APPENDIX A

PUBLIC HEALTH DIVISION
Drinking Water Program
John A. Kitzhaber, MD, Governor

Oregon Health Authority

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December 05, 2012

Michael McWhirter
MWH
806 SW Broadway, #200
Portland, OR 97205

RE: Plan Review #187-2012 / Approval
Disinfection Tracer Study / City of Grants Pass (PWS #4100342)

Dear Mr. McWhirter:

We have received a copy of the Disinfection Contact Time Tracer Study that was conducted at the Grants Pass water treatment plant between July and September 2012.

We note that the protocol for this study was submitted and approved earlier, and the objective of the study was to evaluate the contact time available in the sedimentation basins at low, medium, and high (95% of peak) flowrates. Contact time in the clearwell has been determined with a previous study.

We agree with the results of this tracer study, and it is approved. The City may start using the new contact time (T10) numbers for reporting purposes in the monthly surface water treatment report. Should the plant flowrate exceed that of the study, a new tracer study will be required.

Thank you for submitting this report for our review. We appreciate the City's efforts to ensure their compliance with surface water treatment regulations.

Sincerely,

Scott G. Curry, P.E.
Regional Engineer
Drinking Water Program

cc: Jason Canady, City of Grants Pass

MEMORANDUM

TO: Jason Canady, City of Grants Pass

DATE: November 7, 2012

FROM: Michael McWhirter, MWH
Andrew Nishihara, MWH

CC: Brian Ginter, MSA
Chris Kelsey, MSA

REVIEWED BY: Jude Grounds, MWH
Peter Kreft, MWH

SUBJECT: Grants Pass WTP – Tracer Test Results

Executive Summary

Tracer tests for the sedimentation basins were conducted at the City of Grants Pass Water Treatment Plant (Grants Pass WTP) from July to September 2012. These tests were requested by the Oregon Health Authority (OHA) following the Water System Survey and WTP Inspection conducted in June 2011. Historical calculations of chlorine disinfection performance at the Grants Pass WTP were partially based on estimates of hydraulic efficiency through the sedimentation basins without supporting tracer test data. This technical memorandum summarizes the results of these tests.

The hydraulic efficiency values obtained through tracer testing ranged from 0.46 to 0.57 for the three flowrates tested. These results will be used for future disinfection performance (CT) calculations by plant staff, and produce similar results to the historical CT calculation method. A CT model was created for use by the plant staff based on these findings; operators can input plant flow rate, pH, chlorine residual and water temperature and determine the resulting inactivation of *Giardia*. Staff can use this model to proactively manage operation of the WTP to ensure continued compliance with disinfection requirements.

Introduction

A series of tracer tests were performed at the WTP by plant staff between July and September 2012. MWH assisted in the preparation of the tracer test plan and also in analysis and verification of the results. The tracer tests were performed to meet the requirements of the Surface Water Treatment Rule (SWTR), which was promulgated by the United States Environmental Protection Agency (EPA) in 1989. The SWTR was then augmented by the Interim Enhanced Surface Water Treatment Rule in 1999 and the Long Term 2 Enhanced Surface Water Treatment Rule (LT2ESWTR) in 2006. The objective of these regulations is to protect the public from exposure to waterborne pathogens, particularly *Cryptosporidium* oocysts, *Giardia* cysts, *Legionella* and viruses, which can be found in surface water supplies. The regulations require all utilities served by a surface water supply to achieve a minimum 3-log reduction of *Giardia* cysts, a 4-log reduction of viruses and a 2-log reduction of *Cryptosporidium* oocysts during the treatment of drinking water. The reductions in *Giardia*, bacteria and viruses are to be achieved through a multi-barrier approach of both physical removal and chemical inactivation. Under the LT2ESWTR, utilities were required to provide additional reduction of *Cryptosporidium* if their raw water source was found to be susceptible to elevated concentrations of those protozoa.

The Grants Pass WTP is classified and operated as a conventional filtration plant. The OHA has awarded the Grants Pass WTP with a 2.5-log removal credit for *Giardia*, a 2.0-log removal credit for viruses and a 2.0-log removal credit for *Cryptosporidium* at all plant flows up to its maximum production rate of approximately 20 mgd. The Grants Pass WTP is required to achieve the remaining level of *Giardia* and virus reduction via disinfection. Thus, disinfection at the plant must achieve a minimum of 0.5-log inactivation of *Giardia* and 2.0-log inactivation of viruses for compliance with the existing regulations. Sampling of the *Cryptosporidium* concentrations in the Rogue River, which is the source for the Grants Pass WTP, has shown that no additional removal/disinfection of *Cryptosporidium* is required at this time.

In order to determine the level of inactivation achieved during chemical disinfection, the EPA developed the "CT" concept. "CT" is the product of the disinfectant residual concentration (C) measured at the outlet of a disinfection section(s) and the time (T) representing the minimum detention time experienced by 90% of the water passing (or the time in which 10 percent of an added tracer passes through the section(s)). This time period is commonly referred to as the T_{10}. Tables are provided in the SWTR Guidance Manual identifying the minimum level of CT required to achieve various levels of *Giardia* and virus inactivation based on site specific water quality conditions. The EPA recommends that utilities conduct a tracer test to determine the value of T_{10} available in the disinfection section(s) which will be used for CT compliance.

As a result of a Water System Survey and WTP Inspection conducted in June 2011, the OHA requested that the City complete tracer testing at the WTP to demonstrate the hydraulic efficiency which is achieved through the plant. The City has previously conducted tracer tests for the clearwell; consequently the tests conducted for this report investigated the portion of the WTP between the static mixer, where sodium hypochlorite is first introduced to the water, and the Combined Filter Effluent (CFE) point upstream of the clearwell.

The tracer tests were conducted at three flowrates: 9.4 mgd, 15.1 mgd, and 19 mgd. The flowrates represent low, average, and high (95% of peak flowrate), operating rates at the plant.

WTP Process Description

The Grants Pass WTP is rated a conventional filtration water treatment plant with a maximum capacity of approximately 20 mgd. Raw water is pumped from the adjacent intake on the Rogue River into three sedimentation basins. Valve positions are set to split the flow between the basins based on basin size. Coagulation at the plant is achieved by dosing alum in conjunction with aluminum chlorohydrate (ACH) or poly-aluminum chloride (PACl). Filter aid polymer is added to the settled water to improve filter performance. Disinfection is achieved through pre- and post-filtration chlorination using 12.5% sodium hypochlorite. Potassium permanganate is used occasionally to control taste and odor in the finished water. The plant is frequently operated for less than 24 hours a day when there is low demand for water.

Tracer Test Methodology

Per Oregon Administrative Rules (OAR), the City was required to submit a tracer test plan to the State for approval prior to conducting any tracer tests. The testing plan was completed and submitted in March 2012. Tracer tests were conducted by injecting a solution of calcium chloride ($CaCl_2$) for the 'slug dose' method. Testing under the three flow conditions (low, average and high) as prescribed by the testing plan was completed in July 2012. Additional testing for verification and to confirm results continued intermittently through September 2012.

Tracer testing was conducted in all three of the plant's sedimentation basins at the same time. The slug dose of $CaCl_2$ was added to the flash mixer immediately downstream of coagulant addition and just prior to sodium hypochlorite addition.

Preliminary testing showed that a slug dose of 200 lbs of $CaCl_2$ dissolved with 40 gallons of water was adequate to increase the conductivity of the water high enough above the baseline conductivity to allow accurate analyses. The tracer solution was made up in the plant's polymer batching tanks. Due to the exothermic reaction from dissolution of $CaCl_2$ in water, an ice bath was used to cool the tracer solution before being used in the tests.

Successful slug dose testing introduces the full volume of dosing solution to the water in less than two percent of the hydraulic residence time (HRT) of the portion of the plant being tested. Based on the maximum test flow rate of 19 mgd, this required the tracer solution to be added in less than 2.5 minutes. The more quickly the solution is introduced, the more accurate and reliable the results. The injection system used by the plant staff was able to introduce the tracer solution in approximately 10 seconds or less.

The City of Grants Pass used their HACH conductivity monitor, with six separate sensors, to gather data points at one-minute intervals during the tracer test. Conductivity was measured at the following locations:

1. the inlet to the mixing basin which feeds Sedimentation Basins 1 and 2,
2. the inlet to Sedimentation Basin 3
3. the effluent from Sedimentation Basin 1,
4. the effluent from Sedimentation Basin 2,
5. the effluent from Sedimentation Basin 3, and
6. the CFE immediately upstream of the clearwell.

The sample probes for locations 1-5 were immersed directly into the basins. Water for sample 6 was fed to the conductivity probe through a sample pump and a short length of sample tubing.

The background conductivity was measured at all six conductivity sample points prior to the test, for a period of thirty minutes, to ensure that the background conductivity was stable. The tests were conducted during a period of stable raw water quality and flowrate to ensure there was no need to change the dosing rates of any of the treatment chemicals during the test. Approximately once per hour, grab samples were collected from each of the six locations for conductivity spot checks using the WTP's laboratory conductivity analyzer to verify the on-line conductivity measurements.

All three sedimentation basins and all eight filters were in service throughout each of the tests. No backwashing or recycling occurred during the tests. Each tracer test lasted for at least two HRTs and was conducted until sampling and calculations showed that close to 100% of the tracer had been passed.

Table 1 shows approximate HRTs through the various parts of the plant based on dimensions and volumes of basins, filters, and their related piping.

Table 1: Approximate Hydraulic Residence Times

	Hydraulic Residence Time (minutes)		
Segment of Plant	**@ 9.4 mgd**	**@ 15.1 mgd**	**@ 19 mgd**
Sedimentation Basins	247	153	122
Filters[1]	12	8	6
Total	259	161	128

[1] This estimate of the hydraulic residence times through the filters is based on a porosity in the filter media of 50% and minimum assumed water level above the top of the media of 4-feet .

Due to the long period of time necessary to obtain results from the test at the minimum flow rate, the 19 mgd test was conducted first. The 19 mgd test lasted for 287 minutes (2.2 HRT), the 15.1 mgd test lasted for 422 minutes (2.6 HRT), and the 9.4 mgd test lasted for 963 minutes (3.7 HRT).

Results

Appendix A presents plots of conductivity versus time for the WTP CFE for the tests. Time is plotted on the x-axis where '0' represents the time when the tracer solution was introduced. The primary y-axis on the left side of the plots indicates the percent of tracer solution which had passed the CFE measuring location, while the secondary y-axis on the right side of the plots shows the instantaneous conductivity measurement of each sample point. A single point, highlighting the time when 10% of the tracer solution had passed (T_{10}), was placed on each of the plots based on the observation that 100% of the tracer was recovered once the conductivity drops to background levels. $T_{theoretical}$ (T_{th}) values were equivalent to the HRT for each flowrate. As shown in the plots, the measured peak conductivity after slug addition was at least 38% higher than the measured background conductivity for each of the tests. The calculated T_{10}/T_{th} (hydraulic efficiency) values based on the test results are summarized in **Table 2** as follows:

Table 2: Tracer Test Results

Date	Flow Rate (mgd)	T_{10}/T_{th} (CFE)
7/5/12	19.0	0.48
7/6/12	15.1	0.46
7/18/12	9.4	0.57

The hydraulic efficiencies shown for the CFE are similar under the average and high flow conditions. At the low flow condition, the hydraulic efficiency increased. The measured values are consistent with values that have been measured at similar WTPs in the region. The most conservative approach for the WTP would be to use the lowest hydraulic efficiency measured for all flowrates. However, the rules allow for interpolation between data points based on flow, as is currently practiced for the Clearwell CT calculations. For consistency in CT calculation methodology, we recommend that the plant use the values from this study for the pre-Clearwell CT calculations as summarized in **Appendix B: Table B-1**.

Conclusions

Using the tracer test results for the different flow rates and the EPA's "*Compliance with the Filtration and Disinfection Requirements for Public Water Systems Using Surface Water Sources Guidance Manual*", a profile was developed to interpolate and extrapolate additional T_{10} values to be used for CT calculations at the plant for the 10 currently approved operating flows. The graph and table of these values can be found in **Appendix B**.

As discussed previously, the plant must achieve a minimum of 0.5-log inactivation of *Giardia* and 2.0-log inactivation of viruses for compliance. When using free chlorine as the primary disinfectant, *Giardia* inactivation requirements are higher than the virus inactivation requirements under all conditions.

Water temperature fluctuations have the biggest impact on *Giardia* inactivation with free chlorine, followed by pH and then chlorine residual. The lowest recorded raw water temperature since 2004 has been 0.7°C, and there is a potential for the plant to experience 0.5°C water. The raw water temperature is typically less than 5°C approximately 18 days per year.

Table 3 presents a summary of maximum plant flows to meet CT over a range of water temperatures, as calculated by a CT model. The 0.7 log column represents the WTP's internal disinfection benchmark, while the 1.0 log column shows an additional conservative condition. This analysis assumed the following conservative water quality parameters based on historical plant operating data:

- Sedimentation Basin pH = 7.5
- Sedimentation Basin effluent chlorine residual = 0.1 mg/L
- Clearwell pH = 7.5
- Clearwell effluent chlorine residual = 0.9 mg/L

Table 3: Maximum Plant Flow Rates for Various Temperatures

Temp (°C)	Max Flow that achieves CT = 0.5 log DS of Filters (mgd)	Max Flow that Achieves CT = 0.5 log Total (mgd)	Max Flow that Achieves CT = 0.7 log Total (mgd)	Max Flow that Achieves CT = 1.0 log Total (mgd)
0.5	5.6	8.3	6.0	4.1
5	8.0	11.7	8.4	5.9
10	10.6	15.7	11.2	7.9
15	15.5	20+	16.4	11.4
25	20+	20+	20+	20+

DS – downstream
mgd – million gallons per day

Figure 1 visually displays the modeled log inactivation of *Giardia* through the WTP and clearwell over a range of water temperatures.

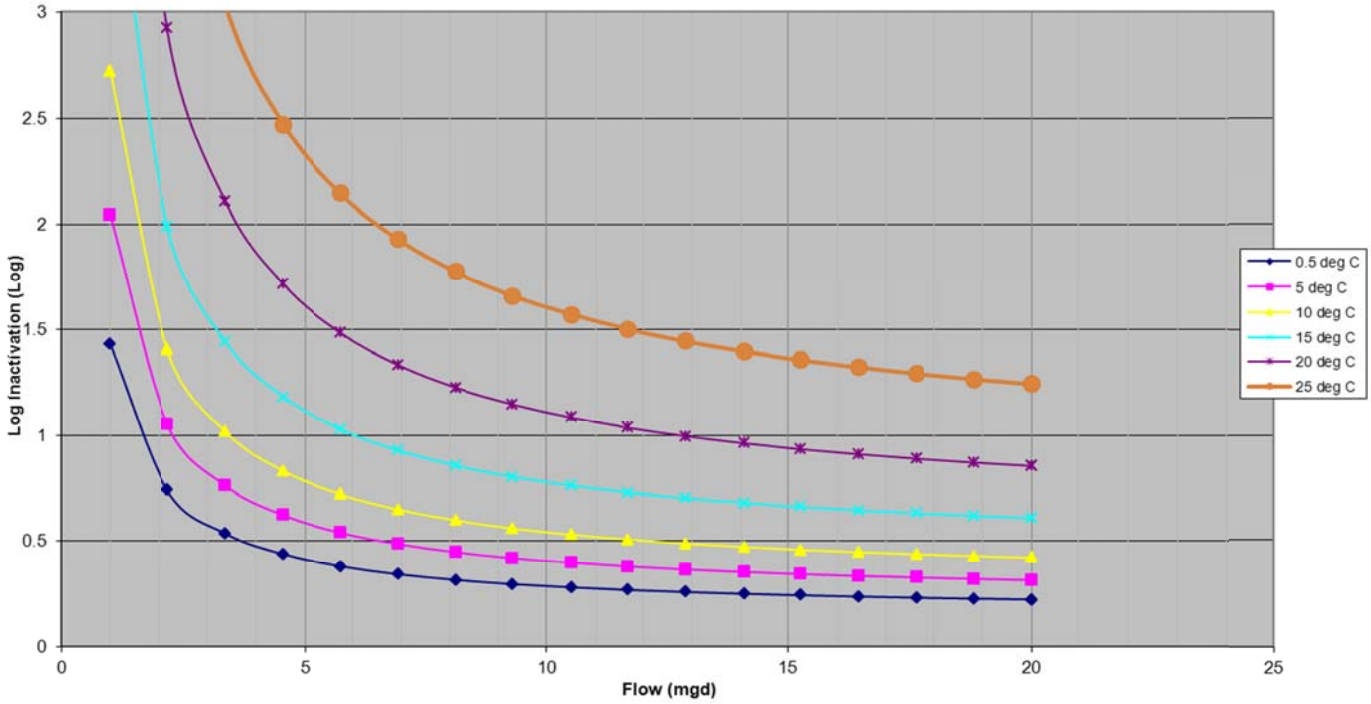

Figure 1: Log inactivation of *Giardia* through the WTP and Clearwell

Under these conservative conditions the calculations demonstrate that the WTP can continue to meet the required 0.5-log inactivation of *Giardia* while meeting customer demands. If/when winter demands increase, the WTP will need to adjust its disinfection practices by increasing the chlorine residual, or expanding the Clearwell volume, or installing an alternative disinfectant like UV irradiation.

[NOTE: A CT model was developed for the Grants Pass WTP, and was used to determine Giardia inactivation (since Giardia disinfection requirements are more onerous than virus for Grants Pass WTP) under different water quality and operating conditions. This model incorporates CT values for free chlorine as presented in the EPA's "Surface Water Treatment Rule Guidance Manual". MWH has successfully used this model for other plants throughout the nation to optimize CT performance. A copy of the model and the User's Guide is included in ***Appendix C****. Though this CT Model will not replace OHA-prescribed CT calculations at the plant, in the future, the model may be used by WTP staff to optimize chlorine use at the plant.]*

Appendix A: Tracer Test Results

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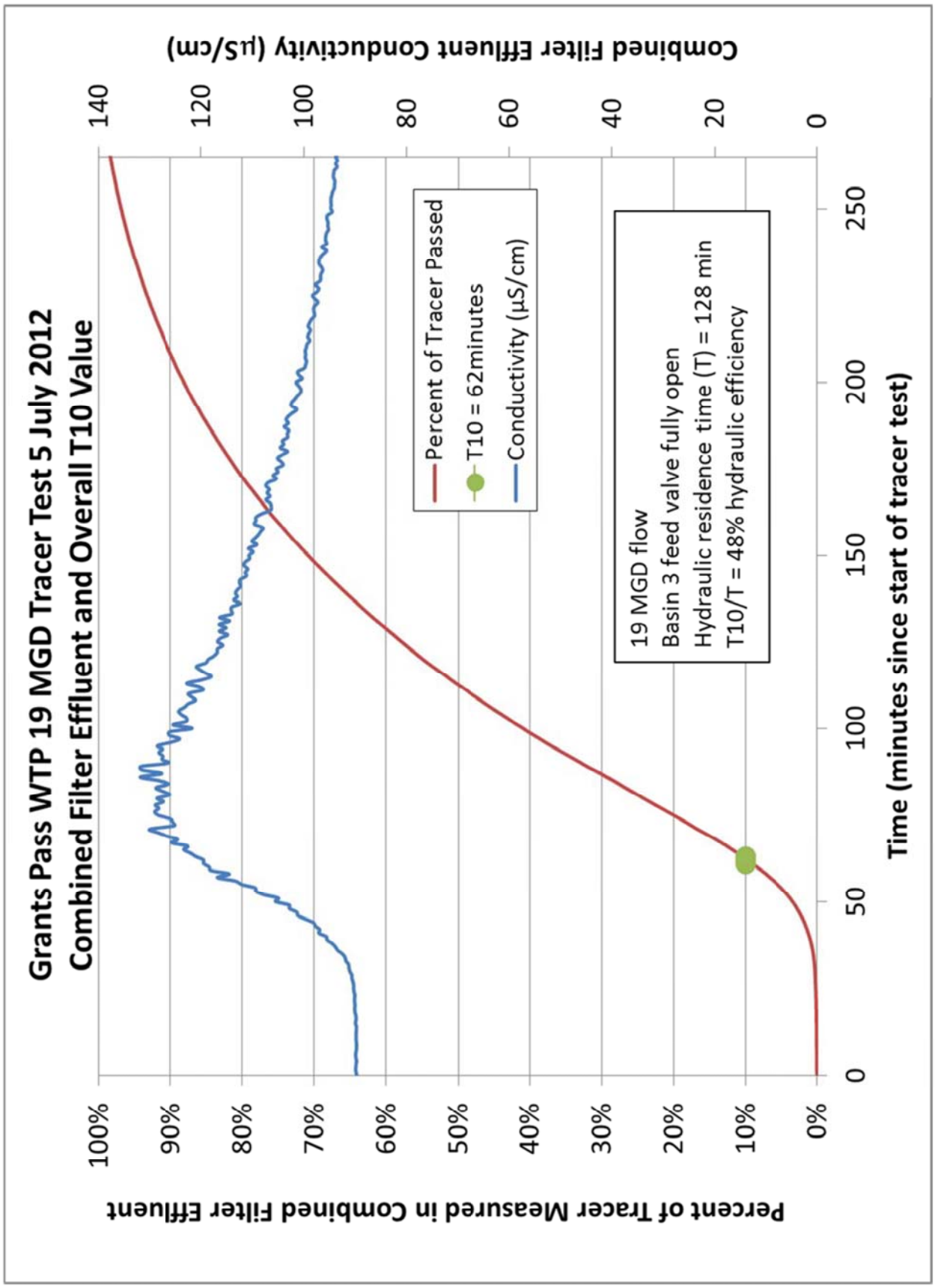
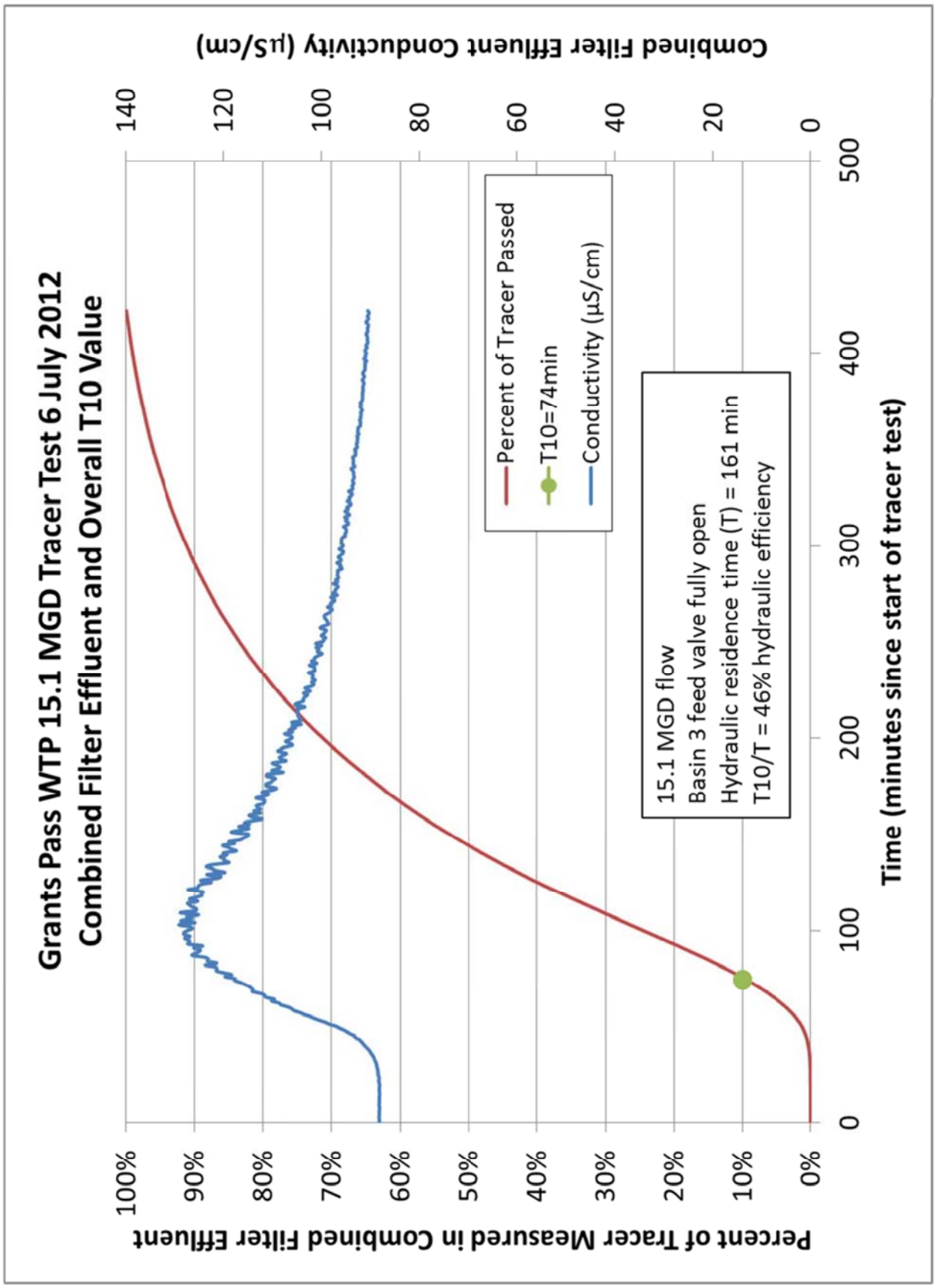
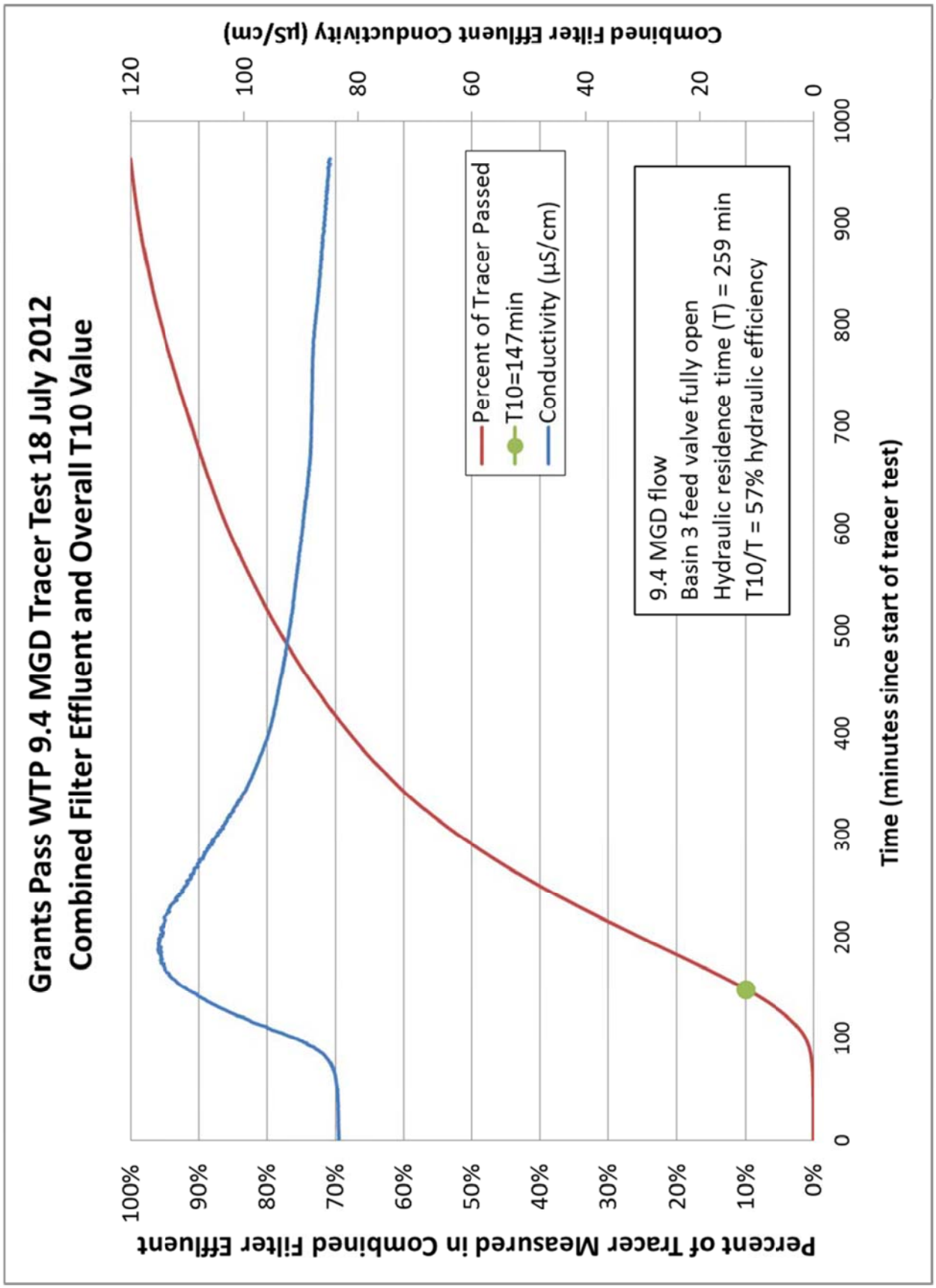

Grants Pass WTP 19 MGD Tracer Test 5 July 2012
Combined Filter Effluent and Overall T10 Value
Percent of Tracer Passed
T10 = 62minutes
Conductivity (µS/cm)
19 MGD flow
Basin 3 feed valve fully open
Hydraulic residence time (T) = 128 min
T10/T = 48% hydraulic efficiency
Percent of Tracer Measured in Combined Filter Effluent
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Combined Filter Effluent Conductivity (µS/cm)
140
120
100
80
60
40
20
0
Time (minutes since start of tracer test)
0
50
100
150
200
250


Grants Pass WTP 15.1 MGD Tracer Test 6 July 2012
Combined Filter Effluent and Overall T10 Value
Percent of Tracer Passed
T10=74min
Conductivity (µS/cm)
15.1 MGD flow
Basin 3 feed valve fully open
Hydraulic residence time (T) = 161 min
T10/T = 46% hydraulic efficiency
Percent of Tracer Measured in Combined Filter Effluent
Combined Filter Effluent Conductivity (µS/cm)
Time (minutes since start of tracer test)
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
140
120
100
80
60
40
20
0
0
100
200
300
400
500


Grants Pass WTP 9.4 MGD Tracer Test 18 July 2012
Combined Filter Effluent and Overall T10 Value
Percent of Tracer Passed
T10=147min
Conductivity (µS/cm)
9.4 MGD flow
Basin 3 feed valve fully open
Hydraulic residence time (T) = 259 min
T10/T = 57% hydraulic efficiency
Percent of Tracer Measured in Combined Filter Effluent
Combined Filter Effluent Conductivity (µS/cm)
Time (minutes since start of tracer test)
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
120
100
80
60
40
20
0
0
100
200
300
400
500
600
700
800
900
1000

Appendix B: Hydraulic Efficiency Values

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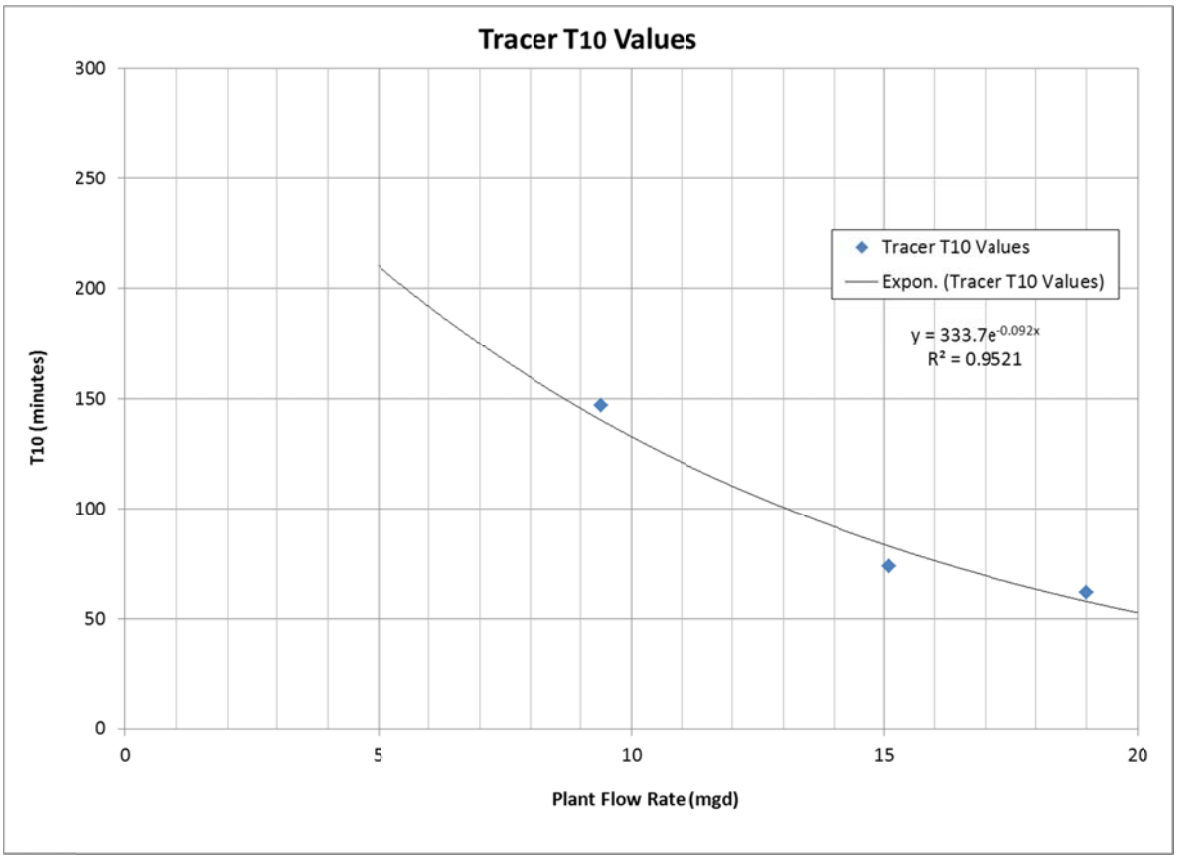

Figure B-1: Plot of 3-value T_{10} Curve

Table B-1: Tracer T_{10} and T_{10}/T_{TH} Values for CT Calculations

Flowrate (mgd)	T10 (mins)	T_{10}/ T_{TH}
5.1	208	0.44
6.5	184	0.49
7.9	161	0.53
9.4	141	0.54
10.5	127	0.55
12.2	108	0.55
13.7	95	0.53
15.1	83	0.51
16.6	72	0.48
18.0	63	0.47
19.0	58	0.45
19.4	56	0.44
20.0	53	0.44

Appendix C: CT Model User Guide

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MEMORANDUM

TO: Jason Canady, City of Grants Pass **DATE:** November 7, 2012

FROM: Michael McWhirter, MWH **CC:** Brian Ginter, MSA

Andrew Nishihara, MWH Chris Kelsey, MSA

REVIEWED BY: Jude Grounds, MWH

SUBJECT: CT Model – User Guide – Draft

Introduction

The City of Grants Pass Water Treatment Plant (WTP) CT Model is intended for two purposes: 1) to serve as a tool for doing "what if" analyses when optimizing the plant's disinfection strategy, and 2) to assist plant operators in accurately calculating and consistently reporting daily CT compliance. The model is interactive, and should be modified to best represent the treatment conditions of interest. The model breaks the plant into several "disinfection sections", and uses look-up tables to calculate the log-removal of *Giardia lamblia* through that particular section. Overall disinfection performance is then calculated by summing the disinfection achieved through the individual sections of the plant.

This Users Guide presents regulatory and theoretical background necessary for determining disinfection compliance, as well as a step-by-step guide to operating the model and interpreting the results.

Background

The following section provides background information on the disinfection requirements for the Grants Pass WTP and a review of the calculations involved when reporting inactivation performance.

CT Requirements

Drinking water requirements, as defined under the Surface Water Treatment Rule (SWTR), are defined in Oregon law under OAR 333-061. The objective of OAR 333-061 is to protect the public from exposure to pathogenic organisms, particularly *Giardia lamblia* cysts, *Legionella*, and viruses, which can be found in surface water supplies. By law, all utilities served by a surface water supply are required to achieve a minimum of 99.9% (3-log) reduction in *Giardia lamblia* cysts and 99.99% (4-log) reduction in viruses during drinking water treatment. Removal credit is awarded to water treatment plants based on the types of processes provided. For plants rated conventional such as the Grants Pass WTP, a 2.5-log and 2.0-log removal credit is achieved for *Giardia lamblia* and viruses, respectively. The remaining reduction in pathogenic

organisms must come in the form of disinfection. For the Grants Pass WTP, a minimum of 0.5-log inactivation of *Giardia*, and 2-log inactivation of viruses is required prior to the first customer.

To determine the level of inactivation achieved during chemical disinfection, the EPA developed the "CT" concept. Compliance with the disinfection requirements is achieved when the following equation is true:

1. $\mathbf{CT_{achieved} \geq CT_{required}}$

Where: $CT_{achieved}$ through the treatment process is calculated by the product of the disinfectant residual concentration measured at the outlet of a disinfection section ("C") and the "effective" detention time through a section of the plant ("T"), commonly referred to as the T_{10}. Additional discussion of the T_{10} is presented in a later section.

$CT_{required}$ can be determined using tables provided in the SWTR Guidance Manual, which identify the minimum level of CT that is required to achieve various levels of *Giardia lamblia* and virus inactivation. This value is a function of the following water quality parameters, as measured at the end of the disinfection section:

- Disinfectant residual
- pH
- Temperature

The Grants Pass WTP relies on free chlorine contact time through the plant to achieve the necessary CT.

Calculating T_{10}

The theoretical detention time (T_{th}) through a basin (in this case, a disinfection section) represents the average time a molecule of water spends in that basin, and is calculated using the following equation:

2. $$\mathbf{T_{th}\ (min) = \frac{Disinfection\ Section\ Volume\ (gal)}{Flow\ Rate\ (gal/min)}}$$

T_{10}, or the effective detention time is used when calculating "CT" to better account for any "short-circuiting" that may occur through a particular disinfection section, and is typically a fraction of the theoretical detention time. T_{10} is defined as the time in which 10% (by volume) of an added tracer would passes through the outlet of the disinfection section. Thus, the ratio of T_{10}/T_{th}, or hydraulic efficiency (*e*) is always less than or equal to 1, depending on the mixing characteristics in the disinfection section. For example, well mixed portions of the treatment process (rapid mix, for example) will have a hydraulic efficiency of approximately 0.1—only 10% of the theoretical detention time will be considered when calculating "CT". Pipelines, where very little mixing occurs, will have hydraulic efficiencies that approach 1.0. The following equation can be used to determine the T_{10} through any disinfection section, at any flow rate:

3. $$\mathbf{T_{10}\ (min) = \frac{Hydraulic\ Efficiency\ (e) \times Disinfection\ Section\ Volume\ (gal)}{Flow\ Rate\ (gal/min)}}$$

Though recommended values for hydraulic efficiency are presented in the SWTR Guidance Manual for various treatment processes, the only way to accurately measure hydraulic efficiency is through a tracer test. Once hydraulic efficiency is determined, it can be used to calculate T_{10} at a range of flowrates through a disinfection section (i.e. flocculation/sedimentation basin, clearwell, etc.).

Calculating CT through a WTP

The overall disinfection achieved through a treatment plant and/or a transmission pipeline is simply the sum of the disinfection achieved through the various disinfection sections of the plant. Because the $CT_{required}$ varies according to the water quality characteristics (chlorine residual, pH and temperature), the boundaries of these disinfection sections are typically defined by the points of chemical addition and chemical monitoring (i.e. pH adjustment, chlorine injection/residual monitoring, etc.). The water quality characteristics used to determine the $CT_{required}$ represent the "worst case" conditions (i.e. the highest pH, lowest temperature and highest chlorine residual measured through the disinfection section).

Calculating overall disinfection performance at the Grants Pass WTP, with various points of chlorine injection and/or pH adjustment, is slightly more complex than simply summing the $CT_{achieved}$ through each disinfection section because the $CT_{required}$ varies between sections. Rather, to quantify the overall disinfection performance, the fraction of the overall disinfection requirement (or ratio of the total $CT_{achieved}$ to the $CT_{required}$), or more simply, the log-inactivation achieved through each disinfection section is summed. For example, if 0.2-log inactivation is achieved in the Basins, 0.05-log inactivation is achieved in the Filters, and 0.4-log inactivation is achieved through the clearwell, a total inactivation of 0.65-log was achieved. In this case, the plant would have exceeded the disinfection requirement of 0.5-log inactivation, in compliance with the regulations.

The following equation is used to calculate the log-inactivation achieved through a disinfection section:

4. Log-inactivation = $\dfrac{CT_{achieved}}{CT_{required}}$

Example 1 illustrates the CT calculation for a single disinfection section at the Grants Pass WTP.

EXAMPLE #1: Calculate $CT_{achieved}$ and resulting log-inactivation through the Basins, given the following information:

- T_{10}/T of Basin = 0.28
- Basin Volume (rate-limiting basin) = 214,000 gallons
- Flow in Basin (rate-limiting basin) = 3704 gpm
- Chlorine residual at Basin Effluent = 0.6 mg/L
- Maximum pH = 7.0
- Minimum Water Temperature = 15 deg C

SOLUTION: The $CT_{achieved}$ through the Basin can be calculated according to the following equation:

1. $CT_{achieved}$ (Basin) = Chlorine Residual (Basin effluent) x T_{10} (Basin)

   Where:

   T_{10} (Basin) = hydraulic efficiency x T_{ave}

   Where T_{ave} = Basin Volume (gal) / Flow in Basin (gpm), so

   $$T_{10}\text{ (Basin)} = \frac{\text{hydraulic efficiency x Basin Volume (gal)}}{\text{Flow in Basin (gpm)}}$$

   $$T_{10}\text{ (Basin)} = \frac{\text{0.28 x 214,000 (gallons)}}{\text{3704 (gpm)}}$$

   T_{10} (Basin) = 16 min

   $CT_{achieved}$ (Basin) = 0.6 mg/L x 16 min

   $CT_{achieved}$ (Basin) = 9.7 mg/L –min

2. Using CT Tables from the SWTR Guidance Manual for 1-log inactivation of *Giardia*, $CT_{required}$ at our water quality conditions is **24 mg/L – min**, well above our $CT_{achieved}$. To calculate log-inactivation use a simple ratio:

   $$\textbf{X-log kill} = \frac{\text{9.7 mg/L -min}}{\text{24 mg/L-min}}$$

   or **0.40-log** inactivation of *Giardia*!!!

NOTE: Due to unequal Basin volumes, an option exists in the model to turn the Basins on or off individually to simulate situations involving cleaning or maintenance activities.

Example 2 illustrates a CT calculation for a WTP with variable water quality characteristics.

EXAMPLE #2: Calculate log-inactivation through the Contact Basins and Clearwell, given the following additional information:

- T_{10}/T of Clearwell = 0.51
- Clearwell Volume = 325,000 gallons
- Flow in Clearwell = 11,111 gpm (or 16 mgd total through the plant)
- Chlorine residual at Clearwell Effluent = 0.85 mg/L
- Maximum pH = 8.0
- Minimum Water Temperature = 15 deg C

SOLUTION: The $CT_{achieved}$ through the Basin and Clearwell, combined, can be calculated according to the following equation:

1. Total inactivation (log) = log-inactivation (Basin) + log-inactivation (Clearwell)

We know the log inactivation through the Basin (from Example #1); we must solve for the log-inactivation through the Clearwell. We do this by calculating the $CT_{achieved}$, then solving for the log-inactivation.

$CT_{achieved}$ (Clearwell) = Chlorine Residual (Clearwell effluent) x T_{10} (Clearwell)

Where:

T_{10} (Clearwell) = hydraulic efficiency x T_{ave}

Where T_{ave} = Clearwell Volume (gal) / Flow in Clearwell (gpm), so

$$T_{10}\text{ (Clearwell)} = \frac{\text{hydraulic efficiency x Clearwell Volume (gal)}}{\text{Flow in Clearwell (gpm)}}$$

$$T_{10}\text{ (Clearwell)} = \frac{\text{0.51 x 325,000 (gallons)}}{\text{11,111 (gpm)}}$$

T_{10} (Clearwell) = 14.9 min

$CT_{achieved}$ (Clearwell) = 0.51 mg/L x 14.9 min

$CT_{achieved}$ (Clearwell) = 12.7 mg/L –min

2. Again, using CT Tables from the SWTR Guidance Manual for 1.0-log inactivation of *Giardia*, $CT_{required}$ at our water quality conditions is **36 mg/L – min**. To calculate log-inactivation use a simple ratio:

$$\textbf{X-log kill} = \frac{\text{12.7 mg/L -min}}{\text{36 mg/L-min}}$$

or **0.35-log** inactivation of *Giardia* through the Clearwell.

3. Total inactivation (log) = log-inactivation (Basin) ***(EX 1)*** + log-inactivation (Clearwell)

Total inactivation (log) = 0.40-log + 0.35-log

Total inactivation (log) = 0.75-log

WTP DISINFECTION MODEL

To accurately model the disinfection performance through the Grants Pass WTP, a model was created to perform these calculations. To do so, the plant was divided into the following disinfection sections:

- Contact basins,
- Filters,
- Clearwell,
- Pipeline (not used/optional)

Some components were intentionally excluded in the model due to poor mixing characteristics and/or potential short-circuiting issues that minimize the effective detention time, and render the overall CT achieved through the component inconsequential. These sections include: the Rapid Mix Basin, the channels/pipelines that convey water from the Contact Basins to the filters and the channel that conveys filtered water to the Clearwell.

The model was built in Microsoft Excel, and consists of a series of cross-referenced worksheets. A list of the worksheets, and a brief description follows.

- "User's Guide": contains a link to an embedded PDF copy of this Guide and contact information for the author.
- "Model Input & Results": presents a system schematic and summary of calculated values from the model. User defined variables such as plant flow rate, water quality parameters (pH, chlorine residual, etc…), and operating parameters (number of basins/filters on-line, etc…) can all be input in this worksheet. In most cases, notes and assumptions have been included beneath each of the individual disinfection sections. **In general, input variables are all contained within yellow cells; output variables are contained within red cells.**
- "Performance Summary": provides a graphical representation of *Giardia* log inactivation for the water quality parameters input for different scenarios.
- "CT Look-up Tables": These are the CT tables as transcribed from the SWTR Guidance Manual for 0.5-log inactivation of *Giardia lamblia*. These tables should not be altered.
- "T10 Reference Tables": this worksheet is provided for the user's reference when inputing the T_{10}/T values into the model.

A discussion of the user-input variables on the "Model Input & Results" worksheet (for each of the disinfection sections), as well as the assumptions made when calculating the disinfection performance of each section is discussed below.

General: User-defined variables include plant flow (in mgd) and water temperature (in ^{o}C). These values are referenced and used throughout the spreadsheet when calculating detention times, flow splitting and CT values. Note: the water temperature may increase slightly through the plant, and if desired, temperature should be input separately for each disinfection section.

***Basins*:** Flow to each of the basins has been set-up to use the Grants Pass WTP's flow split configuration. Basins can be turned on and off as needed for modeling purposes. The T_{10}/T values used in the model are based on recommended values presented in the SWTR Guidance Manual.

In addition, the user can also adjust the chlorine residual and pH for the Contact Basins. NOTE: chlorine residual should be based on the residual monitor in the "flume", downstream of the Basins. The volume of the basins (used to calculate the T_{10}) were based on an operator input "Water level in Basin". The basin water level fluctuates with filter water level, which is typically controlled to +/- 0.1 foot, so there will be little change in basin water level.

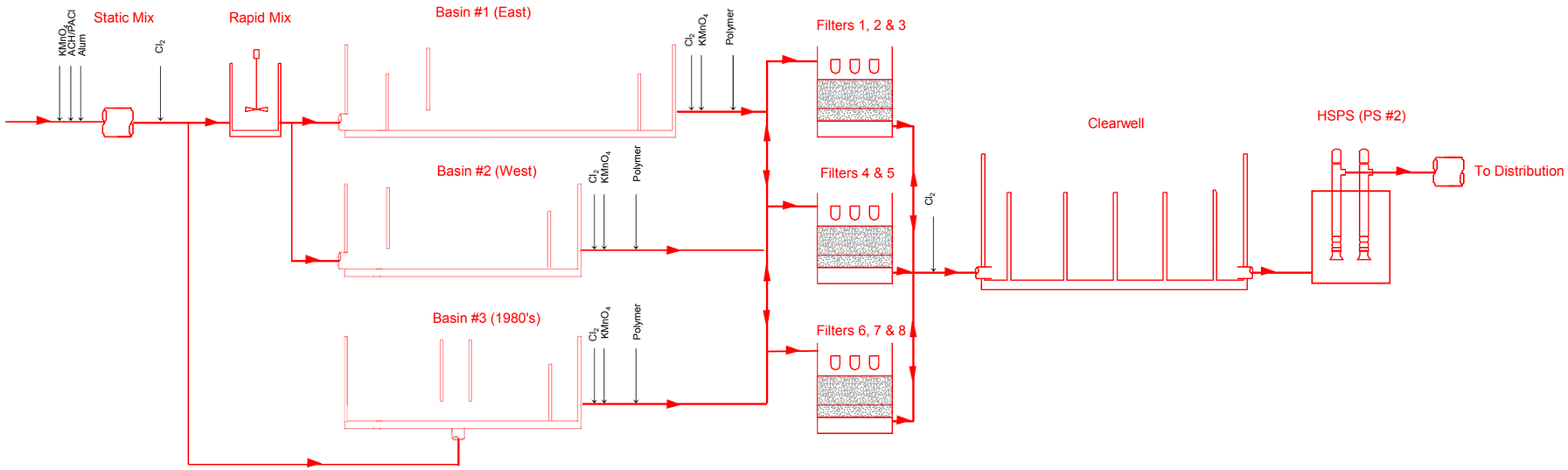
Filters: Flow through the individual filters is calculated by dividing the total plant flow by the number of filters on-line (an user-input variable). In calculating the total volume of the filters, a filter media porosity of 0.5 was used. NOTE: A operator-input variable named "Use Filters for CT?" can be toggled between Y/N, depending on the scenario desired. Typically, the Grants Pass WTP will use the Filters for CT compliance.

***Clearwell*:** For the Clearwell, the user-input variables include: water depth, chlorine residual and pH. Again, water quality characteristics must be measured downstream of the Clearwell (i.e. in the HSPS discharge, for example).

***Pipeline*:** The flow to the transmission pipeline must be input by the user. As with previous disinfection sections, chlorine residual and pH are user-input variables. Again, these water quality values need to be measured at the down-stream side of the transmission pipeline to be considered in the CT calculation. As the Grants Pass WTP does not use the transmission pipeline to meet CT, the input variable are placeholders and the log-inactivation will read "0" for this section. This section of the model is left purely for "what-if" scenarios.

***Totals*:** A summary of the log-inactivation achieved through each of the disinfection sections is presented in this section of the model. Overall totals, including the inactivation achieved through the pipeline (if ever used).

Grants Pass WTP CT Model



Input/Results:

General:

Plant Flow Rate (for CT Calcs)	13500	(gpm)
Plant Flow Rate	19.4	(mgd)
Finished Water Temperature	15.00	(°C)
MAX Design Rate	20	(mgd)
MIN Design Rate	1	(mgd)

Notes:

1. Yellow boxes indicate operator input variables
2. Red boxes indicate calculated values

Notes:

1. Verify flow calculations; include recycle streams where appropriate.

Floc/Sed Basins

General

Flow to Basin #1	6.9	(mgd)
Flow to Basin #2	4.1	(mgd)
Flow to Basins #3	8.4	(mgd)
Basin #1 Online (Y/N)	Y	(mgd)
Basin #2 Online (Y/N)	Y	(mgd)
Basin #3 Online (Y/N)	Y	(mgd)
Water Depth in Basin	14.5	(ft)

Basin #1

MIN Chlorine Residual (effluent)	0.10	(mg/L)
MAX pH (Rapid Mix)	7.50	
Temperature	15.00	(°C)
T_{10}/T	0.44	
Hydraulic Residence Time	119	(min)
T10 (for CT Calculation)	52	(min)
CT Achieved	5.2	(mg/L-min)
Log Inactivation	0.17	(log)

Basin #2:

MIN Chlorine Residual (effluent)	0.10	(mg/L)
MAX pH (Rapid Mix)	7.50	
Temperature	15.00	(°C)
T_{10}/T	0.44	
Hydraulic Residence Time	119	(min)
T10 (for CT Calculation)	52	(min)
CT Achieved	5.2	(mg/L-min)
Log Inactivation	0.17	

Basin #3:

MIN Chlorine Residual (effluent)	0.10	(mg/L)
MAX pH (Rapid Mix)	7.50	
Temperature	15.00	(°C)
T_{10}/T	0.44	
Hydraulic Residence Time	119	(min)
T10 (for CT Calculation)	52	(min)
CT Achieved	5.2	(mg/L-min)
Log Inactivation	0.17	

Notes:

1. T10/T Ratio based on 2012 tracer testing

Anthracite/Sand Filter

General

Number of Filters On-line	8	(no)
Use Filters for CT? (see Note 3)	Y	(Y/N)
Filter Surface Area	311.5	(sf)
Media Depth	30	(in)
MIN Water Depth	6.25	(ft)
Single Filter Volume	11651.66	(gal)

Filters:

MIN Chlorine Residual (effluent)	0.10	(mg/L)
MAX pH (Rapid Mix)	7.50	
Temperature	15.00	(°C)
T_{10}/T	0.44	
Hydraulic Residence Time	6.9	(min)
T10 (for CT Calculation)	3.0	(min)
CT Required	30	(mg/L-min)
CT Achieved	0.3	(mg/L-min)
Log Inactivation	0.01	(log)

Notes:

1. Need to confirm Cl2 & pH sample points to ensure compliance
2. Volume Calcs assume a media porosity of 0.5
3. Filters can be turned off to model other scenarios.

Clearwell:

General

Basin Surface Area	3558	(ft)
Water Depth	13.6	(ft)
Basin Volume	361996.6	(gal)

Clearwell:

MIN Chlorine Residual (effluent)	0.90	(mg/L)
MAX pH (Rapid Mix)	7.50	
Temperature	15.00	(°C)
T_{10}/T	0.53	
Hydraulic Residence Time	27	(min)
T10 (for CT Calculation)	14	(min)
CT Required	30	(mg/L-min)
CT Achieved	12.9	(mg/L-min)
Log Inactivation	0.43	

Notes:

1. T10/T Ratio based on B&V 2003 tracer testing.

Pipeline:

General

Plant Efficiency	0.95	(%)
Pipeline Diameter	36	(in)
Pipe Length	5	(ft)
Pipe Volume	264	(gal)
Pipeline Flow	18.43	(mgd)

Transmission Main to First Customer

Chlorine Residual	0.85	(mg/L)
pH	8.00	
Temperature	15.00	(°C)
T_{10}/T	1.00	
Hydraulic Residence Time	0.0	(min)
T10 (for CT Calculation)	0.0	(min)
CT Required	36	(mg/L-min)
CT Achieved	0.0	(mg/L-min)
Log Inactivation	0.00	

Notes:

1. Pipeline is not used in this calculation and is provided solely for 'what if' scenarios.
2. Pipeline Flow calculated by multipling Plant Flow and Plant Efficiency.

Totals:

In-plant Sub-Total

Process	Log
Floc/Sed Basins	0.17
Clearwell	0.43
Sub-total (In-plant)	***0.61***

24-inch Transmission Main

Pipeline (to First Customer)	0.00
Filter	0.01

Totals:

Total Achieved in Plant	0.61

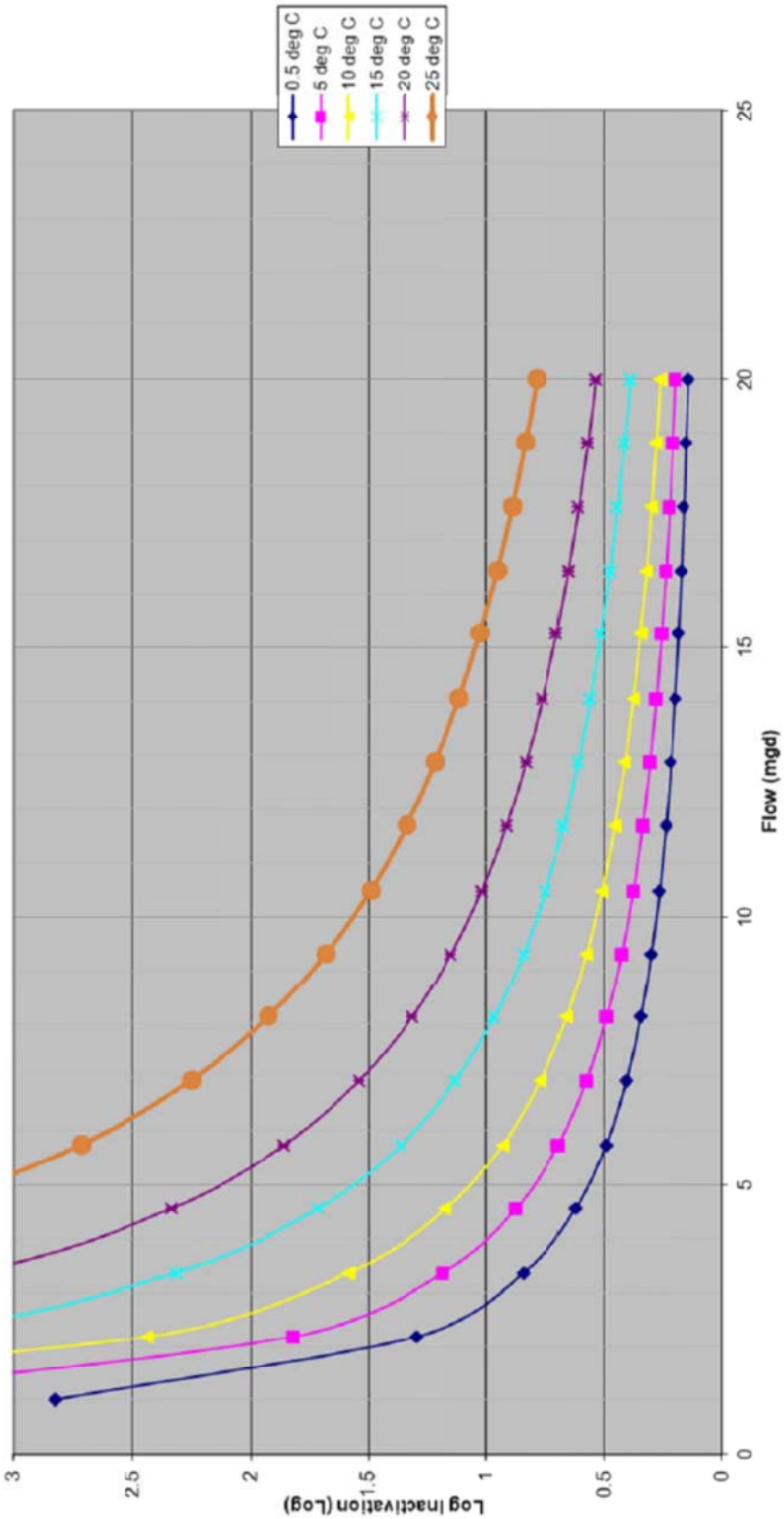


Figure C-2: Log inactivation of *Giardia* through the Clearwell from the CT Model for the Water Quality Parameters Input

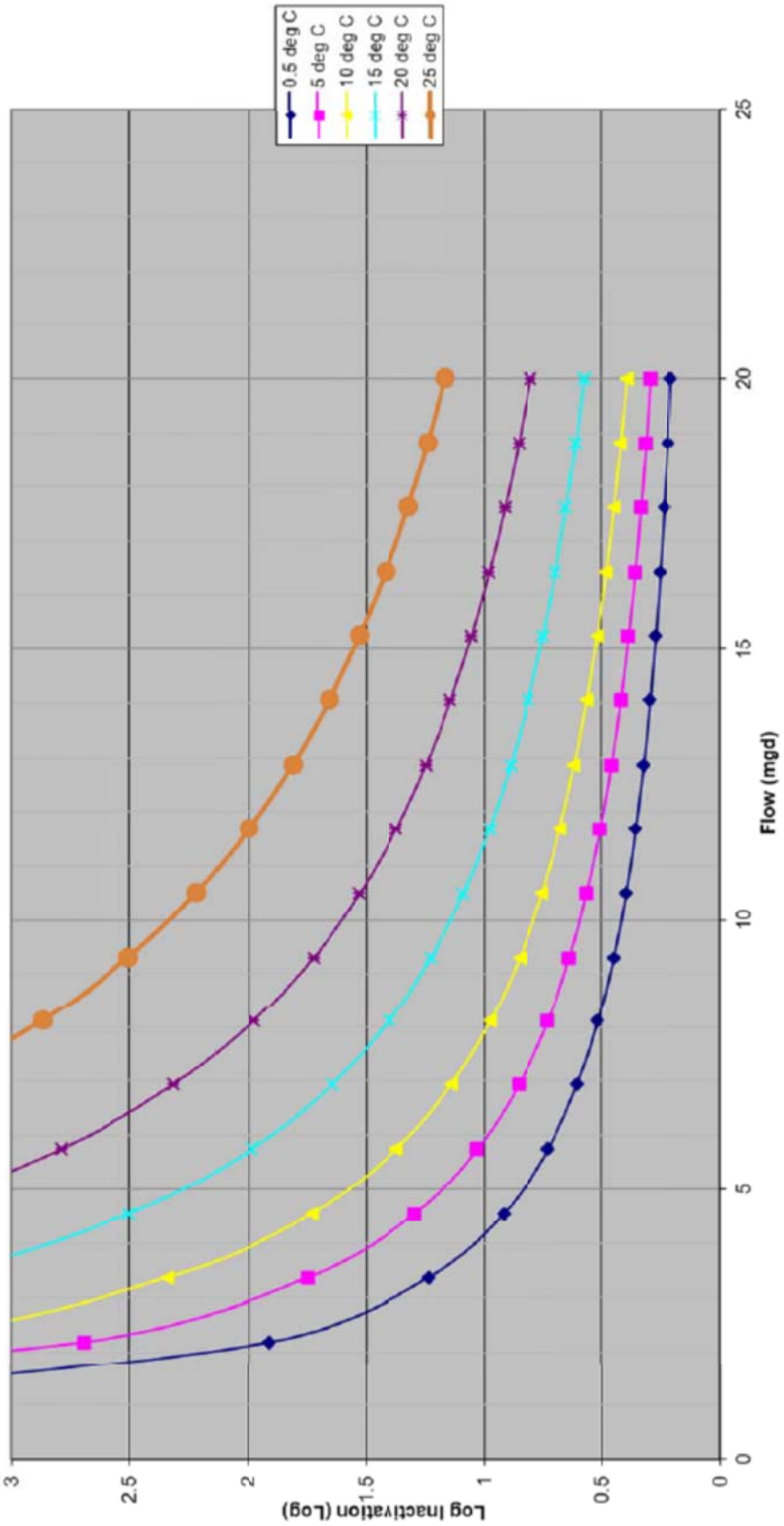


Figure C-3: Log inactivation of *Giardia* through the WTP & Clearwell from the CT Model for the Water Quality Parameters Input