unit Type** and **Unit Shape** cells corresponding to the number of units you entered will pop up.

For each unit, enter the **Unit Type** from the drop-down menu. The choices for **Unit Type** include:

Table 4-1: Unit Type Descriptions

Unit Type	Description
Piping	Any section of piping connecting unit processes, including raw water line.
Rapid Mix	Any unit process that completely mixes the water with the chemical being added.
Flocculation	Applies to basins designed to promote particle-particle collisions. These units are typically moderately mixed and highly baffled.
Sedimentation	Applies to basins designed for removal of particles by sedimentation.
Floc/Sed Comb	A basin designed as combined flocculation and sedimentation process.
Clarifier	This type should be used for solids contact clarification processes such as slurry recirculation or sludge blanket clarifiers.
DAF	Dissolved air flotation process units.
Filter	Any porous media filtration unit including rapid sand filters, slow sand filters, high rate mono media filters with anthracite or granular activate carbon.
Transfer Well	A variable level basin designed to divert or temporarily store water as it passes through the treatment plant (splitter box, pump wet well, head control box, etc)
Clearwell	Any variable level storage facility for retaining treated water prior to distribution. Other names for these basins can include "ground storage tank" or "treated water reservoir".
Other	This unit type should only be selected when one of the above descriptions does not describe the unit of interest. A typical example is a disinfectant contact basin, or the total volume of clearwells in parallel.

Unit Shape

For each unit, enter the **Unit Shape** from the drop-down menu. The available options for **Unit Shape** are:

Table 4-2: Unit Shape Options

Unit Shape	Description
Pipe	This shape should only be used with the "Piping" and "Rapid Mix" Unit Types. The combination of "Pipe" shape and rapid mix type would be used for many static in-line mixers. If the "Piping" is selected as the type, the only shape that is available is "Pipe".
Rectangular	This shape is selected for any rectangular shaped unit, such as rectangular sedimentation basins and rapid sand filters.
Circular	This shape is selected for any unit that has a circular top surface area. Both cylindrical basins and those with cone shaped bottoms fall into this category. Examples include circular clearwells and circular clarifiers.
Other	This shape should only be used when the selected unit does not fall into one of the categories listed above, but it cannot be used with the "Filter" Unit Type. Examples of units that would fall into this category include L-shaped basins or oddly shaped wet wells.

Once you have entered all of the data in the **Disinfection Zone Units** dialog box, click on the [OK] button. The macro will finish running and customize the selected disinfection zone to match the specifications you entered.

BE PATIENT!
It may take some time for this macro to finish running. It is a good idea not to click buttons or type while you are waiting for the program to calculate or run macros.

When the macro finishes running, you will be in the spreadsheet, ready to enter the specific dimensions and flow rates that characterize the selected disinfection zone.

Changing the Number, Type, and Shape of Treatment Units
If you are adding a unit at the end of a disinfection zone, there is no problem, but there are some limitations to adding and changing treatment units once the data has been entered.

If you want to insert a unit between two units that you have already described (by entering information on the T10 Details worksheet), you will lose all of the data from the inserted unit forward. It is possible to add a unit to the end of an already defined zone without having to re-enter any data. For example, if you omitted a process unit when you initially defined the zone, rather than insert it in a correct order and reentering all of the data from that point on, you can add an additional unit at the end of the zone. If you do this, you must clearly explain why you are entering a process unit out of sequence.

If you accidentally click on the [Define Treatment Units] button by mistake and you do not want to make any changes, simply click [Cancel].

4.4 Unit Details

After you complete the Disinfection Zone Units worksheet, the T10 Details worksheet will be customized to represent the unit processes you entered. This customization consists of creating a summary of each unit process. Figure 4-6 shows a summary for the rectangular rapid mix unit (Unit 2 in Figure 4-5).

Figure 4-6: Example Unit Summary

The unit summary shows the Unit Type and Unit Shape you selected in the dialog box. The next step is to fill in the required information in the unshaded cells.

Further Description

The first step in detailing a particular unit is to enter a description of the unit. The description should identify the unit in the same terms you used on your treatment plant schematic and in the narrative description. (Sections 3.2 and 3.3) For example, the rapid mix unit shown in Figure 4-6 may be identified as "Alum Addition Rapid Mix Basin."

Characteristics

Beneath the Further Description cell, several characteristics are listed. The specific characteristics that are shown in each unit summary are dependent on the type and shape of the unit.

Table 4-3: Characteristics

Measurement	Description
Number of Units	Enter the number of units for this unit process. For example, if there are four parallel sedimentation basins, and all four basins are the same size and basic design, enter [4] in the Number of Units cell.
Diameter	If you selected "Pipe" or "Circular" as the unit shape, you will need to enter the diameter of the basin or pipe here. If "Pipe" is the selected shape, enter the diameter in units of inches. If "Circular" is the selected shape, enter the diameter in feet.

Length	This measurement is required when "Pipe" or "Rectangular" is the selected shape. If "Pipe" is the selected shape then this refers to the length of the pipeline. If "Rectangular" is selected, this refers to the length of one side of the rectangular basin.
Width	This measurement is required when "Rectangular" is the selected shape. Enter the length of the other side of the rectangular basin. If the basin is square, the entries for Length and Width should be equal.
Side Water Depth	This measurement is required when either "Circular" or "Rectangular" is the selected shape. Enter the depth of the water at the outside edge of the basin. If the basin is rectangular and the bottom has some slope, enter the average side water depth, (minimum side water depth + maximum side water depth)/2. Typically, this slope is insignificant and entering the minimum side water depth will not underestimate the basin volume by a significant fraction. Please explain which value you entered in the comment section. Figure 4-7 illustrates what is meant by the side water depth. If the Unit Type is "Transfer Well" or "Clearwell", the value that is entered should be the maximum operating level (i.e., the side water depth when the basin is full). The minimum operating level will be entered later.
Center Water Depth	This measurement is required only when the"Circular" shape is selected. The purpose of this entry is to account for circular basins that have cone shaped bottoms. Enter the water depth at the center of the circular basin. If a circular basin does not have a sloped bottom, the entry here should match that for the Side Water Depth. Figure 4-7 shows what we mean by the center water depth. If the Unit Type is "Transfer Well" or "Clearwell", enter the center water depth when the basin is full.

WARNING ON CENTER WATER DEPTH!
Do not leave this cell blank, or the volume of the basin will be severely underestimated because the spreadsheet will assume that the depth in the middle is "0" feet.

Media Depth	This measurement is required only when the "Filter" type is selected. Enter the depth of the media in the filter (including sand, gravel, anthracite, etc.).
Underdrain Depth	This measurement is required only when the "Filter" type is selected. Enter the depth of underdrain in the filter. If there is no underdrain or the drains consist of a perforated pipe, enter a value of [0] in this cell. Most often, the underdrain depth is 1 ft. Check the plans and drawings of your plant if you are unsure.
Minimum Water Depth Over Media	This measurement is required only when the "Filter" type is selected. Enter the minimum depth of water that is present during a normal filter run. If the water level varies over the course of a filter run, be sure that you enter the minimum water depth here. The minimum water depth typically occurs at the beginning of a filter run (i.e., immediately following backwash.)
Average Porosity	This characteristic is required only when the "Filter" type is selected. Enter the porosity, or void fraction as a percentage of the total filter bed volume, including the support media. You should use a value of 50% unless you have specific data.

Maximum Volume (each) (CALC)	This calculation is shown for "Transfer Well or "Clearwell" units when the shape is either "Circular" or "Rectangular". You will know that the cell is (CALC) because it will be shaded gray. The calculated value shown here is the maximum capacity of the variable level basin and is used in the calculation of the Percentage of Maximum Volume.
Maximum Volume (each)	This calculation is shown for "Transfer Well" or "Clearwell" units when the shape is "Other". You will know that the cell is not (CALC) because it will be unshaded. Enter the maximum capacity of the variable level basin (the volume when completely full). The value you enter here will be used in the calculation of the Percentage of Maximum Volume.

WARNING ON MAXIMUM VOLUME (EACH)!
The volume you enter here should be the volume for a single unit, not the combined volume of all identical parallel units.

Minimum Operating Depth	This measurement is required for "Transfer Well" and "Clearwell" units when the shape is either "Circular" or Rectangular". These types of units typically have variable water levels. You must enter the **minimum** side water depth during operation of these types of units. This ensures that the most conservative detention time will be used in determining inactivation ratios.

In the absence of site-specific data, you should assume a minimum operating level that results in a Percentage of Maximum Volume of 50%. When a system fails to meet the minimum total storage capacity requirements specified by TCEQ regulations, the minimum operating level should result in a "Worst Case" Volume that is 30% of the nominal tank capacity. A minimum operating level that results in a "Worst Case" Volume greater than 80% of the nominal capacity will not be approved; keeping the tank "topped off" results in short plant operating cycles and poor particle removal. Please explain how you arrived at the value you entered here in the comment section. |
| Volume (each) | This calculation is required if "Other" is the selected shape for any fixed level unit type. Because these basins are of odd shape, you must manually calculate the volume in gallons and enter the value here. You must provide an engineering drawing of the unit so that we can verify your calculations. |

WARNING ON VOLUME (EACH)!
The volume you enter here should be the volume for a single unit, not the combined volume of all identical parallel units.

"Worst Case" Volume (each)	This calculation is required for variable level basins such as clearwells and transfer wells when "Other is the selected shape. To ensure that the calculation of the detention time is as conservative as it can be, you must enter the minimum volume of water that the unit can hold during the operation of your plant.

WARNING ON "WORST CASE" VOLUME (EACH)!
The volume you enter here should be the volume for a single unit, not the combined volume of all identical parallel units.

*Percentage of Maximum Volume (CALC)	This calculated cell will be displayed for "Transfer Well" and "Clearwell" units. The value calculated in this cell represents the percentage of the maximum volume of a variable level tank that is represented by the Minimum Operating Level (for rectangular and circular basins) or "Worst Case" Volume (for basins with "Other" as the Unit Shape)
Volume (each) or "Worst Case" Volume (each) (CALC)	This cell is calculated using the basin dimensions or volume entered above it in the summary. "Worst Case" Volume is shown when the unit is a variable level basin and Volume is shown when the unit has a fixed water level. The value in this cell is the volume that is used in the calculation of the T_{10} time for the unit.

Flow Rate (each)	Enter the flow rate that passes through a single unit based on operation at the plant rated capacity. For example, if a given unit consists of four parallel filters, the flow rate through *one filter* should be entered in this cell. If do not have flow measure device, use even flow between units.

WARNING ON FLOWRATE (EACH)!
This value should be the flow rate through a single unit based on the plant rated capacity, not the combined flow through all identical parallel units.

Detention Time (CALC)	The value here is automatically calculated by dividing the calculated volume by the user-entered flow rate.
Baffling Factor (CALC)	The baffling factor shown here is calculated using your entry into one of both of the Baffling Characteristics and Approved Baffling Factor cells.
Baffling Characteristics	Using the drop down menu, choose the baffling characteristics that describe each unit. The choices are: Unbaffled Poor Average Superior Plug Flow Tracer Study Manufacturer Approved Other "Unbaffled" is the default value. Section 2.5 explains how to select the appropriate baffling characteristics.

If you have performed a tracer study on the selected unit and it has been approved by TCEQ, select "Tracer Study" rather than selecting from the general baffling characteristics. If the unit has a manufacturer provided and TCEQ approved baffling factor, select "Manufacturer Approved". If your plant has clearwells in series, use the approved baffling factors listed in Table 2-3 and choose "Other". Include a comment stating the unit is a clearwell in series. The "Other" option can also be used for situations that do not fit into any other category, but you must clearly justify your choice in the comments. If you select "Tracer Study", "Manufacturer Approved", or "Other" you must manually enter the value of the approved baffling factor in the Approved Baffling Factor cell.

Approved Baffling Factor	If you have selected "Tracer Study" or "Manufacturer Approved", enter the approved baffling factor from your tracer study or the manufacturer (Table 2-3) in this cell. If you have not selected "Tracer Study" or "Manufacturer Approved" from the drop down menu, any value that is entered here will not be used in the calculation of T_{10}.
T_{10} (CALC)	The effective contact time, T10, is calculated by multiplying the calculated detention time by the baffling factor.
Comments	Space has been provided next to every cell where you are required to enter data. These spaces have been provided for you to document the source and date of the measurements *i.e.*, engineering drawings or a previously approved CT study.
Examples of documentation	Reference to as-built drawings or actual measurements. These types of comments should be entered after the dimensions of each unit.
Assumptions made in the absence of specific information	If the minimum operating level of a clearwell is not known, you may assume that the minimum operating volume is 50% of the nominal basin volume. If such an assumption is made, enter it as a comment.

Baffling Factor Justification	You must comment on your choice of baffling characteristics. If you have selected "Average", explain the inlet, outlet, and baffling characteristics of the unit. If you are using tracer study data, reference the date and approval of the tracer study and submit the tracer study data on a separate spreadsheet. If a manufacturer approved baffling factor is entered, reference the trade name of the unit process.
Miscellaneous	Any comments that you think will clarify your entries.
D_ Flow Rate (CALC)	This cell appears at the bottom of every disinfection zone. The flow rate shown here is the peak hourly flowrate through a single basin in the unit process that contributes the most T_{10} time to the entire zone. This value is copied to the Calculator worksheet.
T10 Sum for D_(CALC)	The T_{10} time shown here is the sum of the T_{10} times for every unit and represents the total T_{10} for the entire disinfection zone. This value is copied to the Calculator worksheet.

*The value displayed in this cell will help you select the appropriate Minimum Operating Level of "Worst Case" Volume in the absence of sit-specific data. For example, if your plant has a clearwell in which the water level is not routinely measured, you should assume a Percentage of Maximum Volume of 50%. Do this by entering a Minimum Operation Level or "Worst Case" Volume that results in a value of 50 being displayed in this cell. If the basin has shape "Other", the "Worst Case" Volume would be half of the volume entered in the Maximum Volume (each) cell. Typically, if the basin is rectangular or circular, entry of a Minimum Operating Level half the side water depth will result in a Percentage of Maximum Volume near 50%.
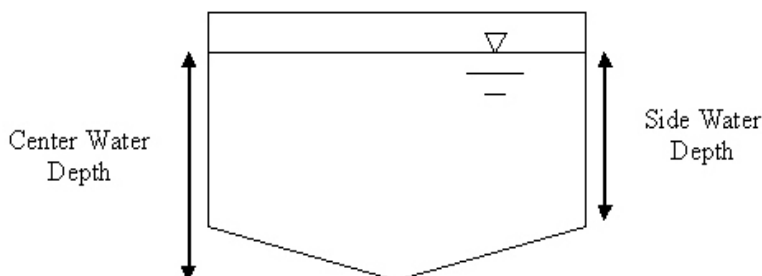
4-7: Illustration of Side Water Depth and Center Water Depth

After filling in all of the unshaded cells in each unit summary, check the Summary worksheet to make sure that the information you entered is correct (see Section 4.5). If the summary is correct, save the file.

When you have checked that the summary for a given zone is correct, repeat the steps above, beginning with selecting the disinfectant and clicking on the [Define Treatment Units] button to run the **Disinfection Zone Units** dialog box for the next zone. You will need to define and complete the details for all of the disinfection zones n your treatment plant. See Appendix A for an example of a completed CT Study Template.

4.5 Summary Worksheet

After entering the data for each zone on the T10 Details worksheet, activate the Summary worksheet by clicking on the tab labeled "Summary" at the bottom of the screen. The purpose of the Summary worksheet is to compile the details entered on the T10 Details worksheet into a summary of the entire treatment and disinfection processes. There is nothing for you to enter on this worksheet, but look over the summary and make sure the information there is correct. See Appendix A for an example of a completed Summary worksheet.

5 EVALUATING YOUR DISINFECTION PROTOCOL

The final task for completing your CT Study is to evaluate your disinfection protocol by entering typical plant operating conditions on the Calculator worksheet. Activate the Calculator worksheet by clicking on the tab labeled "Calculator" at the bottom of the screen.

5.1 Preliminaries

Before performing the tasks described in this Chapter, you should have the following information:

- the maximum rated capacity for the plant;
- the typical daily disinfectant concentration at every disinfectant injection and monitoring point;
- the minimum (over the last 3 years) water temperature in each disinfection zone; and
- the maximum (over the last 3 years) pH at each disinfection injection and monitoring point.

CT Study Parameters (CALC)

Based on the data you entered on the T10 Details worksheet, the CT Study Template will calculate the **Flow Rate** and T_{10} for each disinfection zone and enter the value in these cells. The values in these cells correspond to the **D_Flow Rate** and **T10 Sum for D_** cells for the corresponding zone on the T10 Details worksheet. Once your CT Study is approved, you will enter these values in the corresponding cells of your Surface Water Monthly Operating Report (SWMOR). As you read this section, refer to Appendix A for a completed Calculator worksheet form and Template.

5.2 Performance Standards

Based on your treatment processes for physical removal at the plant, the disinfection process is required to achieve a minimum number of log inactivations of *Giardia lamblia* cysts and viruses.

Log Inactivation for *Giardia lamblia* Cysts

Enter the *Giardia* inactivation level that the disinfection process is required to achieve. Your disinfection process must achieve a 0.5-log inactivation of *Giardia lamblia* cysts, unless the TCEQ has established an alternative performance standard for your plant.

Log Inactivation for Viruses

Enter the virus inactivation level that the disinfection process is required to achieve. Your disinfection process must achieve a 2.0-log inactivation of viruses, unless the TCEQ has established an alternative performance standard for your plant.

5.3 Operating Conditions

Typical operating conditions for your disinfection process are used to test whether your plant provides an adequate level of disinfection. The **Flow Rate** and T_{10} values entered in the **CT Study Parameters** cells are only half of the data necessary to perform CT Calculations. Data entered in the **Performance Data** cells gives the disinfectant that is used, its concentration, and the characteristics of the water (pH and Temperature).

Disinfectant (CALC)

The Disinfectant column on the Calculator worksheet shows abbreviations for the disinfectant that you entered on the T10 Details worksheet. The abbreviations for the possible disinfectants are shown in Table 5-1.

Table 5-1: Abbreviations for Disinfectants

Abbreviation	Disinfectant
FCL	Free Chlorine
CLO2	Chlorine Dioxide
03 (1)	Ozone (Chamber 1)
03 (1+)	Ozone (Any Chamber)
CLA	Chloramines

C(mg/L) -the Disinfectant Residual Concentration in the Disinfection Zone

You must enter the disinfectant concentration, C, at the end of each disinfection zone. This value should be typical of the residuals maintained in your treatment process on a daily basis. The average residual concentration from a typical month of SWMOR data would be a good value to enter here. Record the results in the **C(mg/L)** column. (This value should never be above the TCEQ limits for a specific disinfectant.)

Flow (MGD) - the Flow Rate through the Disinfection Zone

Record the rated plant capacity. If units within a given zone contain parallel basins, the flow rate through the unit that contributes the most T10 time to the zone should be entered here. That unit can be identified by looking at the **T10 Details** worksheet and finding the unit that contributes the most T10 time to the zone. Report this value in units of MGD. Enter the value in the above CT Study Parameters for flow rate.

Temperature

Record the historical minimum water temperature at the end of each disinfection zone in the **Temp(°C)** column. Report this value in degrees Celsius (°C). If you know that the water temperature is essentially constant throughout your treatment plan, you can use a single reading for all of the disinfection zones.

pH

Record the historical maximum pH of the water at the end of each disinfection zone in the **pH** column. Report this value in pH units.

5.4 Results

After providing all of the required operating conditions, the worksheet will calculate the log inactivation and the limiting inactivation ratio achieved by your plant. This information is summarized under the following headings:

CT calc (CALC)
This cell calculates the CT provided by each individual disinfection zone.

Giardia CT REQD
This cell calculates the CT necessary to provide the required inactivation of *Giardia* with the chosen disinfectant.

Virus CT REQD
This cell calculates the CT necessary to provide the required inactivation of viruses with the chosen disinfectant.

Giardial Log Inactivations (CALC)
Viral Log Inactivations (CALC)
The CT Study Template uses a series of mathematical equations to determine the level of *Giardia* and viral inactivation obtained in each of the disinfection zones. The spreadsheet then totals the *Giardia* and viral log inactivation achieved in the entire plant and enters the results in the *Giardia* Log and Virus Log columns, respectively.

Plant Total
An asterisk (*) after the number indicates that the value is not representative of the total number of *Giardia* log inactivations for all disinfection zones because you did not enter the disinfection process data for all zones.

Inactivation Ratio (CALC)
The CT Study Template calculates the total inactivation ratio for both *Giardia* and viruses, and records the lower inactivation ratio in the **Inact. Ratio** column. The letter beneath the number tells you if the lower inactivation ratio is the one for *Giardia* or for viruses. The letter "G" shows that *Giardia* produces the lower inactivation ratio. The letter "V" indicates that viruses produce the lower ratio.

If the total inactivation ratio is equal to or greater than 1.00, using this disinfection protocol your plant meets both the minimum *Giardial* and viral inactivation requirements.

If the ratio is less than 1.00, you must make changes to your treatment system or disinfection protocol to provide additional CT.

Rounding numbers on your CT Study

The CT Study Template is designed to automatically round any value you enter to the proper number of decimal places. The Template may not show or print all of the decimal places that you entered when you filled out the template, but you should enter as many decimal places as necessary.

Locking and Unlocking Disinfectant Cells

The calculator worksheet is a convenient place to "test" different disinfection strategies and can be a useful tool for investigating proposed changes to your disinfection protocol. You can use this procedure to identify whether you need to make changes to your disinfection protocol under "worst case" conditions. It is easy to test different scenarios of flow, concentration, temperature, and pH by entering different values. Because the disinfectant cells initially reference cells on the T10 Details worksheet, changing the disinfectant in each zone requires an additional step.

Two buttons [Unlock Disinfectants] and [Lock Disinfectants] are present on the Calculator worksheet adjacent to the calculated Log Inactivation Ratio cell (Figure 5-1)
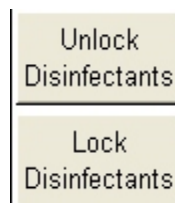
Figure 5-1: Lock and Unlock Disinfectants Buttons

Clicking on the Unlock Disinfectants button replaces the locked Disinfectant cells with drop-down menus containing the 5 choices of disinfectants. This allow you to choose disinfectants other than those currently used at your treatment plant (and entered on the T10 Details worksheet). For example, if you want to investigate switching from free chlorine to chloramines in a particular disinfection zone, you would unlock the disinfectants and then re-enter the disinfectants you would like to test using the drop-down menus. When the disinfectants have been unlocked, you must re-enter all of the disinfectants for the worksheet to calculate correctly.

To return the values in the Disinfectant cells to the values you entered on the T10 Details worksheet, click on the [Lock Disinfectants] button. This will lock the Disinfectant cells and remove the drop-down menus.

APPENDIX A: EXAMPLE OF A CT STUDY COMPLETED USING THE AUTOMATED TEMPLATE

CT STUDY
FOR PUBLIC WATER SYSTEMS THAT ARE USING SURFACE WATER SOURCES OR GROUND WATER SOURCES UNDER THE INFLUENCE OF SURFACE WATER (cont.)
Description Worksheet

PUBLIC WATER
SYSTEM NAME: City of Somewhere   PWS ID No.: 7543216

PLANT NAME   Month: March
OR NUMBER: Downtown WTP   Day: 16
                                               Year: 2005

Enter a detailed narrative description of the plant treatment processes and disinfection protocol.

The City of Somewhere Water Treatment Plant takes raw water from Wet Creek Reservoir and Lake Somewhere. The raw water enters a splitter box which supplies water to two treatment trains. One treatment train has an upflow clarifier and another one consists of a rapid mix, a flocculator, and a sedimentation basin equipped with tube settlers. Settled water from the two treatment trains travels to two sets of two dual media filters. Treated water is stored in a 200,000-gallon clearwell. Disinfection is accomplished by injecting chlorine prior to the upflow clarifier, at the rapid mix, and prior to the clearwell. Liquid ammonium sulfate is added prior to the filters. Chlorine residual is monitored at the effluent of the upflow clarifier and the sedimentation basin. Chloramine residuals are monitored at the filter effluent and after the clearwell.

Based on the information we had at the time of our review, three disinfection zones are defined for the plant. The first disinfection zone is divide into two treatment trains: D1A and D1B. Disinfection zone D1A is the upflow clarifier. Disinfection zone D1B includes flocculator and sedimentation basin. The second disinfection zone (D2) is the filters. The third disinfection zone (D3) is the clearwell.

TCEQ - (6-10-03)   CT STUDY

CT STUDY

FOR PUBLIC WATER SYSTEMS THAT ARE USING SURFACE WATER SOURCES
OR GROUND WATER SOURCES UNDER THE INFLUENCE OF SURFACE WATER (cont.)
T10 Details Worksheet

PUBLIC WATER
SYSTEM NAME: _____City of Somewhere_____   PWS ID No.: _____7543216_____

PLANT NAME
OR NUMBER: _____Downtown WTP_____   Date: _____March 16, 2005_____

Treatment Plant Capacity _____1,800_ gpm
                          _2.592_ mgd

Disinfection Zone: _____D1A_____   Disinfectant: _____Free Chlorine_____

Unit - 1   Type: _____Clarifier_____   Shape: _____Circular_____

Further Description: _____

Characteristic			Comments
Number of Units	1		
Diameter	34.83	ft	As per letter, Mr. B. Good, 12/31/2004.
Side Water Depth	13.67	ft	As per letter, Mr. B. Good, 12/31/2004.
Center Water Depth	13.67	ft	
Volume (each)	97,444	gal	
Flow Rate (each)	812	gpm	Based on 120-minutes detention time in the clarifier as per letter, Mr. B. Good, 12/31/2004
Detention Time	120.0	min	
Baffling Factor	0.3		
			Baffling Characteristics: _____Poor_____
			Approved Baffling Factor: _____
T_{10}	36.0	min	

D1A FLOW RATE	1.169	mgd

T10 SUM FOR D1A	36.0	min

Disinfection Zone: _____D1B_____   Disinfectant: _____Free Chlorine_____

Unit - 1   Type: _____Flocculation_____   Shape: _____Rectangular_____

Further Description: _Flocculator_____

Characteristic			Comments
Number of Units	1		
Length	27	ft	As per CT study of October 28, 2001
Width	12.5	ft	As per CT study of October 28, 1995
Side Water Depth	10	ft	As per CT study of October 28, 1995
Volume (each)	25,250	gal	
Flow Rate (each)	1,117	gpm	Based on 120-minutes detention time in the sedimentation basin as per CT study of October 28, 1995
Detention Time	22.6	min	
Baffling Factor	0.3		
			Baffling Characteristics: _____Poor_____
			Approved Baffling Factor: _____
T_{10}	6.8	min	

Unit - 2   Type: ___Sedimentation___   Shape: _____Circular_____

Further Description: Sedimentation Basin _____

Characteristic			Comments
Number of Units	1		
Diameter	46.25	ft	As per CT study of October 28, 2001
Side Water Depth	10.67	ft	As per CT study of October 28, 2001
Center Water Depth	10.67	ft	As per CT study of October 28, 2001
Volume (each)	134,112	gal	
			Based on 120-minutes detention time in the sedimentation basin as per CT study of October 28, 2001
Flow Rate (each)	1,117	gpm	
Detention Time	120.1	min	
Baffling Factor	0.5		
			Baffling Characteristics: ___Average___
			Approved Baffling Factor: _____
T_{10}	60.0	min	

D1B FLOW RATE	1.608	mgd

T 10 SUM FOR D1B	66.8	min

Disinfection Zone: ___D2___   Disinfectant: ___Chloramines___

Unit - 1   Type: _____Filter_____   Shape: ___Rectangular___

Further Description: _____

Characteristic			Comments
Number of Units	4		
Length	12	ft	As per CT study of October 28, 2001
Width	7.5	ft	As per CT study of October 28, 2001
Media Depth	3	ft	As per CT study of October 28, 2001
Underdrain Depth		ft	
Minimum Water Depth Over Media	2.5	ft	As per CT study of October 28, 2001
Average Porosity	50	%	Assumed
Volume (each)	2,693	gal	
			Based on flow through a single filter. Assumed that flow is divided equally between each filter
Flow Rate (each)	450	gpm	
Detention Time	6.0	min	
Baffling Factor	0.7		
			Baffling Characteristics: ___Superior___
			Approved Baffling Factor: _____
T_{10}	4.2	min	

D2 FLOW RATE	0.648	mgd

T 10 SUM FOR D2	4.2	min

Disinfection Zone: ____D3____   Disinfectant: ____Chloramines____

Unit - 1   Type: ____Clearwell____   Shape: ____Circular____

Further Description: _____

Characteristic			Comments
Number of Units	1		
Diameter	55.67	ft	As per CT study of October 28, 2001
Side Water Depth	11	ft	As per CT study of October 28, 2001
Center Water Depth	11	ft	As per CT study of October 28, 2001
Maximum Volume (each)	200,315	gal	
Minimum Operating Level	5.5	ft	Assumed
Worst Case Volume (each)	100,158	gal	
Percent of Maximum Volume	50	%	
Worst Case Volume (each)	100,158	gal	
Flow Rate (each)	1,800	gpm	Based on treatment capacity of the plant
Detention Time	55.6	min	
Baffling Factor	0.1		

Baffling Characteristics: ____Unbaffled____
Approved Baffling Factor: _____

T_{10} 5.6   min

D3 FLOW RATE	2.592	mgd

T10 SUM FOR D3	5.6	min

CT STUDY
FOR PUBLIC WATER SYSTEMS THAT ARE USING SURFACE WATER SOURCES
OR GROUND WATER SOURCES UNDER THE INFLUENCE OF SURFACE WATER (cont.)
Schematic Worksheet

PUBLIC WATER
SYSTEM NAME: _____City of Somewhere_____

PLANT NAME
OR NUMBER: _____Downtown WTP_____

PWS ID No.: _____7543216_____

Date: _____March 16, 2005_____

Use this worksheet to create your plant schematic with the Microsoft Drawing Tools.
If you are not familiar with the drawing tools, you may create your schematic using any other suitable medium.
Please refer to Section 3.3 of the Guidance Manual for instructions and guidance.
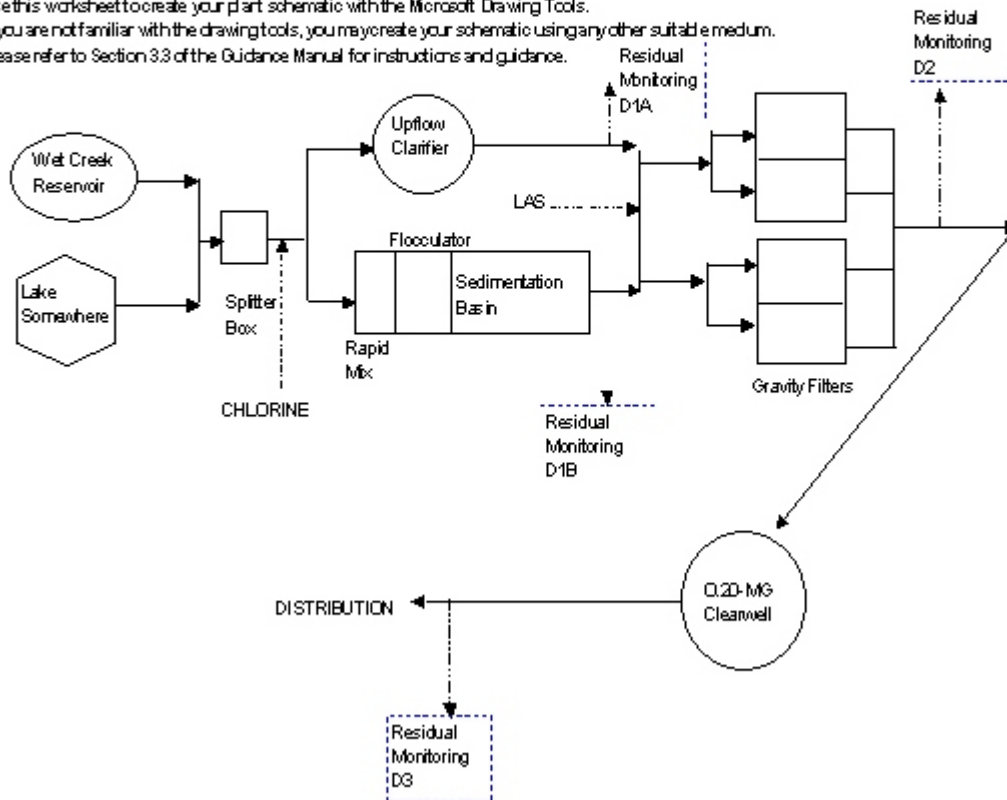
CT STUDY

FOR PUBLIC WATER SYSTEMS THAT ARE USING SURFACE WATER SOURCES
OR GROUND WATER SOURCES UNDER THE INFLUENCE OF SURFACE WATER (cont.)
Summary Worksheet

PUBLIC WATER
SYSTEM NAME: City of Somewhere   PWS ID No.:   7543216

PLANT NAME
OR NUMBER: Downtown WTP   Date: March 16, 2005

Disinfection Zone	Treatment Unit	Volume* (each) (gal)	Flow Rate* (each) (MGD)	Baffling Factor*	T₁₀* (min) Unit	T₁₀* (min) Zone
D1A	Clarifier (1)	97,444	1.169	0.3	36.0	36.0
D1B	Flocculator (1)	25,250	1.608	0.3	6.8	66.8
	Sedimentation Basin (1)	134,112	1.608	0.5	60.0	
D2	Filter (4)	2,693	0.648	0.7	4.2	4.2
D3	Clearwell (1)	100,158	2.592	0.1	5.6	5.6

* These values are calculated on the T10 Details Sheet

TCEQ - (6-10-03)   CT STUDY

APPENDIX B: EXAMPLE OF A CT STUDY APPROVAL LETTER

March 16, 2005

Mr. Ben A. Good, Superintendent
Smart Engineers, Inc.
123 Main Street
Somewhere, Texas 76548

> Subject: Public Drinking Water System
> Revision of CT Study
> City of Somewhere - PWS ID No. 1190002
> Backroads County, Texas

Dear Mr. Good:

We are in receipt of your letter, dated December 31, 2004, requesting a revised CT study for the City of Somewhere to reflect the addition of a solids contact clarifier and a dual media gravity filter at the Downtown Water Treatment Plant (WTP). The City of Somewhere's CT study has been revised based on the information received from you and from our files. The information in this letter will replace not supplement all previous CT studies.

Revised CT Study
The City of Somewhere Water Treatment Plant takes raw water from Wet Creek Reservoir and Lake Somewhere. The raw water enters a splitter box which supplies water to two treatment trains. One treatment train has an upflow clarifier and another one consists of a rapid mix, a flocculator, and a sedimentation basin equipped with tube settlers. Settled water from the two treatment trains travels to two sets of two dual media filters. Treated water is stored in a 200,000-gallon clearwell. Disinfection is accomplished by injecting chlorine prior to the upflow clarifier, at the rapid mix, and prior to the
clearwell. Liquid ammonium sulfate is added prior to the filters. Chlorine residual is monitored at the effluent of the upflow clarifier and the sedimentation basin. Chloramine residuals are monitored at the filter effluent and after the clearwell.

A disinfection zone is a section of the plant that starts at a disinfectant injection or monitoring point and ends at the subsequent disinfectant injection or monitoring point. Every disinfectant injection point is the start of a new disinfection zone, even if it is not always used. Every injection point must have an associated monitoring point. However, a plant may have only one disinfectant point and choose to monitor at more than one point, creating multiple disinfection zones. Based on the information we had at the time of our review, three disinfection zones are defined for the plant. The first disinfection zone is divide into two treatment trains: D1A and D1B. Disinfection zone D1A is

Subject: Revision of CT study
        City of Somewhere- PWS ID No. 7543216

the upflow clarifier. Disinfection zone D1B includes flocculator and sedimentation basin. The second disinfection zone (D2) is the filters. The third disinfection zone (D3) is the clearwell.

CT calculations are used to evaluate the disinfection process. Since T_{10} values are required to calculate the CT for the treatment process, a T_{10} table was developed for the City of Somewhere Water Treatment Plant. The T_{10} table as shown in Table 1 was developed based on the data provided in the October 28, 2001 CT study and the December 31, 2004 CT study included with your letter.

TABLE 1: T_{10} TABLE FOR CITY OF SOMEWHERE WATER TREATMENT PLANT

DISINFECTION ZONE	TREATMENT UNIT	VOLUME	FLOW RATE	BAFFLING FACTOR	T_{10}	Zone T_{10}
D1A	Upflow Clarifier	97,400 gals.[1]	1.169 MGD[6]	0.3[9]	36.0 min.	36.0 min.
D1B	Flocculator	25,300 gals.[2]	1.608 MGD[6]	0.3[9]	6.8 min.	66.8 min.
	Sedimentation Basin	134,000 gals.[3]		0.5[10]	60.0 min.	
D2	Filters	2,700 gals.[4]	0.648 MGD[7]	0.7[11]	4.2 min.	4.2 min.
D3	Clearwell	100,000 gals.[5]	2.592 MGD[8]	0.1[12]	5.6 min.	5.6 min.

Notes:
(1) Based on a 34.83-foot diameter clarifier with a side water depth of 13.67 feet as per CT study of December 31, 2004.
(2) Based on a 27-foot by 12.5-foot flocculator with a side water depth of 10 feet as per CT study of October 28, 2001.
(3) Based on a 46.25-foot diameter basin with a side water depth of 10.67 feet as per CT study of October 28, 2001.
(4) Based on one 12-foot by 7.5-foot filter with a media depth of 3 feet and 2.5 feet of water over the media as per CT study of October 28, 2001. An average media porosity of 50% is assumed.
(5) Based on a "worst case" operating condition. In the absence of site specific information, a "worst case" operating level of 50% of the nominal capacity is assumed. The nominal capacity of the clearwell is based on a 55.67 feet diameter with a maximum water level of 11 feet as per CT study of October 28, 2001.
(6) Based on 120 minutes detention time in the clarifier and sedimentation basin as per CT Study of October 28, 2001.
(7) Based on the flow through a single filter. Assumed that flow is split equally between each filter. Based on the assumption of "perfect" baffling characteristics.
(8) Based on the treatment capacity of the plant as per CT study of October 28, 2001.
(9) Based on the assumption of "poor" baffling characteristics.
(10) Based on the assumption of "average" baffling characteristics.
(11) Based on the assumption of "superior" baffling characteristics.
(12) Based on the assumption of "unbaffled" baffling characteristics.

We have prepared a Disinfection Process Parameters table to help operators complete their SWMORs. In Table 2, we have characterized the T_{10} available in each of the disinfection zones based on the flow rate through the unit(s) that contribute most to the disinfection process within that zone. We have also provided the operators with the disinfection requirements that they must meet on an on-going basis.

TABLE 2: DISINFECTION PROCESS PARAMETERS

APPROVED CT STUDY PARAMETERS						PERFORMANCE STDs	
	Disinfection Zones					Log Inactivation	
Parameters	D1A	D1B	D2	D3	D4	Giardia	Viruses
Flow Rate (MGD)	1.169	1.608	0.648	2.592	NA	0.5	2.0
T_{10} Time (minutes)	36.0	66.8	4.2	5.6	NA		

As you review Tables 1 and 2 , you may have noted that we have based the detention time in disinfection zone D2 on the volume of, and the flow rate through a single filter. We have taken this approach because it allows the plant to continue to operate when one of the treatment units is out of service for backwashing, inspection, or repair. Please ensure that the operators understand that they need to base their CT calculations for zone D2 on the maximum flow rate that is occurring through the individual unit that is experiencing the highest flow rate. If the flow rate through each individual filter is not being measured, the operators should assume an equal distribution of water is occurring in parallel treatment units.

If you have any questions concerning our evaluation or if we may be of other assistance, please contact me at (512) 239-9999 or at the Commission's address.

Sincerely,

Ima Competent, P.E.
Technical Review and Oversight Team
Public Drinking Water Section, MC 155
Water Supply Division

Enclosure: (1) CT study spreadsheet

cc with enclosure: TCEQ Tracer Study File
                      TCEQ PWS File
                      TCEQ Regional Office