University of Alberta

Wall Decay Coefficient of Combined Chlorine in
a Drinking Water Distribution System

by

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ABSTRACT

Using water quality models to predict disinfectant concentrations in water distribution systems requires a knowledge of the wall decay coefficient. In this study, field water sampling was conducted in conjunction with a SynerGEE Water hydraulic model for an area of the water distribution system of the City of Edmonton to calibrate a wall decay coefficient for combined chlorine. Using the least squares method, a unique wall decay coefficient, 0.0295 m/d, was obtained. Using the same method it was found that the wall decay coefficient was 0.0455 m/d for a sub-section of the studied area with predominantly cast iron pipes, and 0.0160 m/d for another sub-section where the pipes had been extensively renewed. By identifying wall decay coefficients for individual areas using this method, it is feasible to turn SynerGEE Water hydraulic model into a working model to predict water quality for the City of Edmonton.

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NOMENCLATURES

A	constant in Arrhenius equation
A_i	cross-sectional area of pipe i (m^2, cm^2)
c	c-factor in Hazen-Williams roughness equation
C	chlorine concentration (mol/m^3, mg/L)
C_i	concentration in pipe i as a function of distance x and time t (mol/m^3, mg/L)
$C_{i,ni}$	concentration entering junction node from pipe i (mol/m^3, mg/L)
C_{lim}	limiting concentration, which is the minimum concentration to which a substance can decay for decay reactions (mol/m^3, mg/L)
C_o	initial chlorine concentration (mol/m^3, mg/L)
C_{OUTj}	concentration leaving the junction node j (mol/m^3, mg/L)
d	molecular diffusivity of chlorine in water (m^2/s, cm^2/s)
D	pipe diameter (m, cm)
E_a	activation energy (J)
IN_j	set of pipes entering node j
k	rate constant
k_b	bulk chlorine decay reaction rate coefficient (s^{-1}, hr^{-1}, d^{-1})
k_f	mass transfer coefficient (m/s, m/d, m/hr, cm/s)
k_w	wall chlorine decay reaction rate coefficient (m/s, m/d, m/hr, cm/s)
$k_{w,0}$	zero order wall decay coefficient ($kg/m^2/s$, $mg/m^2/d$)
$k_{w,1}$	first order wall decay coefficient (m/s, m/d, m/hr, cm/s)
L	pipe length (m, cm)
n	reaction rate order constant
OUT_j	set of pipes leaving node j
Q_i	volumetric flow rate in pipe i (m^3/s, m^3/hr)
Q_i	volumetric flow rate entering the junction node from pipe i (m^3/s, m^3/hr)
R	gas constant, 8.314 J/(mol·K)
Re	Reynolds number
R_H	hydraulic radius of pipeline (m, cm)
S_H	Sherwood number
t	time (s, hr, d)
T	absolute temperature in Kelvin
U_j	concentration source at junction node j (mol/m^3, mg/L)
V_B'	LeBas molar volume of chemical (cm^3/mol)
α	fitting coefficient in Hazen-Williams roughness equation
η_w	dynamic viscosity of water (cp)
v	kinematic viscosity of bulk fluid (m^2/s)

1 INTRODUCTION

1.1 Water Distribution Systems, Water Quality Control

1.1.1 Water Distribution Systems, Pipe Materials

Municipal water systems usually consist of water treatment plants, pump stations, reservoirs and pipeline distribution systems covering the entire municipality. Fresh water is drawn from rivers, lakes and/or from underground water sources, and purified in the water treatment plants to make it potable. The treated water is pressurized and stored in reservoirs that supply the water to the neighborhoods.

The most common pipe materials in the water distribution systems are cast iron, asbestos cement and polyvinyl chloride (PVC). Pipes in the older neighborhoods (built prior to the 1950s) were mostly made with cast iron. From the 1960s to the 1970s, asbestos cement pipes became more common than cast iron pipes. After the 1980s, PVC became a predominant choice for pipe material in water distribution systems.

1.1.2 Water Quality Control and Monitoring

In order to control the quality of the distributed water, a disinfectant is typically used. Chlorine gas or hypochlorite salt has been used as a common disinfectant. When added to water, chlorine gas and hypochlorite salt go through hydrolysis and ionization processes and form hypochlorous acid (HOCl) or hypochlorite ions (OCl^-), which are referred to as “free available chlorine”, or “free chlorine” for short. However, free chlorine is volatile and does not stay in water for long. Alternatively, “combined chlorine”, a mixture of hypochlorite salt and ammonia, can be used instead of free chlorine. When combined chlorine is used, free chlorine and ammonia quickly react to form monochloramine (NH_2Cl), dichloramine ($NHCl_2$) and nitrogen trichloride (NCl_3). Monochloramine is usually the dominant form so that combined chlorine is also referred to as monochloramine, or simply chloramine. As the monochloramine is less volatile and more chemically stable than free chlorine, it stays in water for a longer period of time to protect the water quality (EPA, 1999). In this thesis, the term “chlorine” is used in its generic sense so it can mean both the free chlorine and combined chlorine, unless specified otherwise explicitly.

The concentrations of the disinfectants in water needs to be monitored to ensure that water quality is maintained. As the disinfectant is typically added to the treated water, its concentration tends to drop along the water flow lines due to reactions with chemical and biological species in water (bulk decay) and with the pipes (wall decay). It is known that cast iron and asbestos cement pipes are more reactive with chlorine than PVC pipes. Biofilms and other deposits accumulated over time on pipe walls can also react with chlorine. Therefore, materials of construction and age of the pipes in the water distribution systems can significantly affect chlorine concentration and water quality.

Currently there is no efficient and effective way to continuously monitor the chlorine concentration and water quality in the water distribution systems. For example, combined chlorine is used in EPCOR Water Services Inc. (EWSI)’s water distribution system in the City of Edmonton, and EWSI monitors water quality in its water distribution system by following a routine of field sampling at selected locations and testing the chloramine concentration of the collected water samples in the laboratory. However, this routine requires tremendous resources to carry out and even then, cannot provide up-to-date real-time water quality information for the entire water distribution system.

For many years, hydraulic models have been used to solve water flow problems in water distribution systems but they have been used to a much lesser extent to simulate water quality in the water distribution systems. EWSI installed a hydraulic modeling software, SynerGEE Water, in 2002, to predict the hydraulics in its water distribution system. SynerGEE Water has a built-in water quality model that can be used to predict water quality, that is, to calculate the chlorine concentrations at all locations in the entire water distribution system, provided that related water quality parameters are known. However, due to a lack of good model parameters such as the bulk decay and wall decay coefficients of chlorine, and also due to the difficulties in testing and validating the model, the water quality model in SynerGEE Water has never been used at EWSI.

1.2 Objectives of the Research

The objective of this research was to use a water quality model to predict the decay of combined chlorine in a water network with predominantly cast iron pipes. More specifically, a methodology was adopted to determine the wall decay coefficient of combined chlorine* in a selected area of the water distribution system of EWSI. The determined wall decay coefficient could be used as input to the water quality model of SynerGEE Water so that it could accurately predict the chloramine concentration in the selected study area.

The establishment of such a working model for water quality prediction would allow EWSI to develop solutions to water quality issues in existing water distribution systems without trial and error, and to optimally design new water distribution systems.

1.3 The Study Area

One area of EWSI's water distribution system in the City of Edmonton, approximately 1.5 square kilometers (determined through measurement from Google Maps), was selected as the area to be studied in this research. Figure 1

* Bulk chloramine decay will also be determined as it is needed in the model to calculate chloramine concentrations. However, as the bulk decay coefficients can be determined by routine bottle tests, it is not the primary objective of this research.

shows a map of the area. This area will be referred to as the Study Area from this point on. The population in this area was 7776 based on the 2012 municipal census conducted by the City of Edmonton, and the area mainly consists of single-family dwellings built between the 1950s and 1970s. Therefore the pipe material in the water distribution system is mainly cast iron, mixed with certain percentages of asbestos cement and PVC pipes as a result of maintenance and renewal over the years. There has historically been complaints and concerns about the water quality in this area, which was partly the reason for its being selected as the Study Area.

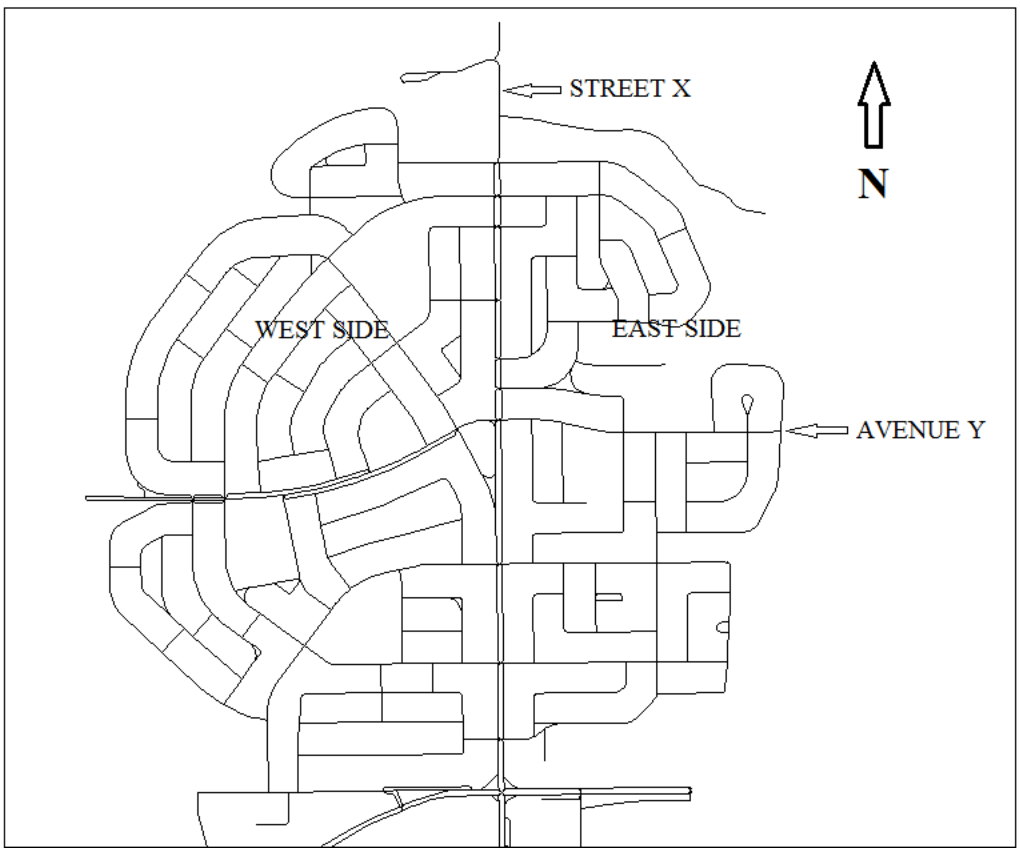

Figure 1 Map of the Study Area (EWSI, 2013).

1.4 The Organization of this Thesis

Following this introductory chapter, Chapter 2 presents a literature review on the development and the current status of water quality modeling, as well as on the case studies in which the wall decay coefficient of chlorine was determined. Chapter 3 presents the general methodologies, extraction and updating of the hydraulic model, and laboratory experiment procedures used in this work. Chapter 4 presents results and discussions, and Chapter 5 summarizes the major findings of the work, the conclusions and recommendations for further work. The raw data and interim calculations are listed in the eleven appendices at the end.

2 LITERATURE REVIEW

2.1 Constituents in the Supplied Water in Distribution Systems

The constituents in the supplied water in distribution systems can be classified into two types depending on its reactivity (AWWA, 2012). A constituent is either conservative or reactive. The concentration of a conservative substance does not change as it moves through the water distribution system. Examples include fluoride and sodium, which are usually used as tracers in water quality studies due to their conservative nature. On the other hand, a reactive substance experiences changes in concentration as it moves through the water distribution system. Disinfection by-products (DBPs), such as trihalomethanes or haloacetic acids, accumulate in distribution systems so that their concentrations increase (AWWA, 2012). Disinfectants, the most common being chlorine, can undergo reactions with other substances in distribution systems and their concentrations decrease over time. This literature review will only focus on water quality modeling and studies that are associated with chlorine.

2.2 Water Quality Modeling

2.2.1 Principles of Water Quality Models

Water quality modeling is based on the fundamental principle of the conservation of mass, that is, the mass of a modeled constituent remains the same in a water distribution system, unless the constituent undergoes decay or growth reactions (AWWA, 2012). In most water quality models, the movement and fate of a constituent are modeled using the physical processes of transport and mixing, and the chemical processes of decay or growth (Haestad Methods et al., 2007).

2.2.1.1 Transport within Pipes

In most water quality models, one-dimensional advective transport is used to model the concentration of a constituent as it moves through a pipe, as expressed by Equation 1 (Haestad Methods et al., 2007). The growth or decay of the constituent in an infinitesimal section of pipe, i.e. ∂x, can be modeled by substituting for the reaction term in Equation 1 (Haestad Methods et al., 2007).

$$\frac{\partial C_i}{\partial t} = \frac{Q_i}{A_i}\frac{\partial C_i}{\partial x} + \theta(C_i) \qquad \text{Equation 1}$$

Where C_i = concentration in pipe i as a function of distance x and time t (mol/m^3, or mg/L)

Q_i = volumetric flow rate in pipe i (m^3/s, or m^3/hr)

A_i = cross-sectional area of pipe i (m^2)

$\theta(C_i)$ = reaction term (mol/m^3/s, or mg/L/hr)

This equation assumes that the constituent is traveling at the average velocity of the fluid and that the longitudinal dispersion in the pipe can be neglected (AWWA, 2012; Haestad Methods et al., 2007). Also, complete radial mixing is assumed for the bulk fluid, which is only valid under turbulent flow conditions (Haestad Methods et al., 2007).

2.2.1.2 Mixing at Pipe Junctions or Nodes

In most water quality models, the constituent concentrations from individual pipes are combined and mixed at pipe junctions or nodes, as expressed by Equation 2 (Haestad Methods et al., 2007). From this equation, it can be seen that the concentration leaving the node is essentially the flow-weighted average of all incoming concentrations (AWWA, 2012; Haestad Methods et al., 2007). The fluid mixing at the node is assumed to be complete and instantaneous (AWWA, 2012; Haestad Methods et al., 2007).

$$C_{OUT_j} = \frac{\sum_{i \in IN_j} Q_i C_{i,n_i} + U_j}{\sum_{i \in OUT_j} Q_i}$$ Equation 2

Where C_{OUTj} = concentration leaving the junction node j (mol/m^3, or mg/L)

OUT_j = set of pipes leaving node j

IN_j = set of pipes entering node j

Q_i = volumetric flow rate entering the junction node from pipe i (m^3/s, or m^3/hr)

$C_{i,ni}$ = concentration entering junction node from pipe i (mol/m^3, or mg/L)

U_j = concentration source at junction node j (mol/s, or mg/hr)

2.2.1.3 Chlorine Decay

Chlorine residuals in water distribution systems dissipate by reacting with natural organic matter in the bulk flow, known as bulk chlorine decay, as well as by reacting with biofilms and pipe material at the pipe walls, known as wall chlorine decay (Haestad Methods et al.).

2.2.1.3.1 Bulk Chlorine Decay

Bulk chlorine decay can be modeled using Equation 3 (Haestad Methods et al., 2007).

$$\frac{dC}{dt} = -k_b C^n$$ Equation 3

Where C = chlorine concentration (mol/m^3, or mg/L)

t = time (s, or hr)

k_b = bulk chlorine decay reaction rate coefficient [$(m^3/mol)^{n-1}/s$, or $(L/mg)^{n-1}/hr$]

n = reaction rate order constant

Equation 3 shows that the reaction is modeled with respect to chlorine only. This reaction model assumes that all other constituents in the water that can react with chlorine are in excess of chlorine. Equation 3 also suggests that bulk chlorine decay can be modeled to any order. Its unit depends on the reaction rate order.

2.2.1.3.2 Wall Chlorine Decay

In general, there are many uncertainties regarding various aspects of wall chlorine decay, including but not limited to, the transport of chlorine to the pipe walls, the reactions at the pipe walls and the limiting reagents in the reactions. At this point, there is no universal model to describe wall chlorine decay and its reactions. Nevertheless, there have been attempts to model this type of decay. The most common and successful water quality models that include wall chlorine decay will be discussed in this literature review.

2.2.2 Development of Water Quality Models

2.2.2.1 Early Developments

The development of water quality models for water distribution systems dates back to the 1980s. Wood (1980) and Males et al. (1985) developed the first water quality model that accounted for the movements of constituents in water distribution systems. These early models were steady state. While a steady state model can be useful as a first step in modeling the movements of constituents in water distribution systems (Clark et al., 1988; Males et al., 1988), it does not account for any temporal variation in the system. To overcome this shortcoming, in the mid to late 1980s, Clark et al. (1986), Hart et al. (1986), Liou and Kroon

(1987), and Grayman et al. (1988) developed time varying water quality models that took into account the dynamics of water distribution systems.

A steady state water quality model requires a steady state hydraulic model as a pre-requisite, just as a time varying water quality model requires a time varying hydraulic model as a pre-requisite.

2.2.2.2 Rossman et al. (1994) Model

In 1994, Rossman, Clark and Grayman developed a mass-transfer-based water quality model that became the most widely used model. This model describes the movement of chlorine in distribution networks using the same principles of transport and mixing as those discussed earlier. It also accounts for the bulk and the wall chlorine decay reactions, as well as the mass transfer effect (that is, the physical transport of chlorine from the bulk flow to the pipe walls) in distribution networks.

The model assumes a first order overall decay process, as shown by Equation 4. Both the bulk and the wall chlorine decay are assumed to be first order in this model. The reaction rate coefficient *K* in Equation 4 is the overall decay coefficient, which is defined by Equation 5. This coefficient accounts for the bulk and the wall decay as well as the mass transfer effect. This model assumes that chlorine is the limiting reagent and that all other constituents in the bulk flow and at the pipe walls that can react with chlorine are in excess. The “±” sign in the equation indicates that the reaction can be a decay process (choose the “–” sign), or a formation process (choose the “+” sign).

$$\frac{dC}{dt} = \pm KC \qquad \text{Equation 4}$$

Where K = overall reaction rate coefficient (s^{-1}, or hr^{-1})

$$K = k_b + \frac{k_w k_f}{R_H (k_w + k_f)} \qquad \text{Equation 5}$$

Where k_b = bulk chlorine decay reaction rate coefficient (s^{-1}, or hr^{-1})

k_w = wall chlorine decay reaction rate coefficient (m/s, or m/d)

k_f = mass transfer coefficient (m/s, or m/d)

R_H = hydraulic radius of pipeline (m)

Equation 5 demonstrates that the mass transfer effect is accounted for by the mass transfer coefficient, which is the rate at which chlorine is transported from the bulk flow to the pipe walls. This parameter is calculated using Equation 6. The Rossman et al. (1994) model assumes that the rate of wall chlorine decay is the same as the rate of mass transfer of chlorine from the bulk flow to the pipe walls, that is, chlorine does not accumulate at the pipe walls.

$$k_f = \frac{S_H d}{D} \qquad \text{Equation 6}$$

Where S_H = Sherwood number

d = molecular diffusivity of chlorine in water (m^2/s, or m^2/hr)

D = pipe diameter (m)

The Sherwood number is dimensionless and its value depends on the flow regimes. It is equal to 2.0 for stagnant flow regimes where the Reynolds number is less than 1. It is calculated using Equation 7 for laminar flow regimes where the Reynolds number is between 1 and 2300, and using Equation 8 for turbulent flow regimes where the Reynolds number is greater than 2300.

$$S_H = 3.65 + \frac{0.0668(\frac{D}{L})(\mathrm{Re})(\frac{v}{d})}{1 + 0.04[(\frac{D}{L})(\mathrm{Re})(\frac{v}{d})]^{2/3}}$$ Equation 7

$$S_H = 0.023\,\mathrm{Re}^{0.83}(\frac{v}{d})^{0.333}$$ Equation 8

Where *Re* = Reynolds number

v = kinematic viscosity of bulk fluid (m^2/s, or m^2/hr)

L = pipe length (m)

2.2.2.3 Other Notable Water Quality Models

Another water quality model that is widely recognized is the model developed by Biswas, Lu and Clark in 1993. Similar to the Rossman et al. (1994) model, this model also assumes first order kinetics for both the bulk and the wall chlorine decay. The main difference is that, unlike the Rossman et al. (1994) model, the Biswas et al. (1993) model assumes that chlorine is transported from the bulk flow to the pipe walls by diffusion.

In 1998, Zierolf et al. (1998) developed an input-output model to simulate chlorine transport and decay in distribution networks. This model is different from the "conventional" models such that in this model, the predicted chlorine concentration at a particular time at a node is essentially the weighted average of the chlorine concentrations at all the nodes that are upstream of this node. Moreover, in 2002, Ozdemir and Ucak (2002) developed a computer program DYNAQ, which can be used to model chlorine in distribution networks.

2.2.2.4 Water Quality Modeling Software Packages

Water quality modeling theories and principles are implemented into user-friendly modeling software packages. These software packages are very powerful as they can be used to simulate chlorine transport and decay in large distribution networks. These software packages also contain hydraulic modeling capabilities, since hydraulic simulation is a pre-requisite for any water quality simulations. Many water/utility organizations use these software packages for both the hydraulic and the water quality modeling of their water distribution systems.

The most widely used software package is EPANET, which is essentially the water quality model developed by Rossman et al. (1994). Other notable software packages include, but are not limited to, InfoWorks, MikeNet, PipelineNet and WaterCAD (Clark, 2012). The software package used in the current study is SynerGEE Water.

2.2.3 SynerGEE Water

SynerGEE Water is a network modeling software developed by GL Industrial Services USA, Inc. This software has the capability to perform steady state and time varying hydraulic and water quality simulations. The current study involved only steady state analysis, thus only the steady state water quality modeling functions of SynerGEE Water will be discussed. The current study used version 4.5.1 of the software and the following discussion draws heavily from the user manual of this version.

2.2.3.1 Transport, Mixing and Decay

The water quality modeling module in SynerGEE Water can be used to simulate the movement of chlorine in a network system. Its principles of chlorine transport and mixing are the same as those described earlier. The bulk chlorine decay can be modeled as any order and the wall chlorine decay can be modeled as either zero or first order. Equations 9 and 10 show the decay model that is a combination of the *n*-th order bulk chlorine decay and zero or first order wall chlorine decay, respectively.

$$\frac{dC}{dt} = -k_b(C - C_{\lim})C^{n-1} - \min\left(\frac{k_{w,0}}{R_H}, \frac{k_f(C - C_{\lim})}{R_H}\right) \qquad \text{Equation 9}$$

$$\frac{dC}{dt} = -k_b(C - C_{\lim})C^{n-1} - \frac{k_{w,1}k_f}{R_H(k_{w,1} + k_f)}(C - C_{\lim}) \qquad \text{Equation 10}$$

Where C_{lim} = limiting concentration, which is the minimum concentration to which a substance can decay for decay reactions (mol/m^3, or mg/L)

$k_{w,0}$ = zero order wall decay coefficient (m/s, or m/d)

$k_{w,1}$ = first order wall decay coefficient (m/s, or m/d)

SynerGEE also accounts for the mass transfer effect of chlorine. The mass transfer coefficient, k_f, is calculated internally by SynerGEE, using results of hydraulic simulations and user-specified values for water properties. The equations used to calculate this coefficient are the same as those in the Rossman et al. (1994) model (see Equations 6 to 8 on pages 11 to 12).

2.2.3.2 Water Quality Modeling Requirements

When modeling chlorine decay using SynerGEE, the bulk and the wall decay coefficients, as well as the boundary and the initial conditions, are required as model inputs.

2.2.3.3 Bulk Decay Coefficient

In SynerGEE, the same bulk decay coefficient can be assigned globally to all pipes in the system or each pipe can be assigned a unique bulk decay coefficient. In both cases, the value of each pipe remains the same during model simulation. On the other hand, a unique coefficient can be assigned to each water source, and then the system hydraulics is used to calculate the coefficients of all pipes in the system. In this particular case, when only steady state simulation is run, the value of each pipe will remain the same during model simulation.

In reality, the bulk chlorine decay rate may vary throughout water distribution systems (Powell et al., 2000a; Courtis et al., 2009). The bulk decay coefficient at any location in the system can be determined by conducting bottle tests on water samples collected at the location (see section 2.3). Usually, the coefficients at water sources (inflows) and dead-ends in the system are determined, since comparing the values of these extremities gives more insight as to how the decay rate varies in the system. Ultimately, it is the decision of the modeler as to how this parameter should be treated in the model.

2.2.3.4 Wall Decay Coefficient

In reality, the wall decay coefficient of each pipe in the system may be different. In SynerGEE, the wall decay coefficient is considered as a property of pipes. A unique value can be assigned to each pipe or a single value can be assigned to all pipes in the system. Also, pipes with the same characteristics can be assigned the same value. The wall decay coefficients of all pipes remain the same during model simulation.

2.2.3.5 Boundary Conditions

The boundary conditions in chlorine decay models are defined by sources of chlorine in the system. In SynerGEE, nodes, reservoirs and tanks are considered chlorine sources. At a source, a single value of chlorine concentration is assigned for steady state water quality modeling.

2.2.3.6 Initial Conditions

The initial conditions in chlorine decay models are defined by the water ages and chlorine concentrations at all nodes, pipes, reservoirs and tanks in the system at time zero. In SynerGEE, each node, reservoir and tank in the system can be assigned an initial water age and chlorine concentration. The initial values for pipes are then interpolated by the model.

2.3 Methodology to Determine the Bulk Decay Coefficient

An experimental procedure known as the bottle test can be conducted and regression analysis performed on the bottle test results to determine the reaction rate order and the bulk decay coefficient (Rossman et al., 1994; Summers et al., 1996; Vasconcelos et al., 1997; Powell et al., 2000a; Powell et al., 2000b; Jaeger et al., 2003; Vieira et al., 2004).

2.3.1 Bottle Test

The bottle test is carried out in four steps, which are experiment preparation, sample collection, sample testing and data analysis (Rossman et al., 1994; Summers et al., 1996; Vasconcelos et al., 1997; Powell et al., 2000a; Powell et al., 2000b; Jaeger et al., 2003; Vieira et al., 2004).

2.3.1.1 Experiment Preparation

Prior to starting a bottle test, the length of the bottle test and the frequency of sample testing are planned. The length of the bottle test is typically set to, at a minimum, the longest water age observed in the water distribution system under study. The frequency of sample testing depends on the reactivity of the type of chlorine tested. Free chlorine is very volatile and reacts readily, thus samples may need to be tested several times a day. Chloramines are more stable, thus samples may only need to be tested one to two times a day. Generally, samples are tested at a higher frequency at the start of the bottle test and at a lower frequency afterwards.

The bottles used in a bottle test should not react with chlorine in the water sample. Summers et al. (1996) suggested that bottles be soaked in a concentrated solution of chlorine, e.g. 10 mg/L, for about twenty-four hours and then rinsed with clean water of the laboratory.

2.3.1.2 Sample Collection, Testing and Data Analysis

After the experiment is prepared, water samples are collected at selected locations in the water distribution system. The samples are tested according to the pre-determined testing frequency. All samples are stored at a constant temperature as well as in total darkness during the entire bottle test period, as ambient light can potentially affect the bulk decay reaction. After the experiment is completed, regression analysis is performed to determine the order of the bulk decay reaction and the bulk decay coefficient.

2.3.2 First Order Bulk Chlorine Decay

The first order decay model, which is the same as exponential decay, is most commonly used to describe bulk chlorine decay (Rossman et al., 1994; Chambers et al., 1995; Vasconcelos et al., 1997; Kastl et al., 1999; Powell et al., 2000b). Equation 11 shows the integrated form of the first order decay model (Vieira et al., 2004). The differential form of the model is shown as Equation 3 on page 8.

$$C = C_o e^{-k_b t} \qquad \text{Equation 11}$$

Where C_o = initial chlorine concentration (mol/m^3, or mg/L)

2.4 Methodologies to Determine the Wall Decay Coefficient

Literature suggests that there are three methods to determine the wall decay coefficient. The methods are extracted from the reviews of case studies in the next section (section 2.5) and listed in the following.

2.4.1 Field-based Methods

2.4.1.1 Method 1

The methodology used to determine the wall decay coefficient of a water distribution system proves to be the most challenging. As a first step, water quality data of the system in operation are required. Intensive water quality surveys are typically conducted to gather such information. These surveys are labor and resource intensive. Clark and Grayman (1998) devised a detailed methodology on how to plan and conduct these surveys.

A modeling software package is used to perform the hydraulic and the water quality simulations of the system. After the surveys are completed, the chlorine concentrations obtained from the surveys are compared to the values predicted by the water quality model, and the wall decay coefficient is adjusted during calibration to minimize the discrepancy between the simulated data and field survey data. The value that provides the best fit between the model and the field data is the resulting wall decay coefficient.

Both the hydraulic and the water quality model calibration are iterative processes. Traditionally, models are calibrated manually, by adjusting model parameters using the trial-and-error method to minimize the discrepancy between model and field data. Manual calibration is difficult and labor-intensive. In recent years, automated calibrations are becoming more popular. Algorithms for calibration processes are derived and built into modeling software packages (Haestad Methods et al., 2007). These algorithms can identify the optimized solution to calibration problems (Haestad Methods et al., 2007).

2.4.1.2 Method 2

Another way to determine the wall decay coefficient is to find a very long homogeneous pipe in the water distribution system, collect water quality data at various points on the pipe, and then calculate the wall decay coefficient using equations of developed water quality models. This method is field-based but requires much less labor and resources than Method 1. The major difficulties of this method are that the selected pipe has to be very long, i.e., at least a few hundred meters, in order to yield a measurable amount of chlorine decay, and that it has to be uniform in its properties, e.g., diameter, material, etc. Given the ways by which most water distribution systems are built, it is usually very difficult to find such pipes.

2.4.2 Lab-based Methods

2.4.2.1 Method 3

The wall decay coefficient can be determined by constructing a pipe section reactor (PSR), a pipe loop, or a pilot water distribution system in the laboratory.

Each of the structures is made with pipe materials of interest. All conditions are controlled, including flow rates and water temperatures. Typically, the chlorine concentrations are measured, along with other water quality parameters such as pH and disinfection by-product concentrations. The wall decay coefficient is calculated using the chlorine data and the equations of developed water quality models.

Of the three structures, the PSR is the easiest to build and operate. The pipe loop is larger in scale than the PSR and thus, it requires more labor and resources to build and operate than the PSR. However, it provides a closer representation of an actual water distribution system than the PSR. A pilot water distribution system requires the most labor and resources to build and operate, but it is the closest representation of an actual water distribution system that can be achieved in the laboratory.

2.5 Case Studies of the Determination of the Wall Decay Coefficient

This section presents case studies in which the wall decay coefficient was determined for either chloramine or free chlorine. Each study falls into one of the three methods described in the previous section. Note that in all of these studies, the bulk decay coefficient was determined as part of the process in determining the wall decay coefficient, using the methodology and the kinetics discussed earlier.

2.5.1 Chloramine Studies

2.5.1.1 Maier et al. (2000)

Maier et al. (2000) studied chloramine decay in a 1.3 km long pipe which was constructed as a test water distribution system. The pipe was made of predominantly medium density polyethylene (MDPE) and was buried underground. Free and total chlorine measurements were obtained by collecting grab samples from the pipe and testing the samples using amperometric titration, as well as by installing chlorine transducers on the pipes.

Bottle tests were conducted on grab samples collected from the pipes to determine the bulk decay coefficients. The data was plotted versus elapsed time after sample collection and the first order model was used to fit the data using regression analysis. The bulk decay coefficient was found to be 0.125 hr^{-1} for free chlorine and 0.0236 hr^{-1} for chloramine.

The authors used the Rossman et al. (1994) model to determine the chlorine decay parameters. The overall chlorine decay was assumed to be first order, as expressed by Equation 12. This model is first order with respect to chloramine, and the overall decay coefficient, K, was assumed to be constant. The authors determined K for chloramine by setting up the model as a nonlinear optimization problem in which its minimum was K. The K values calculated ranged from 0.0173 to 0.0972 hr^{-1}.

Equation 13 is the expression for the overall decay coefficient, K, in the Rossman et al. (1994) model (it is the same as Equation 5, page 11). The authors determined the entire second term in Equation 13, by subtracting the bulk decay coefficient from the overall decay coefficient (i.e., $K - k_b$). Three values of the second term were found for chloramine, which were 1.95×10^{-7}, 4.11×10^{-8} and 3.90×10^{-7} hr^{-1}. No separate values were determined for the wall decay coefficient k_w for chloramine.

$$C = C_o e^{-Kt} \qquad \text{Equation 12}$$

$$K = k_b + \frac{k_f k_w}{R_H (k_f + k_w)} \qquad \text{Equation 13}$$

2.5.1.2 Mutoti et al. (2007)

Mutoti et al. (2007) studied chloramine decay by constructing four pilot distribution systems. Each system was made of one of PVC, lined cast iron, unlined cast iron or galvanized iron pipes. The pipes were about forty years old and were extracted from an existing water distribution system.

All pilot systems were fed a water source that was a blend of groundwater, treated surface water, or reverse-osmosis-treated water. The bulk decay coefficients of these types of water were determined in the laboratory using bottle tests. Samples were stored at 21°C and 31°C and tested periodically for total chlorine concentration using a spectrophotometer for over 14 days. A first order model was used to fit the data and nonlinear regression was used to determine the bulk decay coefficients. The value for the blend water at 20°C was 0.083 d^{-1}.

The authors used the Rossman et al. (1994) model to determine the chlorine decay parameters. An important finding of this study was that for galvanized and unlined cast iron pipes, chloramine decay occurred predominantly at the pipe walls, whereas for PVC and lined cast iron pipes, chloramine dissipated predominantly in the bulk flow. As a result, wall chlorine decay in PVC and lined cast iron pipes was assumed negligible and wall decay coefficients were not calculated for these two pipe materials. The wall decay coefficient at 20°C was calculated to be 0.103 m/d for galvanized iron pipe and 0.015 m/d for unlined cast iron pipe.

2.5.1.3 Westbrook and Digiano (2009)

Westbrook and Digiano (2009) studied the wall decay of chloramine using a pipe section reactor (PSR). The PSR were constructed of an old unlined tuberculated cast iron pipe and a new cement-lined ductile iron pipe. The PSR was supplied with water treated with chloramine, and free chlorine was assumed negligible. Total chlorine was measured using the DPD colorimetric method.

The water used in the PSR was from Raleigh's E.M. Johnson Water Treatment Plant (EMJWTP). Bottle tests were conducted using grab samples collected at several locations in the Raleigh water distribution system to determine the bulk decay coefficients. The water samples were collected in chlorine-demand free glass bottles, stored in the dark at 12.0, 22.5 and 30.0°C, and tested for total chlorine periodically over 3,500 hours.

The first and the second order model were linearized and linear regression analysis was used to fit both models to the bulk chlorine decay data. It was found that the first order model fitted the data well, and that the second order model did not fit the data. The first order model also fitted the total chlorine data in the ductile iron PSR. The bulk decay coefficients at 22.5°C are summarized in Table 1. This table shows that the bulk decay coefficient varied between locations in the water distribution system. Only first order coefficients were used further in their study.

Equations from the Rossman et al. (1994) model were used to calculate the wall decay coefficients. For test conditions of varying velocities but with a constant pH of 8 and temperature of 23.5°C, the average wall decay coefficient was found to be 0.67 m/d for the cast iron PSR and 0.026 m/d for the ductile iron PSR.

Table 1 The bulk decay coefficients of Raleigh's water distribution system at 22.5°C (Westbrook and Digiano, 2009).

Sampling Location*	First Order k_b (hr^{-1})	Second Order k_b ($(mg*hr/L)^{-1}$)
EMJWTP	1.7E-04	2.7
FS17	2.8E-04	7.8
FS1	2.8E-04	10.0
FS2	3.0E-04	9.2
FS20	2.7E-04	7.4

*FS - Fire Station

2.5.2 Free Chlorine Studies

2.5.2.1 Vasconcelos et al. (1997)

The AWWA Research Foundation (AWWARF) and the EPA collaborated to study the kinetics of free chlorine decay in five water distribution systems in the U.S. in 1997. Field sampling, laboratory and modeling studies were carried out for all five systems.

There were a total of eleven water sources for the five systems. Bottle tests were conducted to determine the bulk decay coefficients of all eleven water sources. Water samples were collected using chlorine-demand free glass bottles. The first order model was used to fit the bulk chlorine decay data and nonlinear least squares regression analysis was performed to determine the bulk decay coefficients. The coefficients varied among the eleven water sources, ranging from 0.082 d^{-1} to 17.7 d^{-1}.

For each system, the part in the system that was easily isolated in terms of hydraulics or a long pipeline was selected as the sampling area. These sampling areas were set to be as small as possible so that less data and effort were required in the field sampling. The sampling areas consisted of one or more of the following types of pipe: unlined cast iron, asbestos cement, unlined galvanized iron, cement-lined ductile iron. The pipes were more than thirty or forty years old.

A detailed sampling plan was devised for each sampling area. In four of the five systems, hydraulic data were collected by using tracers. Each system had a hydraulic model prior to this study. The hydraulic data collected were used for hydraulic model calibration. For water quality data, grab samples were collected in all five systems and tested for free chlorine concentrations using the DPD colorimetric method. The number of sampling locations selected for all systems ranged from eight to thirty-one. In particular, field sampling was conducted at one of the systems from July 8 to 9, 1993 for a period of twenty-four hours and in another system from October 11 to 13, 1993 every hour for a period of thirty-five hours.

The EPANET model software package was used to model the chlorine decay kinetics and to calibrate the wall decay coefficients of all systems. The chlorine decay kinetics were set to either first order bulk decay and first order mass transfer-limited wall decay, or first order bulk decay and zero order mass transfer-limited wall decay.

The first order bulk decay coefficients found using the bottle tests were used in modeling. For systems with multiple water sources, the bulk decay coefficient for each water source was used.

The wall decay coefficient was adjusted when calibrating the water quality model to minimize the discrepancy between the field and model data. The wall decay coefficient was assigned to pipes in three ways. The first way was that all pipes in a system were assigned the same coefficient. The second way was that all pipes in specifically divided zones were assigned the same coefficient. The third way was that the wall decay coefficient of each pipe was assumed to be inversely proportional to its Hazen-Williams roughness coefficient, as expressed by Equation 14, in which the fitting coefficient was adjusted during calibration.

$$k_w = \frac{\alpha}{c} \qquad \text{Equation 14}$$

Where k_w = wall decay coefficient

α = fitting coefficient

c = Hazen-Williams C-factor

The hydraulic and water quality models used in this study were all time varying models. First order wall decay coefficients ranged from 0.03 m/d to 1.52 m/d and zero order values ranged from 53.8 mg/m^2/d to 215 mg/m^2/d. It was observed in this study that both the first and the zero order wall decay kinetics could model the wall chlorine decay in the systems and that both models provided similar fits to the field data.

2.5.2.2 Jaeger et al. (2003)

Jaeger et al. (2003) conducted a study to investigate the mixing of two water sources in the water distribution system of the City of Caen in Normandy, France. The study involved modeling, laboratory testing and field sampling work. The authors used the SynerGEE Water software for both hydraulic and water quality modeling.

The City of Caen was supplied by a surface water and a groundwater source and it used free chlorine as a disinfectant to maintain the water quality in its water distribution system. Its water distribution system was divided into six pressure zones and one of the zones was chosen for the study. Eighty-five percent of the pipes in this zone were unlined cast iron pipes installed in the 1950s and the remaining pipes were cement-lined ductile iron pipes that were installed after the

1970s. The study was conducted for three mixing ratios of the two water sources, which were 50%-50%, 80%-20% and 100%-0% of surface water and groundwater, respectively.

Field sampling was conducted in the summer season from August to October 2001 as well as in the winter season from January to March 2002. During field sampling, hydraulic data including flow, pressure and tank level were collected using telemetry systems and ground hydraulic devices, and water quality data were collected using online chlorine analyzers. Hydraulic and water quality data were collected for five consecutive days at a time, and data were collected several times during each season. The frequency of hydraulic data collection was set to five minutes and that of water quality data collection was set to ten minutes. Locations in the system that were feasible to install the meters and that were representative of the hydraulic and the water quality conditions in the system were selected as field sampling locations.

The study area already had an existing hydraulic model that was constructed in 1999. This model was modified using SynerGEE Water. In addition, this hydraulic model was calibrated and validated using the field hydraulic data. The hydraulic model was calibrated to the extent such that the average discrepancy between the field and the model data was less than 5%.

The bulk decay coefficients of the two water sources were determined by conducting bottle tests in the laboratory. Samples of the two water sources were collected in glass bottles, stored at system water temperatures and tested periodically for over ninety-six hours. Only first order model was used to fit the bulk chlorine decay data. Nonlinear least square regression analysis was performed to determine the bulk decay coefficient, assuming a 95% confidence interval. Their results are shown in Table 2 and Table 3.

Table 2 The bulk decay coefficients determined for the summer season (Jaeger et al., 2003).

Water Source	Parameters	100% Surface Water	80% Surface Water - 20% Groundwater	50% Surface Water - 50% Groundwater
		August 2001	September 2001	October 2001
Surface Water	k_b (hr^{-1})	0.03 ± 0.03	0.03 ± 0.02	0.03 ± 0.03
	Temperature (°C)	22	19	16
Groundwater	k_b (hr^{-1})	n/a	0.005 ± 0.006	0.004 ± 0.01
	Temperature (°C)	n/a	22	14

Table 3 The bulk decay coefficients determined for the winter season (Jaeger et al., 2003).

Water Source	Parameters	100% Surface Water	80% Surface Water - 20% Groundwater	50% Surface Water - 50% Groundwater
		January 2002	February 2002	March 2002
Surface Water	k_b (hr^{-1})	0.04 ± 0.02	0.04 ± 0.02	0.04 ± 0.02
	Temperature (°C)	8	9	7
Groundwater	k_b (hr^{-1})	n/a	0.003 ± 0.005	0.003 ± 0.005
	Temperature (°C)	n/a	11	10

After calibrating/validating the hydraulic model and determining the bulk decay coefficients, the wall decay coefficients were calibrated using the water quality model. During calibration, one wall decay coefficient was assumed for all pipes in the study area and this value was adjusted until there was a reasonable discrepancy between the model and field water quality data. Only first order wall decay kinetics was considered. The wall decay coefficient was determined to be 0.2 m/d for the summer field season and 0.5 m/d for the winter field season. The hydraulic and the water quality models considered in this study were all time varying models.

2.5.2.3 Digiano and Zhang (2005)

Digiano and Zhang (2005) studied the wall decay of free chlorine using a pipe section reactor (PSR). The PSR was constructed of a 6” diameter old unlined cast iron pipe and a 6” new cement-lined ductile iron pipe. Grab samples were collected from the PSR. The water samples were tested for free chlorine using the DPD colorimetric procedure, which included a spectrophotometer and chemical pillows.

A series of bottle tests were conducted to determine the bulk decay coefficient of the water that was used in the PSR. Two liter glass bottles were used and all water samples were stored in the dark at 21°C. The samples were tested periodically over either sixteen or seventy-two hours. The first order model was found to fit the data well. The average bulk decay coefficient was found to be 0.033 hr^{-1}.

In the cast iron PSR, the overall chlorine decay rate was found to be zero order. The overall decay coefficient was assumed to be a combination of the bulk and the wall decay coefficients. However, no wall decay coefficients were determined.

In the ductile iron PSR, the overall chlorine decay rate was found to be first order. The Rossman et al. (1994) model was used to determine the chlorine decay parameters. The overall decay coefficient, K, was determined by fitting the model to the chlorine data. The entire second term of Equation 5 on Page 11 and Equation 13 on Page 21 was obtained by subtracting the overall decay coefficient by the average bulk decay coefficient (i.e., K - k_b). The values were found to range from 0.07 to 0.26 hr^{-1}.

2.5.2.4 Clark and Haught (2005)

Clark and Haught (2005) conducted an experiment program to study the wall decay of free chlorine in unlined ductile iron pipes. Pipe loops constructed of this pipe material were set up at EPA's Test and Evaluation Facility in Cincinnati, Ohio. Several tanks were connected to the pipe loops, which acted as the water source. This experimental set up was similar to that of a typical water distribution system and all conditions were controlled.

Water was circulated in the pipe loops at a constant flow rate. Overall, the experiment was conducted for seven flow rates, which are shown in Table 4. For each flow rate, grab samples were collected from the tank and the pipe loops and tested for chlorine concentration and other parameters. First order bulk decay coefficients were determined by applying regression analysis to the chlorine data of the tank and the times of decay, and the values for all flow rates are shown in Table 4.

The authors used equations of both Rossman et al. (1994) and Biswas et al. (1993) models to simulate chlorine transport and decay using the data from this experiment. The wall decay coefficient was assumed to be a property of pipes and had a fixed value, and it was calculated using the data for the flow velocity of 2.08 cm/s. The value was 0.118 m/d using the Rossman et al. (1994) model and 0.55 m/d using the Biswas et al. (1993) model. In addition, the authors came to the conclusions that the Rossman et al (1994) model was more widely used than the Biswas et al. (1993) model because it was simpler, but the latter had fewer limitations in modeling chlorine transport and decay.

Table 4 Model parameters estimated by Clark and Haught (2005).

Flow Velocity (cm/s)	k_b (hr^{-1})	k_w (m/d)	
		Rossman et al. (1994) Model	Biswas et al. (1993) Model
0.69	0.00445	0.118	0.55
2.08	0.0018		
5.20	0.0026		
10.40	0.00296		
20.80	0.0049		
31.20	0.00296		
41.60	0.00345		

2.5.2.5 Clark et al. (2010)

Clark et al. (2010) conducted an experiment program to study the wall decay of free chlorine in unlined ductile iron and PVC pipes, using pipe loops constructed of these two pipe materials at EPA's Test and Evaluation Facility in Cincinnati, Ohio. A stainless steel mixing tank was connected to the pipe loops and acted as the water source. This experimental set up was similar to that of a typical water distribution system and all conditions were controlled.

Water was circulated in the pipe loops at a constant flow rate. Overall, the experiment was conducted for five flow rates, which are shown in Table 5. For each flow rate, grab samples were collected from the tank and the pipe loops and tested for chlorine concentration and other parameters. A first order bulk decay coefficient was determined by applying regression analysis to the chlorine data of the tank and the times of decay, and its value was 0.042 hr^{-1} for all flow rates, as shown in Table 5.

It was observed from the experiment that the wall decay of chlorine was negligible in PVC pipes and thus, the decay coefficient was assumed to be zero. The authors used the equations of the Rossman et al. (1994) model to calculate the wall decay coefficients of the ductile iron pipe loops. The wall decay coefficients were calculated based on the assumption that the rate of the chlorine wall decay was limited by the reaction rate of chlorine with the pipe walls, and not by the mass transfer rate of chlorine from the bulk flow to the pipe walls, which was assumed in the Rossman et al. (1994) model. Thus, the authors modified the model according to the new assumption in this study. The wall decay coefficients calculated for all five flow rates are tabulated in Table 5. All values were obtained from the first order model.

It can be seen that the wall decay coefficients are negative at low flow rates. The negative values have no physical meaning, which suggest that there are limitations in modeling chlorine decay at low flow rates when the rate of the chlorine wall decay is assumed to be limited by wall reaction.

Table 5 Model parameters estimated by Clark et al. (2010).

Flow Rate (m^3/s)	k_b (hr^{-1})	k_w (m/d)
0.0	0.042	-2.5861E-03
189.3	0.042	-9.7425E-03
378.5	0.042	-2.3847E-01
630.9	0.042	-3.6219E-01
6309.0	0.042	5.9495E-01

An important finding of the study by Clark et al. (2010) is that free chlorine reacts very quickly in unlined ductile iron pipes while it is very stable in PVC pipes (this was similar to an earlier study by Mutoti et al. (2007) who observed that the wall decay of chloramine was negligible in lined cast iron pipes and PVC pipes). Therefore, pipe wall demand for chlorine can be significantly different between pipe materials, and that this is an important factor to consider in the design and operation of water distribution systems.

2.6 Considerations from the Literature Review

There are not many studies that have been carried out using the field-based methods to determine the wall chlorine decay coefficient, and there are even less studies for chloramine in general. These may be because field-based methods require intensive field sampling, a lot of planning, labor and resources, and the conditions in the water distribution systems cannot be controlled easily, if at all. There are more studies that were done using the lab-based method. The latter is much easier to carry out than the field-based methods, as it requires less work and allows the control of all conditions in the system. However, the relevance of the laboratory test is limited as it is often far removed from the actual water distribution system.

The most important conclusion that can be drawn from this literature review is that the bulk and the wall chlorine decay coefficients are very site-specific as their values are a result of the combination of many conditions in the water distribution system in which they are determined. These conditions include, but are not limited to, water source, water temperature, pipe material, age, diameter, and flow rate, etc. The effects of many of these conditions have been studied, mostly separately, but not fully understood as to what their actual and quantitative effects are on the bulk and the wall chlorine decay coefficients in the water distribution system. As a result, the coefficients determined in each study should not be applied directly to other systems. Therefore, if a utility company wants to know the bulk and the wall decay coefficients for its water distribution system, field-based methods, particularly Method 1 (page 18), must be carried out under the operating conditions of the water distribution system.

3 METHODOLOGIES

As outlined in Chapter 1, the objective of this research was to develop the water quality model in SynerGEE Water into a working model so that it could be used as a working model to predict the chloramine decay in the Study Area.

Based on a comprehensive literature review and taking into consideration of available resources, the general methodology adopted to achieve the research objective was as follows: SynerGEE Water hydraulic model was set up to calculate the chloramine concentrations at all nodes and pipes in the Study Area. This required the input of relevant model parameters as well as the chloramine bulk and wall decay coefficients. The bulk decay coefficients were determined by carrying out standard bottle tests on water samples taken from selected sites of the Study Area, while the wall decay coefficients were determined by parametric fitting using the least squares method.

The parametric fitting and least squares analysis were performed as follows: field sampling programs were conducted to collect water samples from the Study Area. Chloramine concentrations in the collected water samples were determined by laboratory measurements. A wall decay coefficient was assumed so that the SynerGEE Water hydraulic model could calculate chloramine concentrations in all nodes and pipes in the Study Area. The calculated concentrations were compared with measured concentrations. The difference was taken as a residual. Through least squares analysis, a unique chloramine wall decay coefficient for the Study Area was determined which led to the least sum of squared residuals.

Therefore, in the following, the description will be focused mainly on the SynerGEE Water hydraulic model, the field sampling programs, and the methods used to determine the chloramine concentration as well as the bulk and the wall decay coefficients.

3.1 SynerGEE Water Hydraulic Model

In this study, the average day demand (ADD) SynerGEE Water hydraulic model that was built and calibrated by EPCOR Water Services Inc. (EWSI) in 2002 was used[*] (Appendix A describes the status of EWSI's hydraulic models). The portion of the Study Area in the ADD hydraulic model was extracted as an independent hydraulic model. The extracted model was then updated with respect to pipe materials and water demands.

3.1.1 Extraction of the Hydraulic Model for the Study Area

SynerGEE Water has a module, named the Subsystem Management Module (SMM), which is used to extract pieces of hydraulic models from an overall hydraulic model (GL Industrial Services USA, Inc., 2010). An area that has its piece of hydraulic model extracted from the overall hydraulic model is referred to as a subsystem. The extracted hydraulic model for a subsystem is saved in a separate SynerGEE Water model file. It is also hydraulically independent from the overall hydraulic model and thus, it could be worked on independently. The extracted hydraulic model could also be merged back into the overall hydraulic model that it is extracted from (GL Industrial Services USA, Inc., 2010).

For this study, the hydraulic model for the Study Area was extracted from the ADD hydraulic model using the SMM in SynerGEE Water. Figure 2 illustrates this extracted model. In this figure, the circles represent nodes and the lines represent pipes. As EWSI did not import all infrastructures in the water distribution system of the City into its hydraulic models, valves and hydrants and their associated components were missing in the extracted hydraulic model for the Study Area (this was dealt with later, see section 4.3). Essentially, the model representation of this area consisted of solely nodes and pipes. There are no tanks

[*] This was the latest version of the hydraulic model in EWSI for the water distribution system in the City of Edmonton.

or reservoirs in this area. The water distribution system of the Study Area is connected to the rest of the water distribution system of the City of Edmonton by the three red-colored nodes, as shown in Figure 2. When the hydraulic model for the Study Area was extracted, these three nodes were the breaking points from the ADD hydraulic model. They were therefore the boundaries of the hydraulic model for the Study Area.

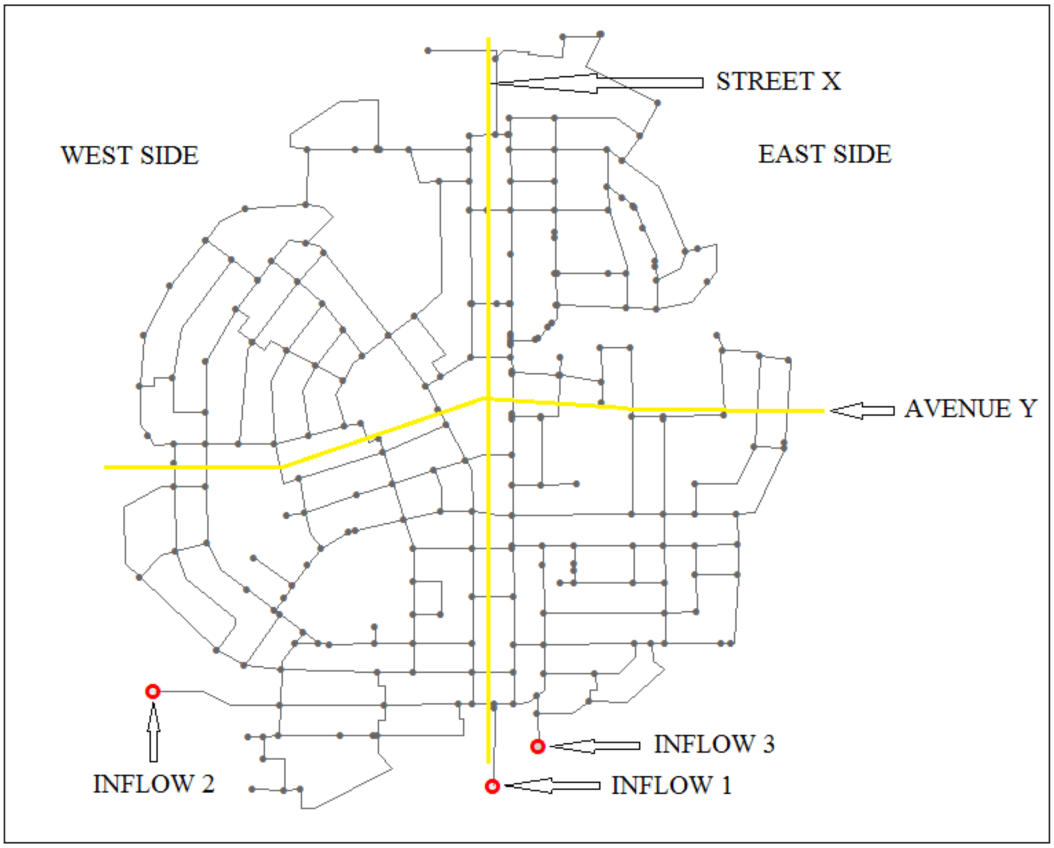

Figure 2 Hydraulic model for the Study Area. The hydraulic model was extracted using the Subsystem Management Module in SynerGEE Water.

The node labeled "inflow 3" in Figure 2 was not a boundary in the original SynerGEE Water hydraulic model in 2002. However, in 2008, a 46.61 m long PVC pipe with a diameter of 200 mm was added to connect this node to the pipe located to its south (EWSI, 2013), as shown in Figure 3. This change turned this node into a boundary of the Study Area. It was manually made as a boundary in the extracted hydraulic model for the Study Area.

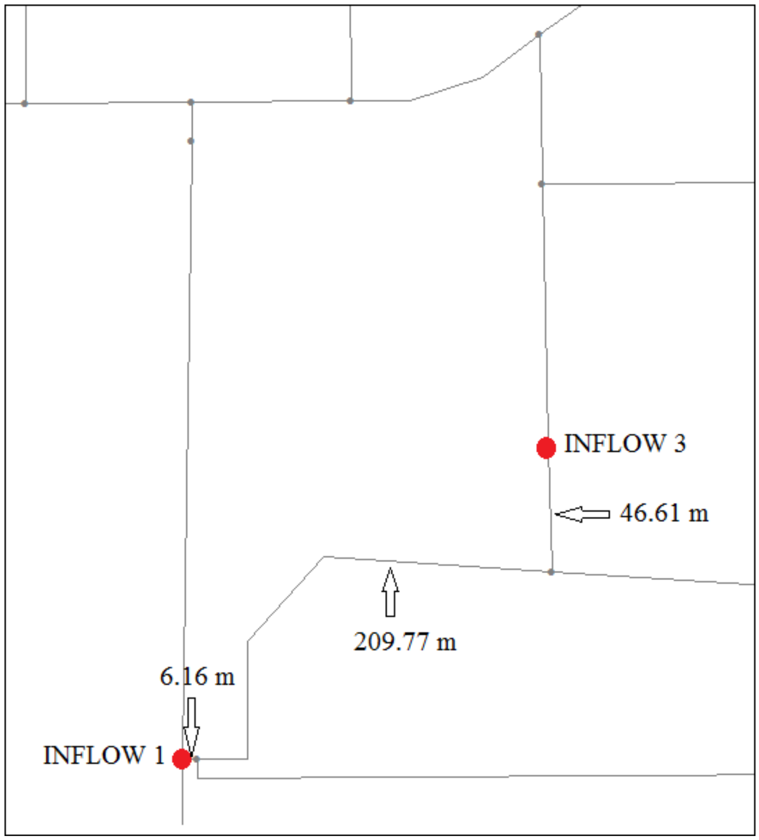

Figure 3 Map of the two boundaries of the Study Area as of 2008.

There are three minimum requirements in SynerGEE Water hydraulic model regarding the number of unknown and known parameters for the model to work properly (that is, to yield a unique solution). The first is that pressure must be unknown in at least one node. The second is that demand must be unknown in at least one node. The third is that the number of nodes at which demands are unknown must equal to the number of nodes at which pressures are known (GL Industrial Services USA, Inc., 2010).

When the hydraulic model for the Study Area was extracted, the three requirements were satisfied by eliminating the demands at the three boundary nodes (that is, the demands at the three boundaries were unknown). The pressures at the three boundary nodes were known as they were calculated by the SynerGEE Water hydraulic model before the extraction. The values are shown in Table 6. The rest of the nodes in the Study Area had known demands and unknown pressures. The demands at these nodes were obtained from the 2001 customer billing information from the Geographic Information System (GIS) at EWSI.

Table 6 Pressures at the three boundaries.

Boundary Number	Node Pressure (kPa)
1	410.39
2	475.65
3	411.82

Since the ADD hydraulic model is steady state, the extracted hydraulic model for the Study Area is also steady state. This extracted piece of model was used for all subsequent work involving hydraulic as well as water quality modeling for the Study Area.

3.1.2 Updating Pipe Materials in the Extracted Hydraulic Model

The Study Area consists of predominantly cast iron pipes that were built around the 1950s. Cast iron pipes are particularly susceptible to the accumulation of residues and biofilms which can lead to blockage of the pipes, and old pipes are also more susceptible to breakage. Consequently, the pipes in the water distribution systems, especially cast iron pipes, need to be lined with epoxy resin or replaced with PVC pipes. According to the GIS at EWSI, many cast iron pipes in the Study Area have gone through such renewals in the last decade. However, they have not been updated in the SynerGEE Water hydraulic model which was last calibrated in 2002.

Therefore, the pipe materials in the extracted hydraulic model for the Study Area were updated manually in this research on a case-by-case basis using information from the GIS at EWSI. The updating covered all pipe renewal projects in the Study Area up to July 20, 2011, which was the only pipe renewal project in the Study Area in 2011.

The SynerGEE Water ADD hydraulic model does not take pipe material as an input parameter. Instead, all pipes were assigned as Darcy-Weisbach pipes, and roughness factor was a required model input parameter for all pipes. Therefore, roughness factors were used as a distinguishing parameter representing pipe materials. It was noted in the extracted model that all the cast iron pipes were assigned the same roughness factor of the order of 0.01 m. To update, for cast iron pipes that were lined with epoxy, only their roughness factors had to be changed in the hydraulic model. For cast iron pipes that were replaced with PVC pipes, in addition to changing their roughness factors, their diameters were also changed to those of the PVC pipes. At EWSI, pipes that have been renewed are assigned a roughness factor of 0.0001 m in the hydraulic models (EWSI, 2011).

Also, pipes in the hydraulic model could be longer than those in the actual water distribution system, since one pipe shown in the model could consist of several pipes with the same attributes. This posed a challenge in updating the pipe renewals. A number of cases were encountered in which only a section of but not the entire pipe in the model had been renewed. To resolve this issue, nodes were inserted on such a pipe to indicate the start and the end points of the renewed section on the pipe. The length of the renewed section was obtained from the GIS. Essentially, such a pipe in the hydraulic model was broken into shorter pipes by the nodes that were inserted. Pipe length was then updated for each shortened pipe. In addition, roughness factor and diameter were also updated for the shortened pipe.

Figure 4 shows the hydraulic model of the Study Area after all the pipe renewals were updated. The green lines represent cast iron pipes and the purple lines represent epoxy-lined cast iron and PVC pipes. As can be seen, renewals were mainly done for pipes on the east side of the area. Cast iron pipes remain the predominant type of pipe on the west side of the area.

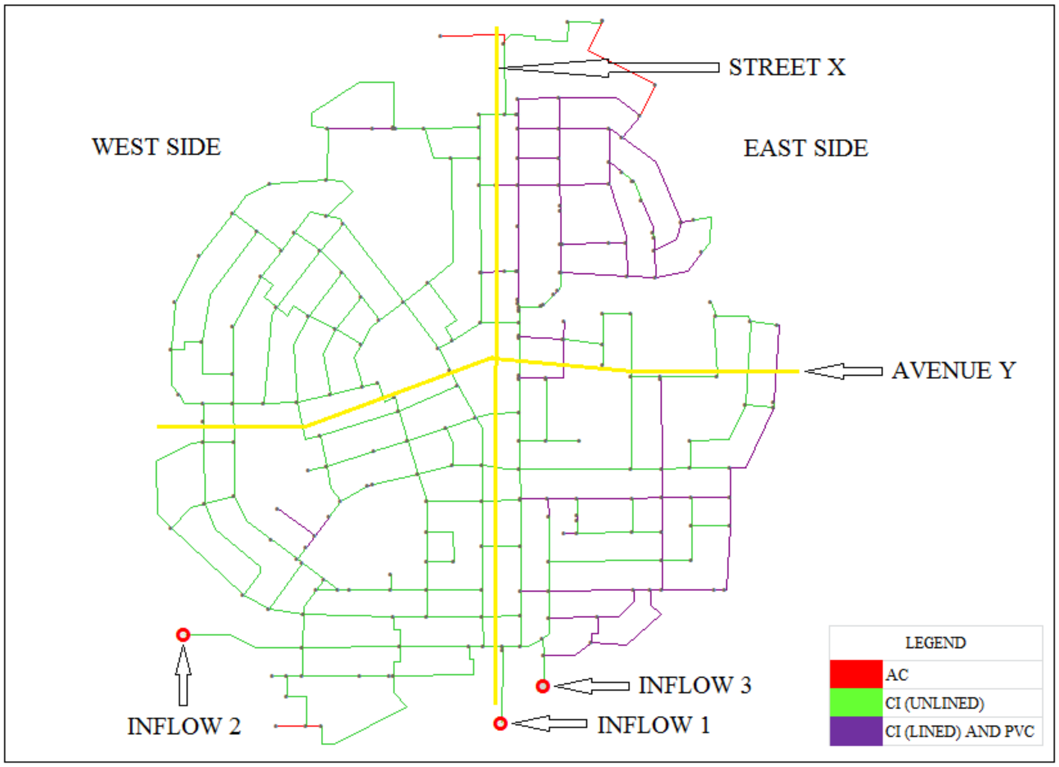

Figure 4 Hydraulic model for the Study Area with updated pipe materials.

3.1.3 Updating Demands in the Extracted Hydraulic Model

The node demands in the extracted hydraulic model were calculated using the customer billing statements in 2001 when the SynerGEE Water model was last calibrated by EWSI in 2002. Therefore, demands at nodes were updated.

EWSI classifies water usages of its customers into usage categories, which include residential (single-family dwellings), multi-residential (apartment or condominium complexes), and commercial (businesses, schools, churches, etc.). An address in the City can have one or more water usage categories. A customer monthly billing statement shows the monthly water usage at an address. This is stored in the GIS at EWSI together with water usage categories.

In the average day demand (ADD) hydraulic model, the average day demand at each node was calculated by extracting the yearly water consumption of the node under each water usage category from GIS and dividing by 365 days. However, to be more accurate, in this research, the monthly water consumption information was extracted from GIS and divided by 31 days, for both July and October 2011, when the field sampling programs were performed.

Depending on the water usage category, the method of assigning water demands to the nodes are different. Residential water usages are often very small in magnitude and they tend to be fairly steady. It is very unlikely that one single-family dwelling would use much more water than the other. Also, residential water usage is the most common category of water usage in the City, especially in the Study Area. Therefore, the residential water demand in the model can be updated for a group of nodes at a time. On the other hand, the multi-residential and commercial water usages can be small or large in magnitude depending on the customer. Also, the multi-residential and commercial water usages are scattered in the Study Area, so they only affect the water usages (demands) at their locations. Therefore, the multi-residential and commercial demand categories in the model were updated on a case-by-case basis.

3.1.3.1 Updating Demands for Residential Usages in the Study Area

As indicated previously, the extracted hydraulic model already had demands associated with each node, although those were based on 2001 data. Therefore, to update the demands, the water usages for either July 2011 or October 2011 were extracted from the GIS at EWSI. These were then compared with the existing

2001 demands data in the hydraulic model by noting a percent difference. The percent difference was then used to adjust the existing 2001 demands to update them to the July 2011 or October 2011 demands.

The assignment of residential usage demands to the nodes in the hydraulic model of the Study Area was performed as follows. First, the nodes were divided into groups[*]. As can be seen from Figure 5, the nodes were divided unevenly into seven groups. The groups were numbered, and the number inside the brackets in each group indicates the number of nodes in the group. The boundaries of each group enclosed the "zones of influence" of all the nodes within it. Next, for each group, the residential water usages for the month of July 2011 or October 2011 of all the addresses within the group were extracted all at once from the GIS at EWSI, and divided by 31 days to obtain the average day demand for the group (the monthly average for July 2011 or October 2011). In the meantime, the average day demands of residential usages for all nodes within the group based on the 2001 annual water consumption data were summed to obtain the average day demand for the entire group (the yearly average for 2001). These two average daily demands for the group were compared, and a percent difference was calculated using the average day demand in 2001 as the base. Finally, the average day demand of the residential usage for each node in the group was adjusted by the percent difference. Table 7 shows the average day demands, in cubic meters (m^3), for residential water usages in 2001, July and October 2011 for all groups, as well as the percent differences calculated. Note that Group 7 did not have any residential water usage, since this group only included a park and a wastewater treatment plant.

[*] As there are more than 200 nodes in the extracted hydraulic model for the Study Area, manually assigning demands to each node from water consumption data extracted from GIS would be impossible.

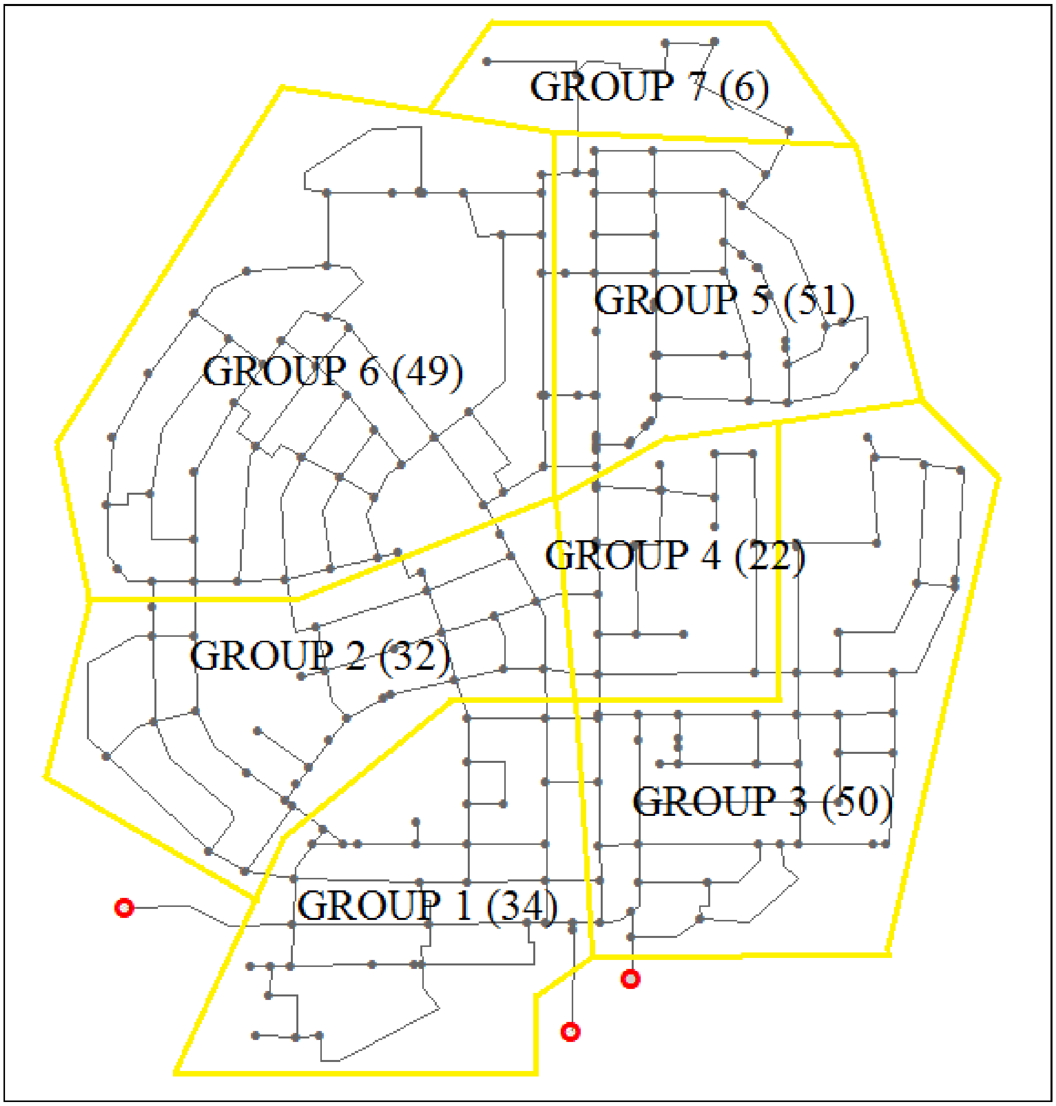

Figure 5 Division of the extracted hydraulic model for the Study Area for water demand assignment.

Table 7 Average day demands of residential water usages for 2001, July 2011 and October 2011.

Group Number	2001 (m^3)		2011 (m^3)		Percent Difference (%)
1	Year	253.4	July	181.5	28.4
			October	189.1	25.4
2	Year	288.1	July	208.8	27.5
			October	216.8	24.8
3	Year	526.6	July	387.9	26.3
			October	387.0	26.5
4	Year	160.8	July	108.1	32.8
			October	109.8	31.7
5	Year	260.8	July	169.5	35.0
			October	184.2	29.4
6	Year	582.4	July	402.2	30.9
			October	416.4	28.5

3.1.3.2 Updating Demands for Multi-Residential and Commercial Usages

For each of the multi-residential and/or commercial water usages at an address in the Study Area, its value for the month of July 2011 or October 2011 was divided by 31 days to yield the average day demand in July 2011 or October 2011. The calculated average day demands were assigned to the corresponding multi-residential and/or commercial demand categories of the node closest to the address.

3.1.3.3 Results of the Demands Update

Once the demands were updated, the hydraulic model of the Study Area was run for both the July and the October 2011 demand scenarios. From the hydraulic model simulations, it was found that all three boundaries were inflows or water sources for the Study Area. Table 8 shows the inflow volumetric flow rate at the three boundaries for both demand scenarios.

Table 8 Inflow volumetric flow rate at the three boundaries.

Boundary Number	July 2011 (m^3/d)	October 2011 (m^3/d)
1	1852	1664
2	619	599
3	514	444

3.2 Field Water Sampling

Field sampling programs were carried out to collect water samples from the Study Area to measure their chloramine concentrations. The water samples were used to find the chloramine bulk decay coefficient which was required as input to the extracted hydraulic model. The water samples were also used to calibrate the wall decay coefficient in conjunction with the extracted hydraulic model for the Study Area.

Several field sampling programs were carried out and each served different needs. These are summarized in the following.

3.2.1 Water Sample Collection Method

In this research, all water samples were collected using the grab sample technique. In this technique, a regularly-used tap at the field site, e.g., a kitchen or a bathroom tap, not affected by any water filtration or softener devices, was identified (EWSI, 2011). The tap was turned on with running cold water. The water was adjusted to a fixed flow rate and ran for at least five minutes (EWSI, 2008). Bottles that were chlorine-demand free were used, e.g., glass and/or plastic (HDPE) bottles. At the end of the five minutes water flow, a bottle was rinsed three times with the water before it was filled to the neck with minimal headspace (EWSI, 2008). The collected water samples were stored in a dark container and at 4±2°C for a maximum recommended storage time of 24 hours (EWSI, 2010).

3.2.2 Preliminary Field Sampling

Prior to this study, there was very little knowledge regarding the behavior of chloramine in the water distribution system in the Study Area. It was not clear if the chloramine concentration at a fixed address changed with time (temporal variation), and if different addresses had different chloramine concentrations (spatial variation). Therefore, before planning for the formal field sampling programs, preliminary field sampling was carried out.

The initial preliminary field sampling was carried out at the author's residence on two different dates. On June 14, 2011, water samples were collected from the kitchen tap at the author's residence from 12:00 to approximately 23:00. One water sample was collected approximately every hour and the chloramine concentration in the water sample was measured immediately. These samples were intended to show the temporal variation of chloramine concentration at the author's residence during the daytime (light water use) and evenings (heavy water use).

On June 21, 2011, starting from 8:00 and ending at 11:00 the next day (June 22, 2011), one water sample was again collected approximately every hour. The chloramine concentration in the collected water sample was again measured immediately. A total of twenty-seven water samples were collected. These samples were intended to give a complete temporal variation of the chloramine concentration at the author's residence in a full 24-hour day cycle.

In conjunction with the initial preliminary field sampling at the author's residence, the third preliminary field sampling was conducted in the Study Area on June 16, 2011 in an effort to gain a knowledge of both the temporal and spatial variation of chloramine concentration in the Study Area. Three sampling points were selected along the water flow line, starting at one of the inflows to the Study Area, and ending at a "dead-end" in a park (a sampling route map is shown in the next chapter in Figure 11, page 64). The sampling started at about 9:00 and ended at about 21:00. Water samples were collected from each point in rotation. At the end, nine to ten water samples were collected from each point. These water samples gave both the temporal variation of chloramine concentration at each point, as well as the spatial variation between the three sampling points.

3.2.3 The First Field Sampling Program

The first formal field sampling program was conducted in the Study Area on July 28 and 29, 2011, starting at 8:00 and ending at 18:00 on each day. Resident volunteers were chosen randomly so they scattered in the entire Study Area. A water sample was collected by the resident volunteers from their residences approximately every two hours. The field sampling program was intended to give a “snapshot” of chloramine concentration in the entire Study Area during these two days.

Resident volunteers were selected following a communication letter that was dropped off to selected residents on April 20, 2011. The communication letter was reviewed and approved by EWSI before distribution. In addition to distributing the communication letter, an email was sent to all employees of EWSI to see if they (and/or their friends) are living in the Study Area and if they would be willing to participate. One of the requirements for a resident volunteer was that they should be available on the sampling days and that they should collect the water samples themselves into the supplied 500-mL plastic (high density polyethylene, HDPE) bottles, and leave the bottles in a cooler box filled with ice cubes (4ºC±2ºC) that was placed outside of their doors.

The search for resident volunteers for the first field sampling program resulted in fifty resident volunteers, forty-three of which were respondents of the communication letter and seven were respondents of the email that was sent to all employees of EWSI.

In order to observe and to compare the temporal and the spatial variation of chloramine concentration at all of the selected sampling sites, a sampling plan was drafted such that water samples were collected every two hours for the duration of ten hours at all sample sites in one day. This sampling plan was fairly intense for field sampling that was to be conducted in residential areas. As a result, not all of the fifty resident volunteers were able to participate fully. In the end, a total of twenty-two resident volunteers participated in this field sampling program, either on a single day or for both days. One of the resident volunteers lived at inflow 2 of the Study Area. In addition to the resident volunteers, inflow 3 was also sampled[*]. Adding inflow 3, there were a total of twenty-three sampling sites for the field sampling program.

Many of the colleagues of the author's at the University of Alberta helped with collecting and transporting the water samples from sampling sites to a work station temporarily set up in a park in the Study Area. Since there was only one field chlorine measurement kit, all of the collected water samples were analyzed by the author.

3.2.4 The Second Field Sampling Program

The second formal field sampling program was conducted on October 5 and 6, 2011. The logistics of the second formal field sampling program were the same as those of the first conducted in July 2011. The purpose of the second field sampling program was to examine the effect of temperature on chloramine decay and more importantly, to examine the spatial variation of chloramine concentration along the routes of the three water flow lines (following the three inflows). A sampling route map for the October field sampling program is shown in the next chapter in Figure 19, page 76. Water samples were collected at 10:00 and 12:00 on both days by the resident volunteers and placed in a cooler box

[*] There were in fact three inflows to the Study Area. However, the chloramine concentrations at inflow 1 were assumed the same as those at inflow 3 as these two inflows were connected.

maintained at 4ºC±2ºC by ice cubes. The cooler boxes were collected starting from about 12:30 on the sampling day and transported to the author's residence for testing.

A total of thirty-four resident volunteers participated in this program. Two businesses (an ESSO gas station and an A&W restaurant) were also chosen as they were on the inflow lines to the Study Area. Therefore, there were a total of thirty-six sampling sites. On October 5, 2011, there were a total of thirty sampling sites, with one at each inflow, and twelve, eight and seven on route 1, 2 and 3, respectively. On October 6, 2011, there were a total of twenty-five sampling sites, with one at each inflow, and eleven, six and five on route 1, 2 and 3, respectively.

Unlike in the first field sampling program conducted in July in which only inflow 2 and inflow 3 were sampled, in the October field sampling program, all three inflows were sampled in order to verify the assumption that inflow 1 and inflow 3 indeed had the same chloramine concentration (see map in Figure 19, page 76).

3.2.5 Sampling and Data Processing to Determine Bulk Decay Coefficients

A working water quality model requires essentially three components: the hydraulic model, the bulk chlorine decay coefficient and the wall chlorine decay coefficient. In this study, the hydraulic model for the Study Area was extracted from the SynerGEE Water hydraulic model. What was required then was the bulk chloramine decay coefficient. Note that the wall decay coefficient for the Study Area, which was another required model input, would be determined by using the least squares analysis after comparing measured chloramine concentrations from the two field sampling programs and the model calculated chloramine concentrations (section 3.4).

The bulk decay coefficients can be determined by collecting water samples from the water distribution systems and performing the bottle test on these water samples in the laboratory. In this study, this method was adopted, and the bottle tests were conducted in the laboratories of EWSI.

3.2.5.1 Selection of Sampling Locations

One of the most important issues that need to be considered is whether or not the bulk decay coefficient remains constant throughout the Study Area. The rate of bulk chloramine decay depends on the types and quantities of constituents in the water, especially those constituents that can react with chloramine. It is possible that water at different locations in the Study Area carries different types and quantities of constituents and thus, the rate of bulk chloramine decay may be different at different locations in the area.

In this field sampling program, water samples were collected at three locations in the Study Area. Bottle tests were performed on the water samples to determine the bulk decay coefficient for each location. The obtained bulk decay coefficients for these three locations were then compared to decide whether or not the rate of bulk chlorine decay remained constant throughout the area.

Two of the three locations selected for sampling were the two locations where the largest extent of chloramine decay was observed. It was suspected that the water at these locations carry constituents that were more reactive with chloramine, and thus determining the bulk decay coefficients at these locations might yield the most information regarding the variability of this parameter in the Study Area. Examination of data from the two field sampling programs (July and October, 2011) indicated that the largest extent of chloramine decay was observed in the region surrounding inflows 1 and 3 and the region on the northern outer boundary of the west side of the Study Area. The ESSO gas station at inflow 1, which was selected as a sampling site in the two field sampling programs, was selected as one of the three locations for the bulk decay coefficient study (site 1). A resident volunteer who participated in the second field sampling program and who lived in the region on the northern outer boundary of the west side of the area agreed to participate and this residence was selected as another location for the bulk decay coefficient study (site 3).

It would be useful to know the bulk decay coefficients for all water sources of the Study Area, in case they were required in the water quality model. Therefore, in the bulk decay coefficient study, the resident volunteer who lived at inflow 2 and who participated in both field sampling programs was contacted and the residence was selected as the final location (site 2). The water sample collected at Site 2 also represented a “normal” water sample as it did not go through the largest extent of chloramine decay. If the bulk decay coefficient determined for this water sample was statistically the same as the other two samples, then it can be concluded that the bulk decay coefficients are the same in the Study Area. Note that inflow 3 was not sampled as it was considered the same as inflow 1. The three sampling locations in the bulk decay coefficient study are shown in Figure 6.

3.2.5.2 Selection of Water Temperature

The water temperature in the Study Area at the time of the first field sampling program (July 28 and 29, 2011) was 17.4°C, and that at the time of the second field sampling program (October 5 and 6, 2011) was 12.9°C (section 4.1.3.3 and 4.1.4.2). Therefore, the bulk decay coefficients for the Study Area at 17.4°C and 12.9°C were determined.

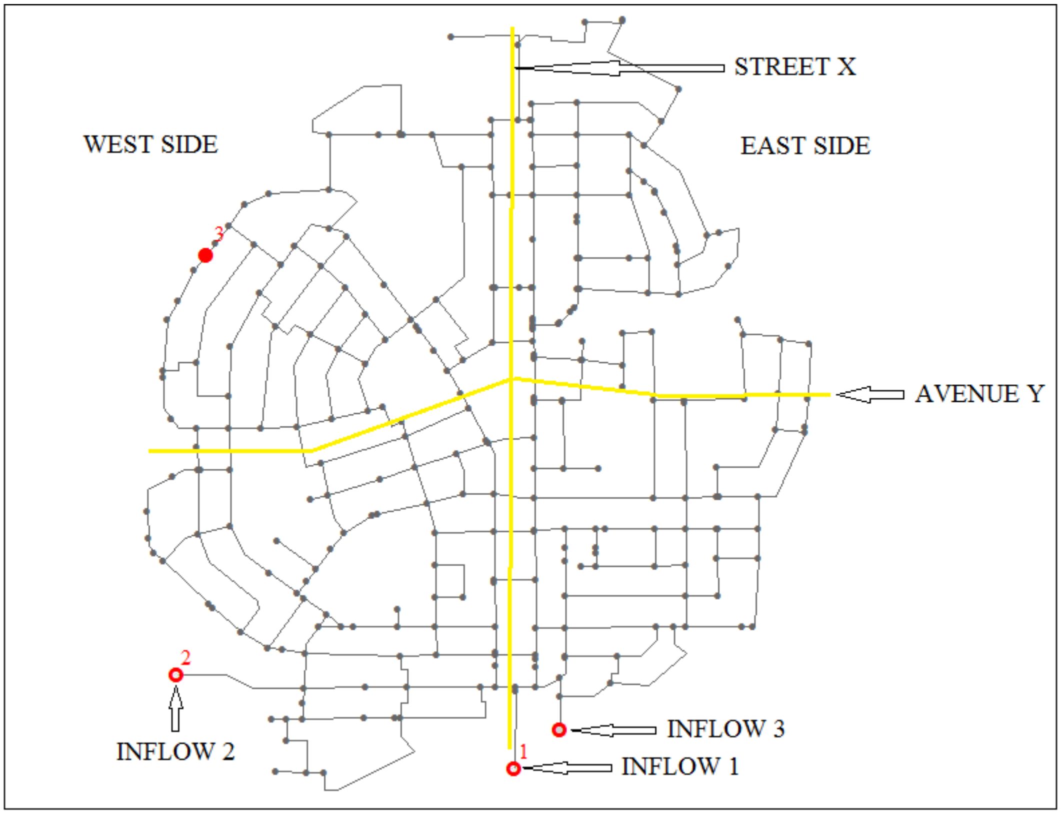

Figure 6 Sampling sites for the bulk decay coefficient study.

As it was not possible to control the temperatures of the collected water samples at exactly 17.4ºC and 12.9ºC, two water temperatures, one at lab bench ambient temperature (which was 19.3ºC), and one in a refrigerator (3ºC±2ºC), were used. After determining the bulk decay coefficients at these two temperatures, values at other temperatures were determined by using the Arrhenius equation, which states that rate constant is related to an activation energy and temperature by an empirical equation as shown in Equation 15 (Swaddle, 1990):

$$k = A\exp\left(-\frac{E_a}{RT}\right) \qquad \text{Equation 15}$$

Where k = rate constant,

A = a constant,

E_a = the activation energy (J)

R = gas constant, 8.314 J/(mol·K)

T = absolute temperature in Kelvin.

A and E_a can be found by the experimentally determined bulk decay coefficients (bottle tests) at the two temperatures of 19.3ºC and 3ºC.

3.2.5.3 Selection of Bottle Materials

Disposable plastic (HDPE) bottles (500-mL) were used to collect all water samples in the two field sampling programs of July and October 2011. It was assumed that this type of bottle did not have any chlorine demand. However, this assumption need to be checked in the bulk decay coefficient study.

Therefore, for all three sampling sites, both glass and plastic (HDPE) bottles were used to collect water samples. Half of each type of bottle were stored at lab bench ambient temperature (19.3ºC), and the other half of the bottles were stored in a refrigerator (3ºC).

By using this methodology, four bottle tests were conducted on the water samples collected at each site, yielding four bulk decay coefficients for each site, that is, the bulk decay coefficients in plastic (HDPE) or glass bottles, at either 19.3ºC or 3ºC. For the three sites, a total of twelve bottle tests were conducted yielding twelve bulk decay coefficients.

To verify if there are significant variations in the obtained bulk decay coefficients, for example, between the glass and plastic (HDPE) bottles, or between the different sites, statistical analysis was performed by comparing the 95% confidence intervals.

3.2.5.4 Laboratory Experimental Work

The bulk decay coefficient study was carried out from November 2 to November 9, 2011. On November 2, the water samples were collected from all three sites by the author (site 1) and the resident volunteers (sites 2 and 3). A total of twelve glass bottles and four plastic (HDPE) bottles of water samples were collected from site 1. Half of these were stored at lab bench ambient temperature (19.3ºC) and half in a refrigerator (3ºC). Similarly, four glass bottles and four plastic (HDPE) bottles of water were collected from each of sites 2 and 3, and half stored at 19.3ºC and half at 3ºC. As there was only one field chlorine kit to measure the chloramine concentration, it was not possible to obtain the chloramine concentration at the absolute time zero for each bottle. Therefore, half of the same types of bottles stored at each temperature for each site were analyzed within three hours after sample collection, and the measured chloramine concentration was taken as time zero chloramine concentration[*]. This was possible as chloramine is fairly stable and the concentration determined within the first three hours were within the experimental error as observed from the preliminary field sampling tests. The other half of the bottles had an elapsed time when their chloramine concentrations were measured. The data for the same type of bottle stored at the same temperature from the same site were combined to calculate the bulk decay coefficients.

As there were more glass bottles of water samples collected from site 1, some of the glass bottles as well as plastic (HDPE) bottles were randomly selected and their chloramine concentrations at a particular time point were measured three times. These yielded statistical information about the repeatability and the

[*] For site 1, twelve glass bottles and four plastic (HDPE) bottles were used. Six glass bottles and two plastic (HDPE) bottles were stored in a refrigerator at 3ºC, and another six glass bottles and two plastic (HDPE) bottles were stored at lab bench ambient temperature (19.3ºC). Therefore, three glass bottles and one plastic (HDPE) bottles stored at each of 19.3ºC and 3ºC were analyzed within three hours after sample collection to determine the chloramine concentrations at time zero. Similarly, for sites 2 and 3, one glass bottle and one plastic (HDPE) bottle stored at each of 19.3ºC and 3ºC were analyzed to determine the chloramine concentrations at time zero.

standard deviation of chloramine concentration measurements. Details are presented in the next section.

3.3 Measurement of Chloramine Concentrations

3.3.1 Instrument and Method

In this study, all water samples were tested for total chlorine using a field chlorine kit from Hach Company, which includes a pocket colorimeter and several 10-mL sample cells. Total chlorine includes both free and combined chlorine. Since chloramine is the most dominant species of chlorine present in the water distribution system of the City of Edmonton, and there are no detectable free chlorine in the system (EWSI, 2011), the total chlorine concentration measurements were deemed as the chloramine concentrations.

The pocket colorimeter operates based on the DPD method (method 8167 of Hach Company) to measure total chlorine concentration (Hach Company, 2001). Method 8167 is adapted by Hach Company from Standard Method 4500-Cl G of the Standard Methods for the Examination of Water and Wastewater (Hach Company, 2001; Hach Company, 2008).

The powder pillow test of method 8167 was used. The powder pillows were the DPD total chlorine reagents for 10-mL water samples. To test a water sample for total chlorine, one powder pillow and two 10-mL sample cells were required (Hach Company, 2001). The two sample cells were rinsed at least three times with sample water and then filled to the 10-mL mark with the test water. One of the sample cells was a blank to zero the pocket colorimeter. A powder pillow was added to the other sample cell and after three minutes, the sample cell was inserted into the colorimeter to obtain the total chlorine concentration reading in mg/L to two decimal places (Hach Company, 2001). This method determined total chlorine in the low range from 0 to 2.20 mg/L (Hach Company, 2001).

3.3.2 Accuracy

The manual of the colorimeter states that it can operate from 0 to 50°C and that its accuracy is ±0.02 mg/L at 25°C (Hach Company, 2001). The absolute accuracy of the colorimeter cannot be verified, since there is no chlorine standard (EWSI, 2011). At EWSI, total chlorine is tested at the Rossdale laboratory using amperometric titration (EWSI, 2010). The Rossdale laboratory verifies the accuracy of the pocket colorimeter by periodically testing a water sample using both the colorimeter and the amperometric titration and comparing the results (EWSI, 2011). If the two measured concentrations are within ±0.2 mg/L of each other, the pocket colorimeter is deemed reliable and its results are considered consistent with those of the titration (EWSI, 2010).

All field water sampling of this study were conducted from June to November 2011. During this period, the pocket colorimeter was checked against the amperometric method for four times. The results of all checks are shown in Table 9. For each check, water sample from the same bottle was used and the measurements were conducted at the same time. From Table 9, it can be seen that the difference between the two test methods was less than 0.2 mg/L for all four checks. Therefore, the pocket colorimeter was reliable for the field water sampling period of this study.

Table 9 Results of accuracy checking of the pocket colorimeter.

Date	Total Chlorine Concentration (mg/L)		
	Amperometric Titration	Hach Chlorine Field Kit	Difference
June 8, 2011	1.90	2.00	0.10
June 20, 2011	1.28	1.25	0.03
October 12, 2011	1.91	2.00	0.09
October 31, 2011	2.01	2.11	0.10

3.3.3 Standard Deviation of Chloramine Concentration Measurements

Water samples in some of the glass and plastic (HDPE) bottles collected from site 1 in the bulk decay coefficient study were tested for three consecutive times for chloramine concentration at a particular time point. The variance and the standard deviation is calculated for each water sample. The raw data and calculations are shown in Table 7 in Appendix F. The results are shown in Table 10 in the following.

Table 10 The standard deviations of chloramine concentration measurements.

Test Temperature (°C)	Bottle Type and Number	Variance	Standard Deviation
19.3	Glass 1	0.00013	0.0115
	Glass 2	0.00003	0.0058
	Glass 3	0.00010	0.0100
	Plastic 1	0.00003	0.0058
	Plastic 2	0.00003	0.0058
3.0	Glass 1	0.00163	0.0404
	Glass 2	0.00023	0.0153
	Glass 3	0.00003	0.0058
	Plastic 1	0.00023	0.0153
	Plastic 2	0.00023	0.0153
Pooled Variance =		0.00012	
Pooled Standard Deviation =		0.0109	

It can be seen from Table 10 that the variance and the standard deviation of the water sample collected in glass bottle 1 and stored at 3.0°C, which are marked in red, were considerably larger than the other water samples. Thus, these values are considered as outliers and were neglected.

The pooled variance is calculated, using the variances of all water samples except the value marked in red. The pooled standard deviation is calculated using the pooled variance. Because all water samples were tested an equal number of times, the pooled variance is the same as the arithmetic average of all variances.

The standard deviation of the chloramine concentration measurement was 0.01 mg/L. This was consistent with the repeatability of the measurement as specified in the manual of the pocket colorimeter, which was also 0.01 mg/L (Hach Company, 2001).

3.4 Least Squares Analysis

After inputting the required parameters and the bulk chloramine decay coefficient into the extracted hydraulic model for the Study Area, the model was run to calculate the chloramine concentration at all nodes and pipes in the Study Area when a trial value of wall decay coefficient was entered. The calculated chloramine concentrations at the nodes of interest (that is, nodes where a measured chloramine concentration was available) were recorded manually and entered to an Excel spreadsheet, and compared with the measured chloramine concentrations from the field sampling program. The difference between the calculated value and the measured value at each node was taken as a residual. Each residual was squared, and all the squared residuals were summed, to give a sum of squared residuals. A new trial value of wall decay coefficient was then entered to the hydraulic model to calculate a new series of chloramine concentrations, which led to a new sum of squared residuals. This process was repeated until an appropriate wall decay coefficient was found that resulted in the least sum of squared residuals. Such a wall decay coefficient was taken as the wall decay coefficient for the area.

The least squares analysis was performed for the entire Study Area, as well as for the west side of the Study Area and the east side of the Study Area separately in view of the significant differences in the pipe materials on these two sides.

4 RESULTS AND DISCUSSION

4.1 Field Sampling Studies

4.1.1 Preliminary Field Sampling at the Author’s Residence

The purpose of the preliminary field sampling at the author’s residence was to observe the temporal variation of chloramine concentration in the water distribution system. Two series of water samples were collected, one on June 14, 2011 over an 11-hour period, and the other from June 21 to June 22, 2011 over a 27-hour period.

4.1.1.1 Water Samples Collected on June 14, 2011

On Tuesday, June 14, 2011, eleven water samples were collected approximately one hour apart starting at 12:00 and ending at 23:00 from the kitchen tap of the author’s residence. The water temperature and chloramine concentration were determined immediately after collecting each water sample. The variation of chloramine concentration and water temperature over the 11-hour period is shown in Figure 7 and Figure 8, while Table 11 summarizes the average, the highest and the lowest values. The complete raw data are shown in Appendix B.

Table 11 Summary of the results of the preliminary field sampling conducted at the author’s residence on June 14, 2011.

Parameter	Average Value	Lowest Value	Highest Value	Range
Water Temperature (°C)	12.0	12.0	12.0	0.0
Chloramine Concentration (mg/L)	1.82	1.80	1.85	0.05

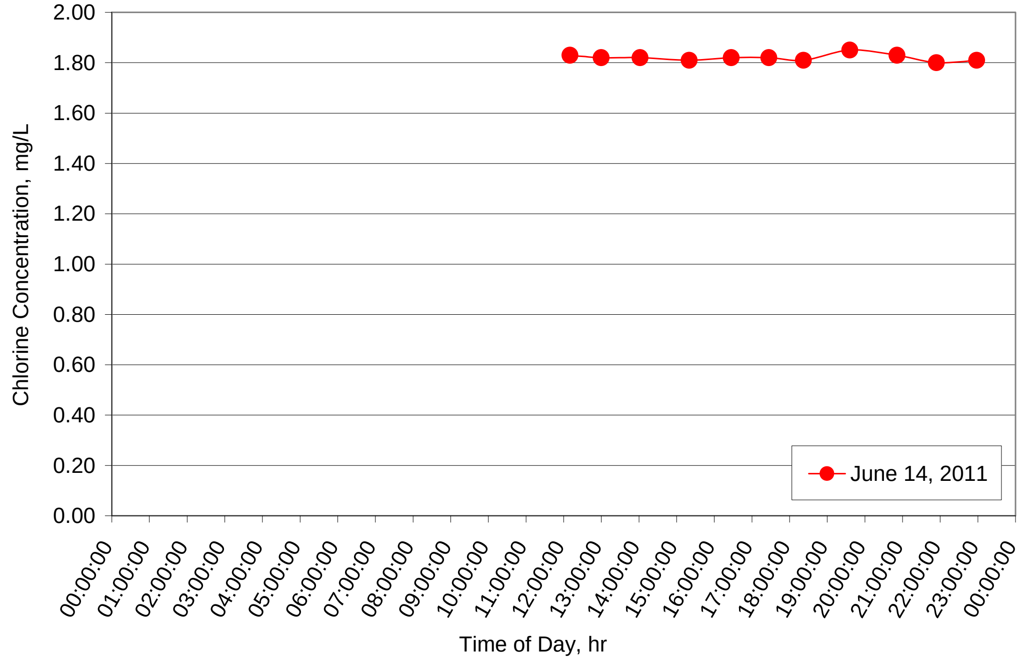

Figure 7 Temporal variation of chloramine concentration at the author’s residence on June 14, 2011.

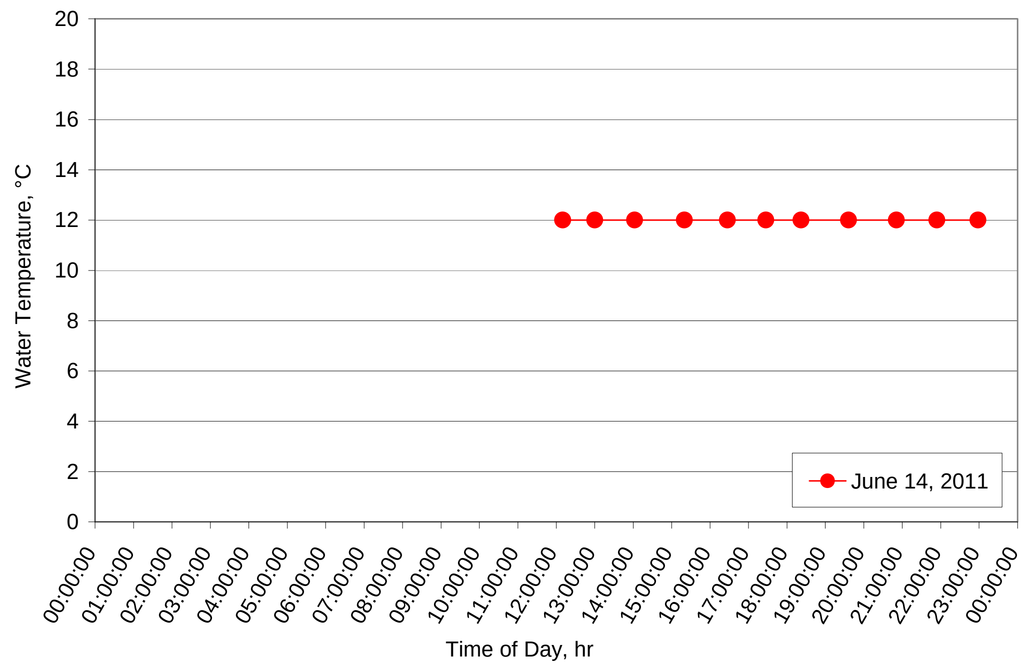

Figure 8 Temporal variation of water temperature at the author’s residence on June 14, 2011.

It can be seen from Figure 7 that the chloramine concentration remained stable at around 1.8 mg/L during the 11-hour sampling period. The data in Table 11 support this observation as they show a fluctuation of only 0.05 mg/L in the entire 11-hour period. It seems to indicate that the chloramine concentration in the area was not affected significantly by changes in water demand as the sampling period covered both the relatively low water demand interval and the high demand intervals (dinner cooking, lawn watering and shower). Table 11 and Figure 8 also show that the water temperature did not change in the sampling period and remained at 12.0°C.

4.1.1.2 Water Samples Collected from June 21 to June 22, 2011

To observe the temporal variation of chloramine concentration and water temperature during the entire 24-hour period, a second preliminary field sampling was conducted at the author's residence. It was started at 8:00 on June 21, 2011 and ended at approximately 11:00 the next day (June 22). A water sample was collected approximately every hour, so that a total of 27 samples were collected. The water sample was tested immediately after it was collected. The temporal variation of the chloramine concentration and water temperature of the 27 samples are plotted in Figure 9 and Figure 10, with a summary shown in Table 12. The raw data of the samples can be found in Appendix B.

Table 12 Summary of the results of the preliminary field sampling conducted at the author's residence from June 21 to 22, 2011.

Parameter	Average Value	Lowest Value	Highest Value	Range
Water Temperature (°C)	11.8	11.0	12.0	1.0
Chloramine Concentration (mg/L)	1.76	1.68	1.82	0.14

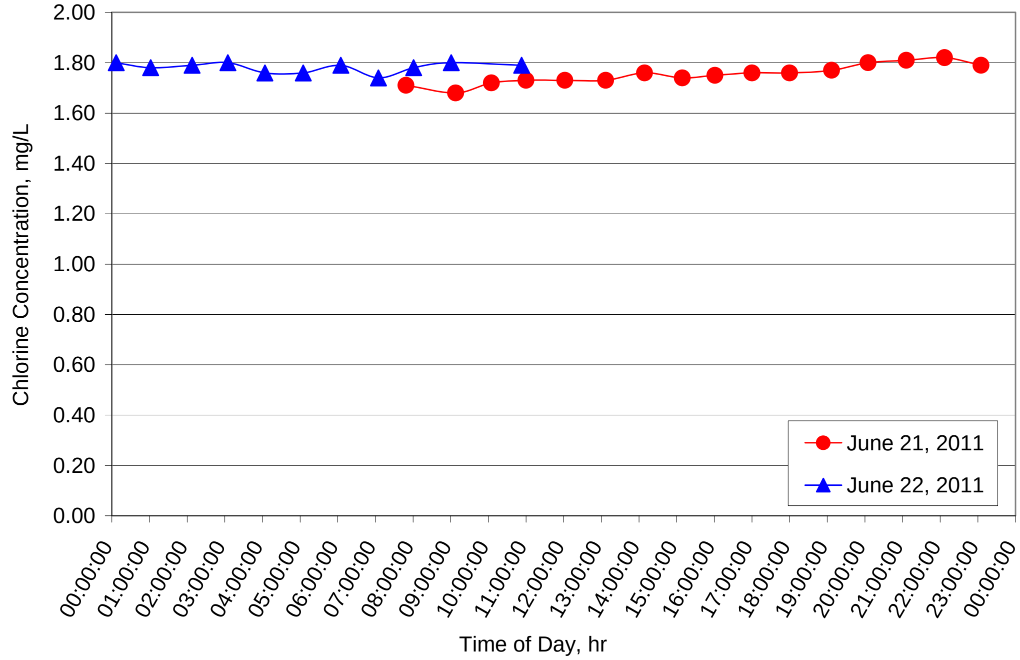

Figure 9 Temporal variation of chloramine concentration at the author's residence from June 21 to 22, 2011.

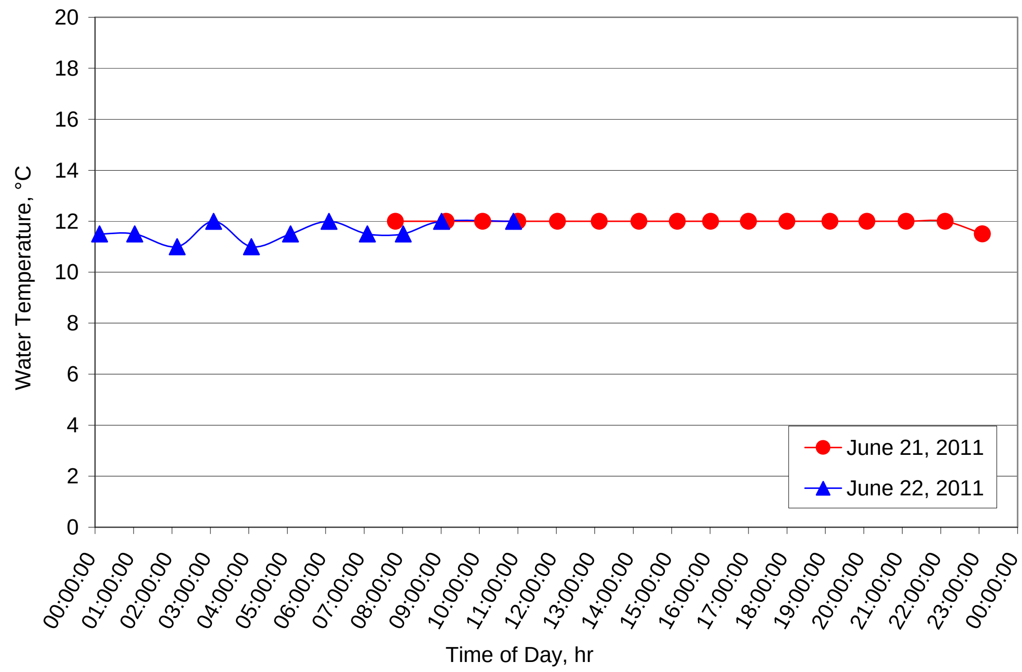

Figure 10 Temporal variation of water temperature at the author's residence from June 21 to 22, 2011.

Figure 9 shows that the chloramine concentration remained relatively stable at around 1.8 mg/L during the 27-hour period. Figure 10 shows that there were slight water temperature fluctuations, by about 1°C, during the midnight and early morning period, but overall the water temperature stayed around 12°C. The trend was summarized in Table 12, which shows that the chloramine concentration fluctuated between 1.68 and 1.82 mg/L, and water temperature between 11°C and 12°C.

Overall, the preliminary field sampling conducted at the author's residence showed that there were no significant variations in either the chloramine concentration or water temperature during a 24-hour period. Although the author's residence is not located in the Study Area, the preliminary sampling prepared the author for systematic water sampling in the Study Area and provided the author with a knowledge of the temporal variations of the chloramine concentration and water temperature in EWSI's water distribution system.

4.1.2 Preliminary Field Sampling in the Study Area

As the author's residence is not located in the Study Area, it was not clear whether the observation, i.e., that there were no significant temporal variations in chloramine concentration and water temperature, was applicable to the Study Area. A preliminary field sampling was therefore also conducted concurrently in the Study Area. The preliminary field sampling in the Study Area was designed so that both the temporal and the spatial variations of chloramine concentration and water temperature could be assessed.

This preliminary field sampling was carried out on June 16, 2011, starting at approximately 9:00 and ending at approximately 21:00 on the same day. Rather than staying at one fixed sampling site, water samples were collected from three different sampling sites (Figure 11) by rotating between the sites during the 12-hour sampling period. Nine water samples were collected from each of site 1 and site 2, and ten from site 3. Each water sample was tested immediately after collection. The raw data of the chloramine concentration and water temperature from all three sampling sites are shown in Appendix C. The data are plotted in Figure 12 and Figure 13, and summarized in Table 13 and Table 14.

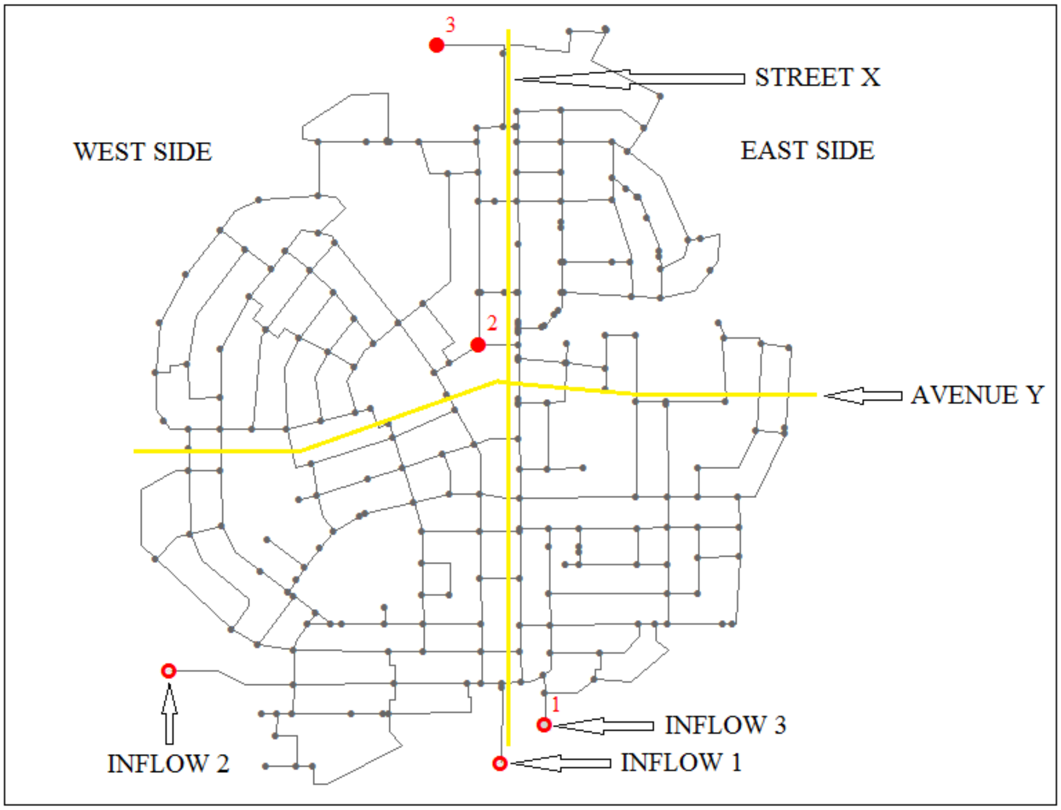

Figure 11 Sampling sites for the preliminary field sampling in the Study Area on June 16, 2011.

Table 13 Summary of the measured chloramine concentrations for the three sampling sites in the Study Area on June 16, 2011.

Site Number	Average Chloramine Concentration (mg/L)	Lowest Chloramine Concentration (mg/L)	Highest Chloramine Concentration (mg/L)	Range (mg/L)
1	1.86	1.83	1.92	0.09
2	1.81	1.79	1.83	0.04
3	1.28	1.08	1.44	0.36

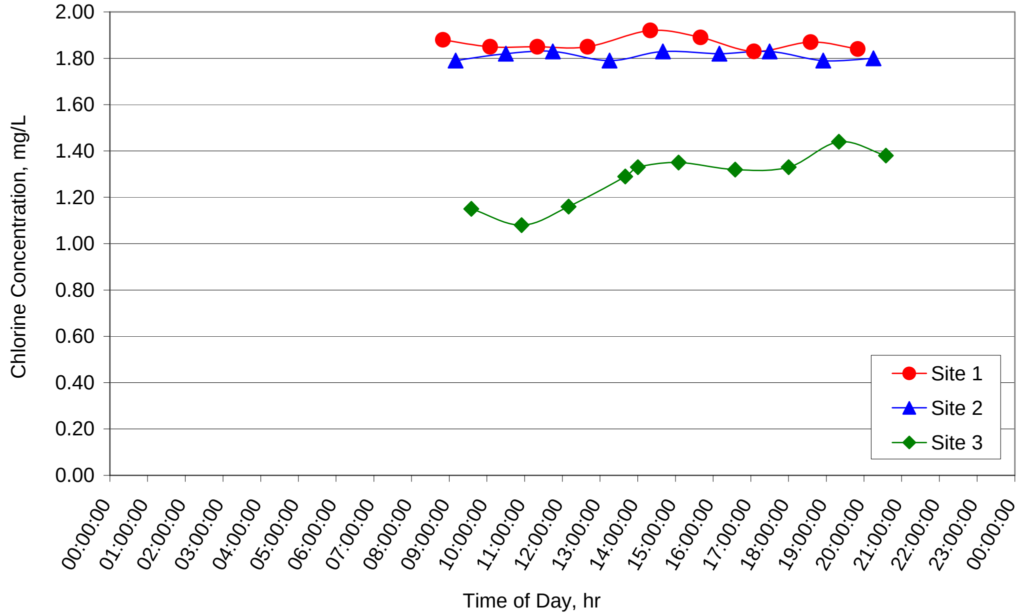

Figure 12 Temporal variation of the chloramine concentration for the three sampling sites in the Study Area on June 16, 2011.

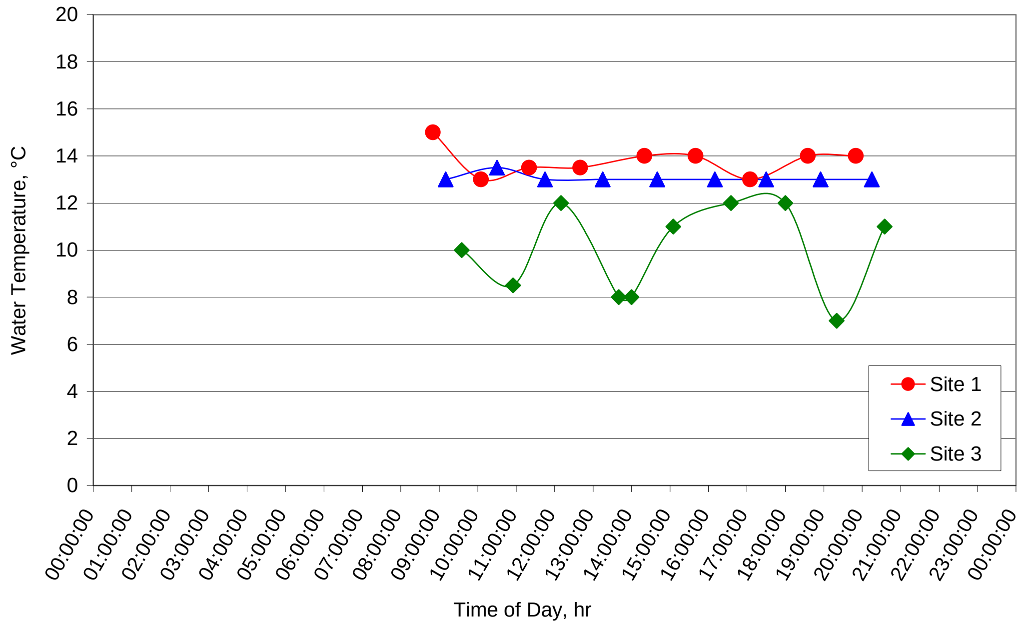

Figure 13 Temporal variation of the water temperature for the three sampling sites in the Study Area on June 16, 2011.

Table 14 Summary of the measured water temperatures for the three sampling sites in the Study Area on June 16, 2011.

Site Number	Average Water Temperature (°C)	Lowest Water Temperature (°C)	Highest Water Temperature (°C)	Range (°C)
1	13.8	13.0	15.0	2.0
2	13.1	13.0	13.5	0.5
3	10.0	7.0	12.0	5.0

Figure 12 and Table 13 show that there was a spatial variation of chloramine concentration. While the chloramine concentrations for site 1 and site 2 differed slightly and stayed between 1.8 and 1.9 mg/L, they were much higher than site 3. The average chloramine concentration was 1.86, 1.81 and 1.28 mg/L for sites 1, 2 and 3, respectively. Figure 11 shows that site 1 is close to the inflows, site 2 is in the middle of the sampling area, and site 3 is at the north end of the sampling area (a “dead-end” in a small recreational park). Therefore, it can be seen that the chloramine concentration was the highest near the inflows and decreased away from the inflows. The data indicate that there was a measurable spatial variation of the chloramine concentration in the Study Area.

Figure 12 also shows that the patterns of the temporal variation in chloramine concentration of the three sampling sites were different. For site 1 and site 2, the chloramine concentration in the sampling period (9:00 to 21:00) fluctuated only slightly and randomly, with site 1 ranging from 1.83 to 1.92 mg/L, and site 2 ranging from 1.79 to 1.83 mg/L. However, for site 3, the chloramine concentration was the lowest (1.08 mg/L) in the morning when the sampling started, and it increased steadily during the day and reached the highest point (1.44 mg/L) close to the end of the sampling period (21:00). Clearly, as site 3 was a dead-end, the chloramine in the stagnant water in the water pipe must have been consumed overnight, leading to low chloramine concentration. As the day went by, the occasional visitors to the park used the washrooms, replenishing the water in the pipes, and thus causing a gradual increase in the chloramine concentration.

In fact, the two rising segments of the chloramine concentration profile for site 3 may reflect such activities (note that this is not a very frequented park, and the day when the sampling was carried out was a normal working day and not a weekend). In this context, site 3 provides a useful site to study the wall chloramine decay kinetics in the water distribution system. Detailed wall decay kinetics study is out of the scope of this work, but any future wall decay kinetics study should consider site 3 as potential test site.

The temporal variation of water temperature in the three test sites (Figure 13) shows a similar trend, in that the variation for site 1 and site 2 are more or less random, while that of site 3 was cyclic and rising. In general, the water temperature in site 3 was lower than sites 1 and 2. It is also interesting to note that the time when the rising water temperature was observed coincided with an increase in chloramine concentration (compare Figure 13 with Figure 12).

The preliminary field sampling program at both the author's residence and the Study Area indicate that the chloramine concentration in the water supply system did not show significant temporal variation as long as the water was not "stagnant", e.g., in a dead-end. The results also show that there was sufficient spatial variation in chloramine concentration. These preliminary results provided the basis of the water sampling programs carried out next, although the data from the preliminary field sampling were not used in the hydraulic model to calibrate the wall decay coefficients.

4.1.3 The First Field Sampling Program (July 28 and 29, 2011)

The first field sampling program was conducted on July 28 and 29, 2011. In this program, water samples were collected from twenty-three sampling sites, eighteen of which were sampled on July 28 and eleven on July 29 (some sites were sampled on both dates).

4.1.3.1 Spatial Variation of Chloramine Concentration

Figure 14 shows the locations of all twenty-three sampling sites. During the sampling program the water samples were collected at a fixed time interval of two hours. Table 15 lists the average daily chloramine concentration of all sites for the two sampling days. The sample site numbers labeled in Figure 14 correspond to those listed in Table 15. The raw data of the first field sampling program are shown in Appendix D.

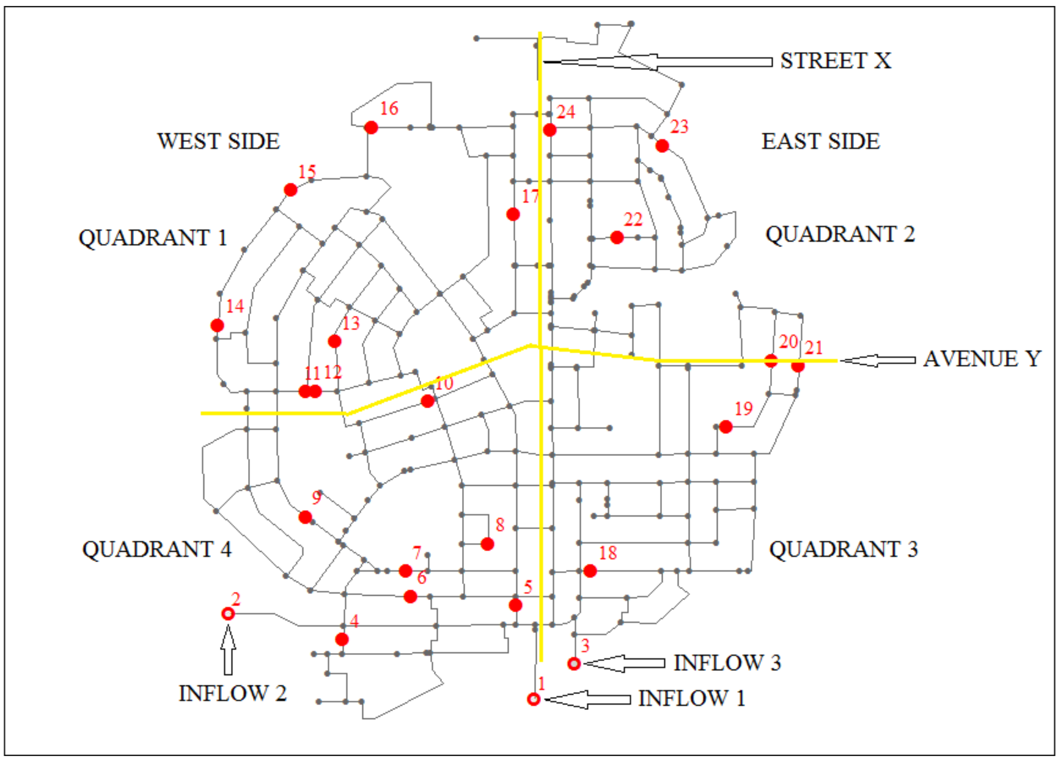

Figure 14 Sampling sites of the first field sampling program (July 28 and 29, 2011).

Table 15 Average chloramine concentrations of all sampling sites of the first field sampling program (July 28 and 29, 2011).

Inflow/Quadrant Number	Sampling Site Number	Average Chloramine Concentration (mg/L)	
		Thursday, July 28, 2011	Friday, July 29, 2011
Inflow 1	1	1.61	1.72
Inflow 2	2	1.35	1.45
Inflow 3	3	1.61	1.72
Quadrant 4 (West Side)	4	1.28	1.32
	5	1.59	-
	6	1.51	-
	7	-	1.55
	8	1.41	1.53
	9	1.33	-
	10	1.19	-
Quadrant 1 (West Side)	11	1.06	-
	12	1.18	-
	13	0.90	-
	14	0.98	-
	15	0.93	-
	16	-	0.88
	17	-	1.55
Quadrant 3 (East Side)	18	-	1.72
	19	1.44	-
	20	1.26	1.30
	21	1.29	-
Quadrant 2 (East Side)	22	1.41	-
	23	-	1.40
	24	1.44	1.55

* Note that inflow 1 was not an actual sampling site. It was the same as inflow 3.

As discussed earlier, in the July 2011 hydraulic model, the three inflows are sources of chloramine for the Study Area. As a result, the chloramine concentration at each of the three inflows must be known. For the first field sampling program, the measured chloramine concentrations at sites 2 and 3 were considered as the source chloramine concentrations at inflows 2 and 3, respectively. No sampling site was available at inflow 1. However, as inflows 1 and 3 were actually joined together as shown in Figure 3, the measured chloramine concentration at site 3 was used to represent both inflows 1 and 3.

Figure 14 shows that the sampling sites are scattered nearly uniformly in the Study Area and have covered the entire area. The average chloramine concentrations listed in Table 15 indeed show that there is a measurable spatial variation of the chloramine concentration in the area, and that the chloramine concentrations are highest near the inflows and decrease away from the inflows.

Table 16 Overall summary of the measured chloramine concentrations in the first field sampling program (July 28 and 29, 2011).

Date	Sampling Site with the Lowest Average Chloramine Concentration	Lowest Average Chloramine Concentration (mg/L)	Sampling Site with the Highest Average Chloramine Concentration	Highest Average Chloramine Concentration (mg/L)	Difference in Chloramine Concentration (mg/L)
7/28/2011	13	0.90	1/3	1.61	0.71
7/29/2011	16	0.88	1/3 and 18	1.72	0.84

Table 16 shows an overall summary of the chloramine concentrations of all sampling sites. The data are shown separately for July 28 and July 29. For each day, what is shown is the number of sites with the lowest average chloramine concentration, and the ones with the highest average chloramine concentration, as well as values of the average chloramine concentration. As can be seen, on both sampling days, the sites with the highest average chloramine concentration were either at inflow 1/3 or close to inflow 1/3, which was as expected since the inflows are sources of chloramine for the area. The sample sites that had the lowest average chloramine concentrations were located in quadrant 1 (Table 15). This was reasonable considering that the west side of the area consists of predominately cast iron pipes and that the sampling sites in quadrant 1 are far from the inflows. As shown in Table 16, the difference between the highest and the lowest average chloramine concentrations is 0.71 and 0.84 mg/L on July 28 and 29, respectively. The magnitude of these differences indicates that the wall chloramine decay in the water supply system in the Study Area may have played a significant role in affecting the water quality in the Study Area. Therefore a wall decay coefficient may be calibrated using the hydraulic model.

4.1.3.2 Temporal Variation of Chloramine Concentration

In this field sampling program, the water sample collection times were set at every two hours starting at 8:00 and ending at 18:00 on both days. This sampling plan allows for the collection of six water samples for each site in the 10-hour sampling period, which reveals the temporal variation of the chloramine concentration in the area in addition to spatial variations.

The measured chloramine concentrations of all sample sites are plotted versus time in Figure 15 (July 28) and Figure 16 (July 29). Note that in the first field sampling program, the actual number of water samples collected from each sampling site depended on the availability of the resident volunteer. That is, not all sampling sites yielded six water samples on each sampling day. In both figures, the sampling sites are grouped into four quadrants.

By examining Figure 15 and Figure 16, it can be seen that there are some patterns in the temporal variations of chloramine concentrations for the sampling sites. However, no generalizations could be made regarding the patterns.

Furthermore, six sites were sampled on both July 28 and July 29, 2011. Figure 17 shows the temporal variations of chloramine concentration of the six sites for the two days. Again, some patterns in the temporal variations are observed for the sampling sites. However, no generalizations could be made regarding the patterns. Since no generalizations could be made, the average chloramine concentrations of the sampling sites (Table 15) were used to calibrate the wall decay coefficient.

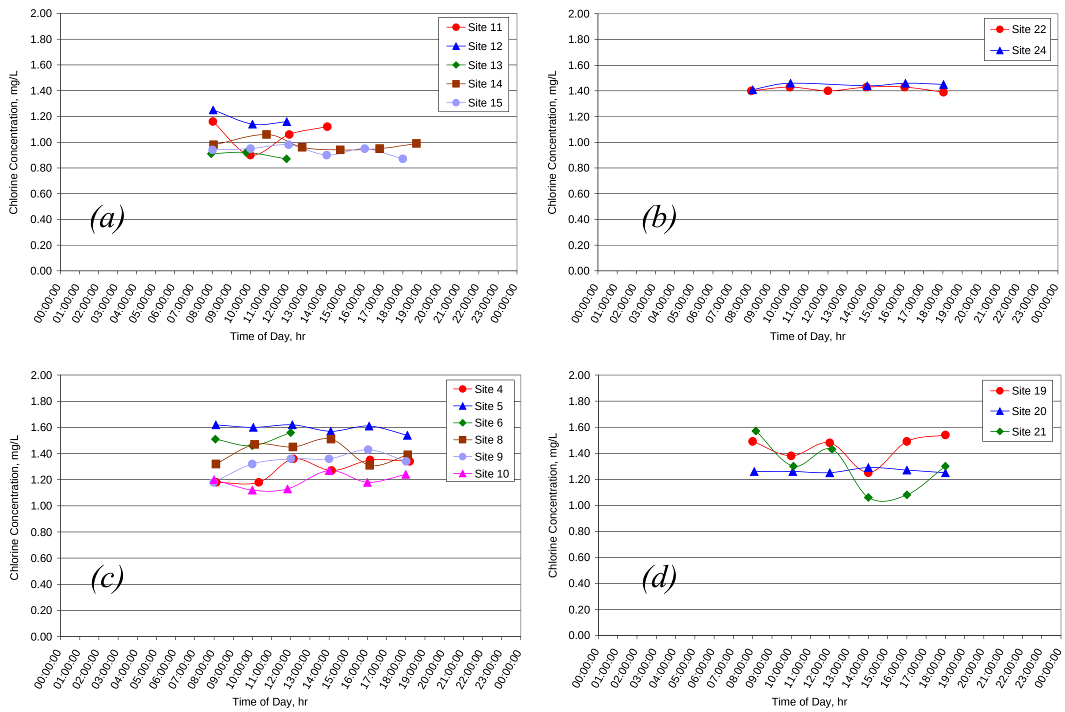

Figure 15 Temporal variation of chloramine concentration on July 28, 2011 in (a) quadrant 1, (b) quadrant 2, (c) quadrant 4 and (d) quadrant 3.

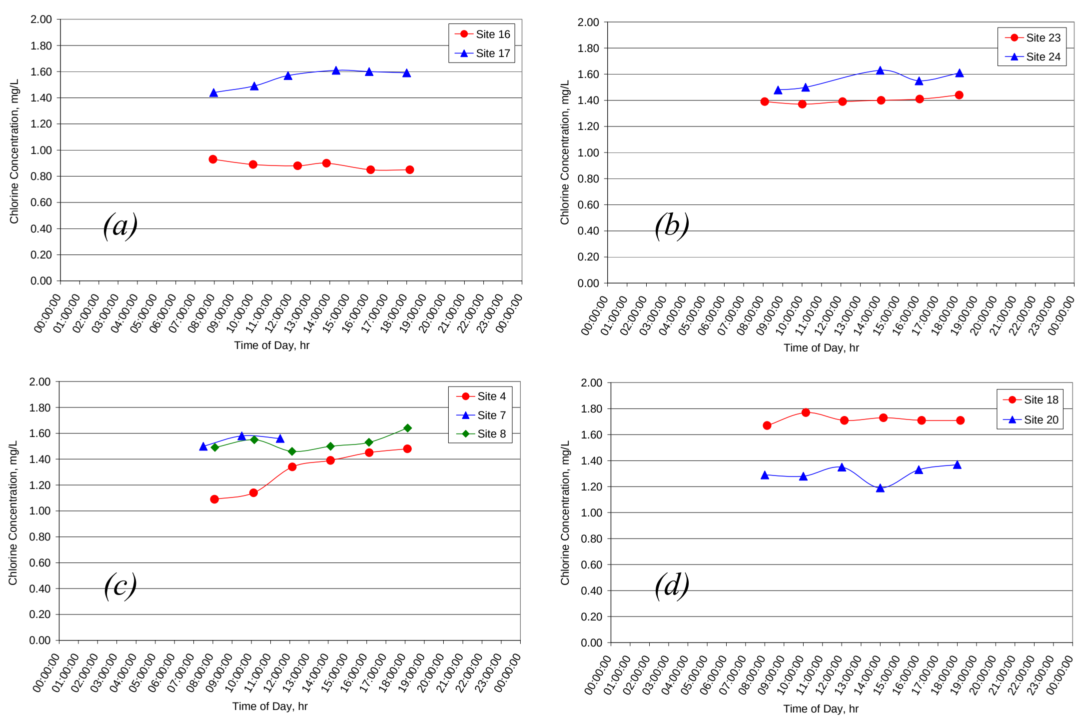

Figure 16 Temporal variation of chloramine concentration on July 29, 2011 in (a) quadrant 1, (b) quadrant 2, (c) quadrant 4 and (d) quadrant 3.

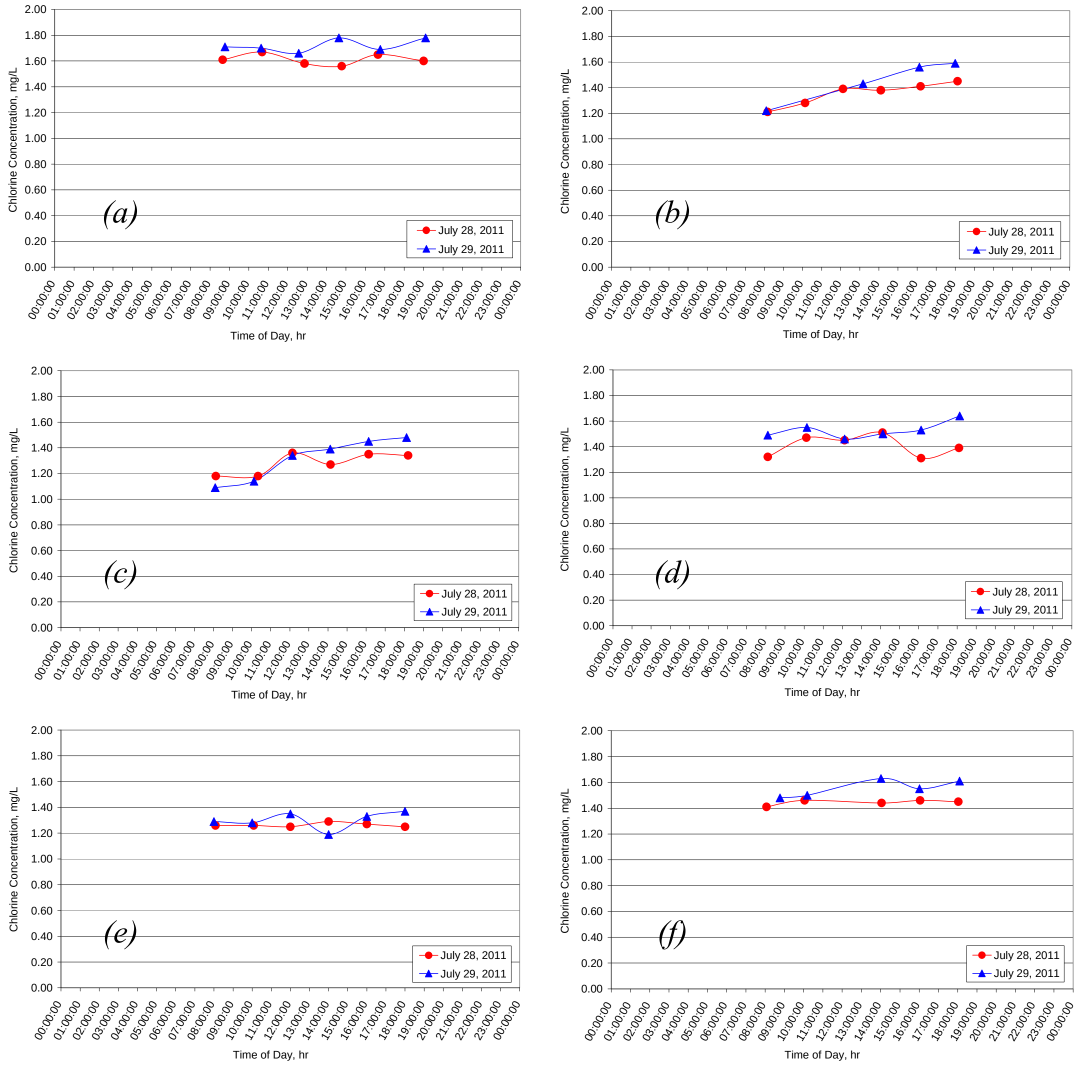

Figure 17 Temporal variation of the chloramine concentration on July 28 and 29, 2011 at (a) site 1/3, (b) site 2, (c) site 4, (d) site 8, (e) site 20 and (f) site 24.

4.1.3.3 Water Temperature

Site 3 is a commercial building and the water samples were collected by one of the student volunteers. Therefore, a complete record of water temperature was available. The raw data of the water temperature are included in Appendix D and plotted in Figure 18. Table 17 shows a summary of the average, the lowest and the highest water temperatures on both sampling days for site 3.

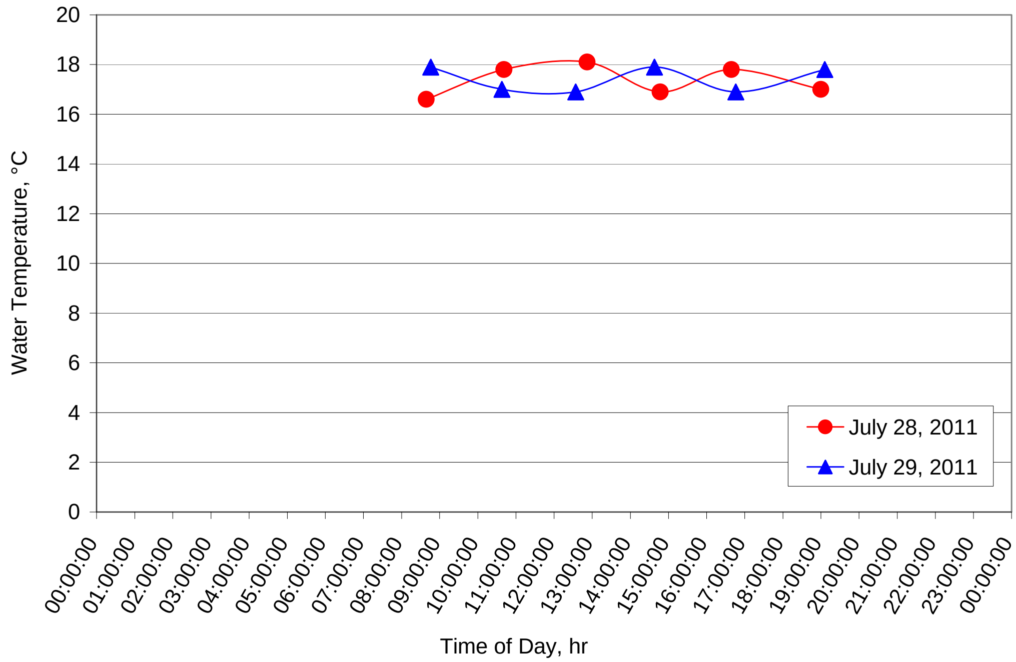

Figure 18 Temporal variation of water temperature at site 3 on July 28 and 29, 2011.

Table 17 Summary of the measured water temperatures in the first field sampling program for site 3.

Date	Average Water Temperature (°C)	Lowest Water Temperature (°C)	Highest Water Temperature (°C)	Range (°C)
7/28/2011	17.4	16.6	18.1	1.5
7/29/2011	17.4	16.9	17.9	1.0

The values in Table 17 and the plots in Figure 18 suggest that there are slight variations in the water temperature on both sampling days at site 3. The preliminary field sampling on June 16, 2011 also showed that there was slight variation of the water temperature both spatially and temporally in the Study Area (Figure 13). Nevertheless, for this study, the water temperature in the area was considered constant, both spatially and temporally, on each sampling day. For the field sampling program conducted on July 28 and 29, 2011, the average water temperature at site 3 was assumed to be the constant water temperature in the area on that day. Table 17 shows that the average water temperatures at site 3 on both sampling days were 17.4°C. Therefore, this average water temperature was used as the water temperature in the subsequent hydraulic model calculations.

4.1.4 The Second Field Sampling Program (October 5 and 6, 2011)

The second field sampling program was conducted on October 5 and 6, 2011. The objectives of the second sampling program were to study the effect of water temperature on the chloramine concentration, and the chloramine decay along water flow directions. In this program, water samples were collected from thirty-six sampling sites, thirty of which were sampled on October 5 and twenty-five on October 6. Some sites were sampled on both dates. A water sample was collected at 10:00 and 12:00 at each site on one or both dates.

4.1.4.1 Chloramine Decay along Water Flow Directions

Different from the first field sampling program which used scattered sampling sites in the Study Area, three water flow paths were selected in the second field sampling program. The three water flow paths were determined by running the 2002 SynerGEE Water steady state hydraulic model.

Figure 19 shows the locations of all thirty-six sampling sites. As can be seen, the sampling sites on routes 1 and 2 have "enveloped" the west side of the Study Area, while the sampling sites on route 3 are scattered in the east side of the Study Area. The arrows on the figure represent water flow directions as predicted by the SynerGEE Water hydraulic model for the October 2011 demand scenario.

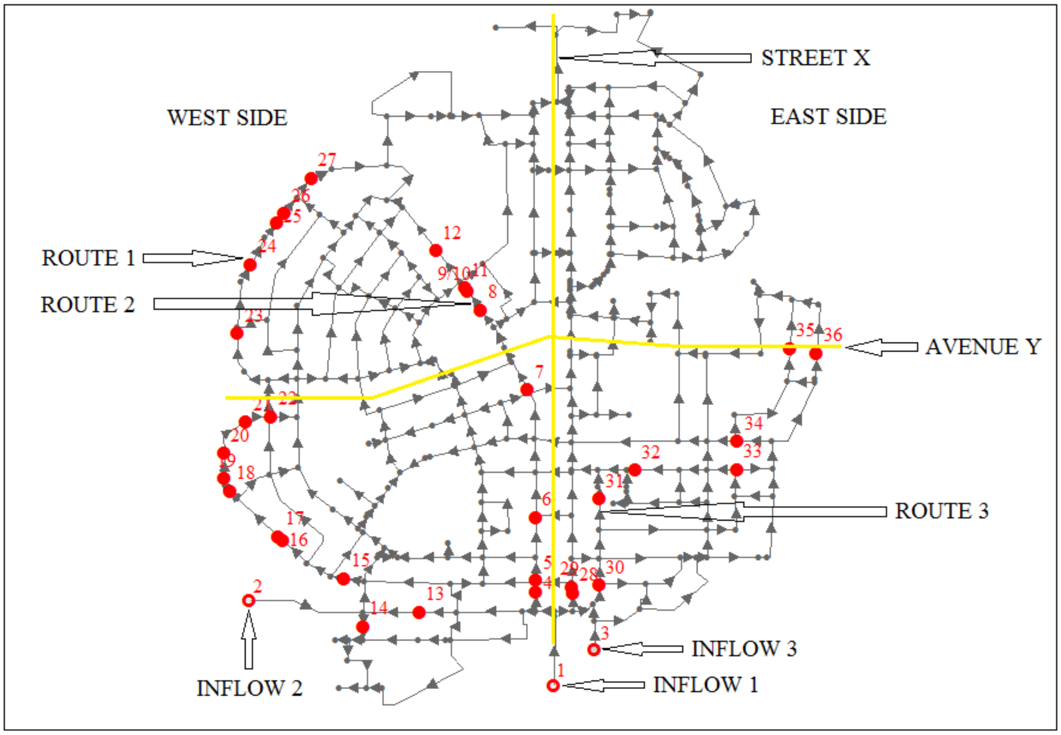

Figure 19 Sampling sites for the second field sampling program conducted on October 5 and 6, 2011.

The daily average chloramine concentrations of all sites for each of the two sampling days are calculated and listed in Table 18. The sampling site numbers noted in Figure 19 correspond to those listed in Table 18. The raw data of all sampling sites are shown in Appendix E.

Table 18 reveals a broad range of measured chloramine concentrations along the three routes. Also, the chloramine concentration was the highest near the inflows and decreased away from the inflows. Both observations were similar to the first field sampling program performed in July 2011.

Table 18 Average chloramine concentrations of all sampling sites in the second field sampling program conducted on October 5 and 6, 2011.

Inflow/Route Number	Sampling Site Number	Average Chloramine Concentration (mg/L)	
		Wednesday, October 5, 2011	Thursday, October 6, 2011
Inflow 1	1	1.91	1.89
Inflow 2	2	1.75	1.75
Inflow 3	3	1.90	1.90
Route 2 (West Side)	4	1.84	1.86
	5	1.89	1.86
	6	1.88	-
	7	1.84	1.68
	8	1.75	-
	9	1.72	1.76
	10	-	1.77
	11	1.71	-
	12	1.35	1.55
Route 1 (West Side)	13	1.63	1.64
	14	-	1.67
	15	1.66	1.66
	16	1.60	-
	17	-	1.61
	18	1.47	1.53
	19	1.43	-
	20	-	1.48
	21	1.30	1.43
	22	1.22	1.34
	23	1.20	-
	24	1.16	1.33
	25	1.12	1.29
	26	1.11	-
	27	1.11	1.17
Route 3 (East Side)	28	-	1.88
	29	-	1.86
	30	1.81	-
	31	1.72	-
	32	1.73	1.78
	33	1.53	1.51
	34	1.36	-
	35	1.54	1.55
	36	1.65	-

Figure 20 and Figure 21 show the daily average chloramine concentrations of the sampling sites as a function of water flow direction along each route. As can be seen, all three routes showed a monotonous decrease in chloramine concentrations on both dates. The exception to this observation is route 3 on October 5, 2011, in which the chloramine concentration increased at the end of the route, as shown in Figure 20(c). The extent and the uniformity of the decrease differed from routes to routes, but the patterns of the decreases for the three routes are very similar on both sampling days. Overall, route 1 showed the most significant decrease in chloramine concentration along the water flow direction, and the decrease was more uniform. Comparatively, routes 2 and 3 showed smaller decreases and the decreases tend to be "jumpy".

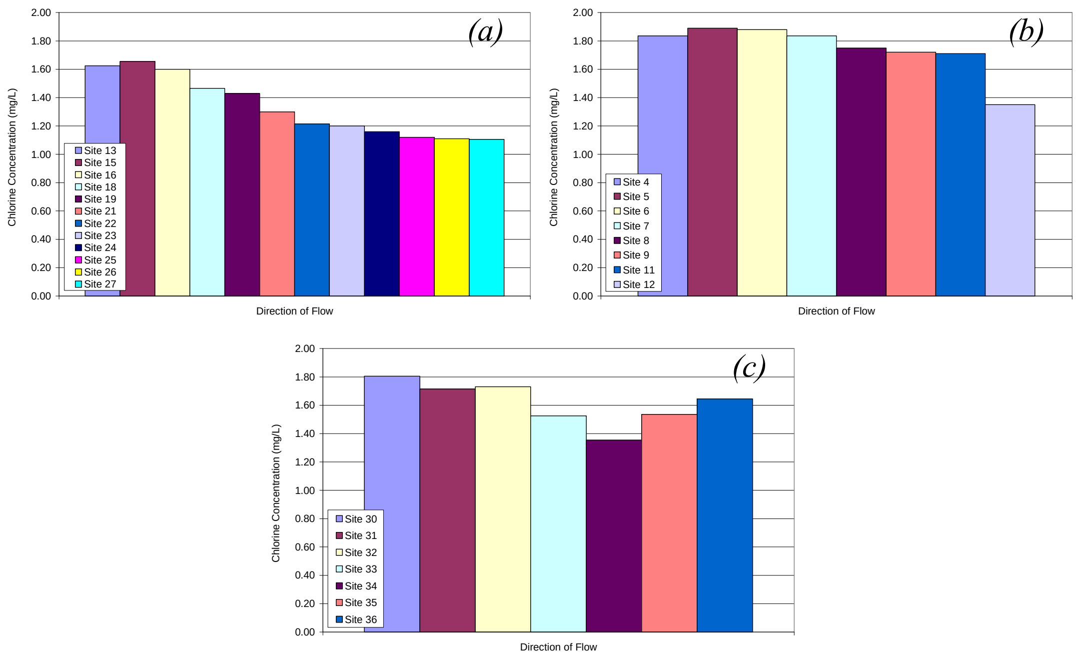

Figure 20 Spatial variation of chloramine concentration on October 5, 2011 for (a) route 1, (b) route 2 and (c) route 3.

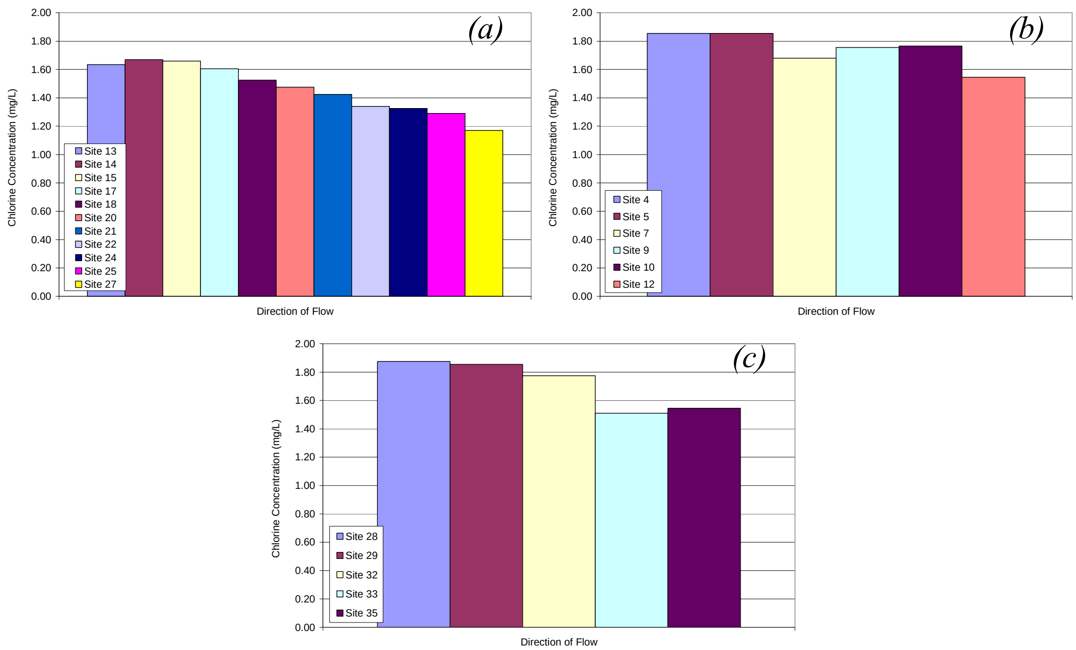

Figure 21 Spatial variation of the chloramine concentration on October 6, 2011 for (a) route 1, (b) route 2 and (c) route 3.

The highest and lowest daily average chloramine concentrations shown in Table 18 and the corresponding sampling sites are extracted and presented in Table 19. As can be seen from this table, the sampling sites with the highest daily average chloramine concentration were at inflows 1 and 3. This was similar to the observation in the first sampling program and consistent with expectation, as inflows should have higher chloramine concentrations. The sampling sites with the lowest average daily chloramine concentration were located at the end of route 1. This result coincided with that of the first field sampling program, which showed that the sampling sites with the lowest daily average chloramine concentration were located in quadrant 1, where route 1 ran. This observation was reasonable, since the west side of the area (quadrant 1) consisted of predominantly cast iron pipes and that the sampling sites at the end of route 1 were the furthest away from the inflows, compared to all the other sampling sites in this field sampling program. As a result, there would be greater chloramine decay as water traveled from the inflows to these sampling sites.

Table 19 Overall summary of the measured chloramine concentrations in the second field sampling program (October 5 and 6, 2011).

Date	Sampling Site with the Lowest Average Chloramine Concentration	Lowest Average Chloramine Concentration (mg/L)	Sampling Site with the Highest Average Chloramine Concentration	Highest Average Chloramine Concentration (mg/L)	Difference in Chloramine Concentration (mg/L)
10/5/2011	26 and 27	1.11	1	1.91	0.80
10/6/2011	27	1.17	3	1.90	0.73

Table 19 also shows that the difference between the highest and the lowest daily average chloramine concentration is 0.80 and 0.73 mg/L on October 5 and 6, respectively. These were similar to the differences observed in the first field sampling program conducted in July, 2011, i.e., 0.71 and 0.84 mg/L on July 28 and 29, respectively (Table 16).

4.1.4.2 Water Temperature

Similar to the first field sampling program, water temperature data were only available for sites 1 and 3 as these water samples were collected by the author. The measured water temperatures are listed in Table 20 and are also included with the raw data of sites 1 and 3 in Appendix E.

Table 20 Water temperature in the second field sampling program (October 5 and 6, 2011).

<table>
<tr><th>Date</th><th>Sampling Site Number</th><th>Water Temperature at First Sampling Time (°C)</th><th>Water Temperature at Second Sampling Time (°C)</th><th>Average Water Temperature (°C)</th></tr>
<tr><td rowspan="2">10/5/2011</td><td>1</td><td>13.0</td><td>13.0</td><td rowspan="2">12.9</td></tr>
<tr><td>3</td><td>12.7</td><td>12.7</td></tr>
<tr><td rowspan="2">10/6/2011</td><td>1</td><td>13.0</td><td>13.1</td><td rowspan="2">12.7</td></tr>
<tr><td>3</td><td>12.7</td><td>12.0</td></tr>
</table>

As can be seen from Table 20, the water temperatures were slightly different between sites 1 and 3, showing some slight spatial variation which was also observed earlier. The average water temperature of 12.9°C was used in the hydraulic model to calculate the wall decay coefficient for the area for the October sampling program.

4.2 Determination of Bulk Decay Coefficients (Bottle Tests)

The spatial variation of chloramine concentration observed in the field sampling programs in the Study Area hinted at the importance of wall decay in the measured chloramine concentration. As the chloramine concentrations can be calculated by the SynerGEE Water hydraulic model, the field sampling program provided an opportunity to use the measured chloramine concentrations to calibrate the chloramine wall decay coefficient in the hydraulic model. This can be done as follows: first, the chloramine concentrations are calculated by the hydraulic model by assuming a value of the wall decay coefficient. The calculated values are then compared with the measured data from the field sampling programs. The difference (i.e., the residuals) are squared and summed. A least squares analysis of the sum of squares would likely lead to a unique wall decay coefficient, which gives the lowest sum of squares of the residuals.

Besides requiring a wall decay coefficient, the calculation of chloramine concentration by the hydraulic model also requires the input of a bulk decay coefficient and the selection of several model parameters related to the properties of water, such as viscosity, specific gravity, etc. The bulk decay coefficient is dealt with in this section (section 4.2), while the selection of model parameters is considered in the next section (section 4.3).

4.2.1 Selecting Sampling Sites for the Determination of Bulk Decay Coefficient

On November 2, 2011, water samples were collected from three representative locations in the Study Area (Figure 6, page 52) using both glass bottles and plastic (HDPE) bottles. Both types of bottles were divided into two groups, with one group stored in a refrigerator (3°C) and the other left in a cabinet at lab bench ambient temperature (19.3°C). Both groups of the water samples were analyzed for chloramine concentrations in the one-week period following sample collection, i.e., from November 2 to November 9, 2011, to determine the bulk decay coefficient. Details of the procedures of sample collection and bulk decay coefficient determination are described in section 3.2.5, page 49.

4.2.2 The Test Temperatures

Throughout the bulk decay experiment, the temperatures inside the refrigerator and the cabinet were monitored using a traceable total-range thermometer made by Control Company. This thermometer was calibrated on February 23, 2010 and the calibration was still valid at the time of this study. In addition to using the total-range thermometer, a beaker filled with water in which was submerged an alcohol thermometer was stored inside the refrigerator at the start of the experiment to monitor the temperature. The two thermometers gave slightly different temperature readings (Table 1 in Appendix F), and the average was used as the water temperature, which was 3°C in the fridge and 19.3°C in the cabinet.

4.2.3 Initial Data Processing

The raw and the processed data of the bottle tests conducted for the bulk decay water samples of sites 1, 2 and 3 are shown in Appendix F, Appendix G, Appendix H, respectively. Details of the initial data processing are described below.

4.2.3.1 Initial Data Processing for Site 1

From site 1, twelve glass bottles and four plastic (HDPE) bottles of water samples were collected on November 2, 2011. Half of the bottles (i.e., six glass bottles and two plastic (HDPE) bottles) were stored in a refrigerator at 3ºC and half left in a cabinet at lab bench ambient temperature (19.3ºC). As there was only one field chlorine kit to measure chloramine concentration, it was not possible to simultaneously determine the chloramine concentration for all bottles when the water sample was collected. Since the chloramine in the water sample is fairly stable, half of the bottles stored at each temperature for each site were analyzed as quickly as possible and within three hours after sample collection, and the measured chloramine concentration was taken as the concentration at time zero for the bottle. The first chloramine concentration measured for the other half of the bottles then had an elapsed time. The glass and plastic (HDPE) bottles at both temperatures were analyzed in rotation and the time when the water sample was analyzed was converted to time elapsed since time zero. The data for the same type of bottles from the same site stored at the same temperature were combined to find the bulk decay of chloramine, so that four datasets were obtained, for glass or plastic (HDPE) bottles at either 19.3ºC or 3ºC.

At some time point (which was chosen randomly), the chloramine concentrations in three glass bottles and two plastic (HDPE) bottles stored at each of 19.3°C and 3°C were measured repeatedly three times in order to determine the repeatability and standard deviation of the chloramine concentration measurements. The repeatability and standard deviation of chloramine concentration measurements were discussed in section 3.3.3, page 57.

4.2.3.2 Initial Data Processing for Sites 2 and 3

The initial data processing for sites 2 and 3 were essentially the same as site 1, except that only four glass bottles and four plastic (HDPE) bottles were collected from each of sites 2 and 3. No repeatability measurements of the chloramine concentration was performed for samples from sites 2 and 3.

4.2.4 The Decrease of Chloramine Concentration versus Time

Figure 22, Figure 23 and Figure 24 show the decrease of chloramine concentration as a function of elapsed time in the water bottles collected from sites 1, 2 and 3, respectively. Note that the tests ended on different time periods.

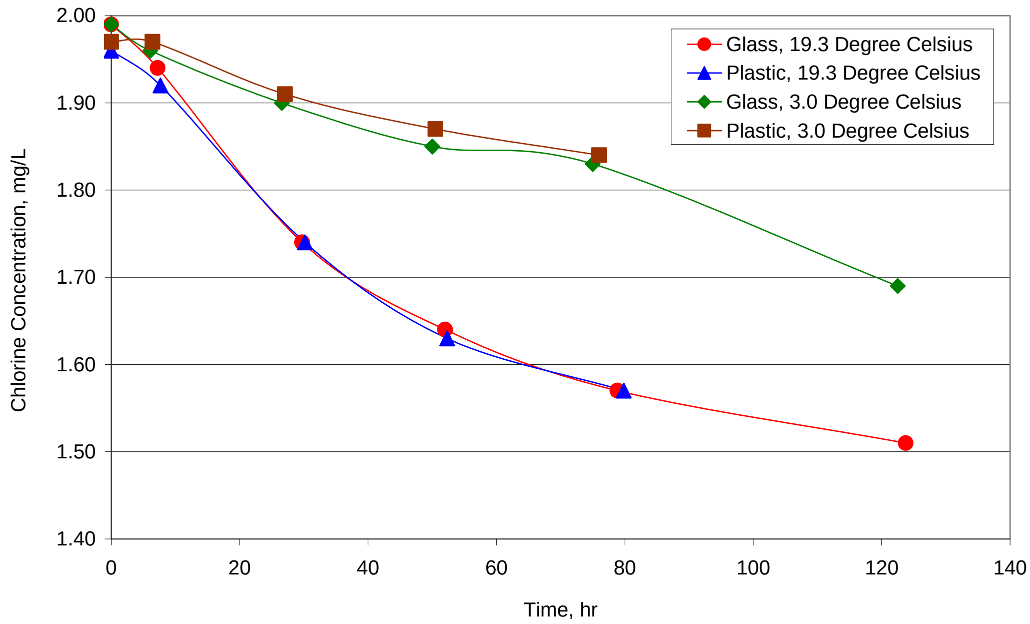

Figure 22 Chloramine concentration as a function of time for all bottle tests conducted for site 1 (Note: some of the data points are average values of repeated measurements. Refer to Appendix F for details).

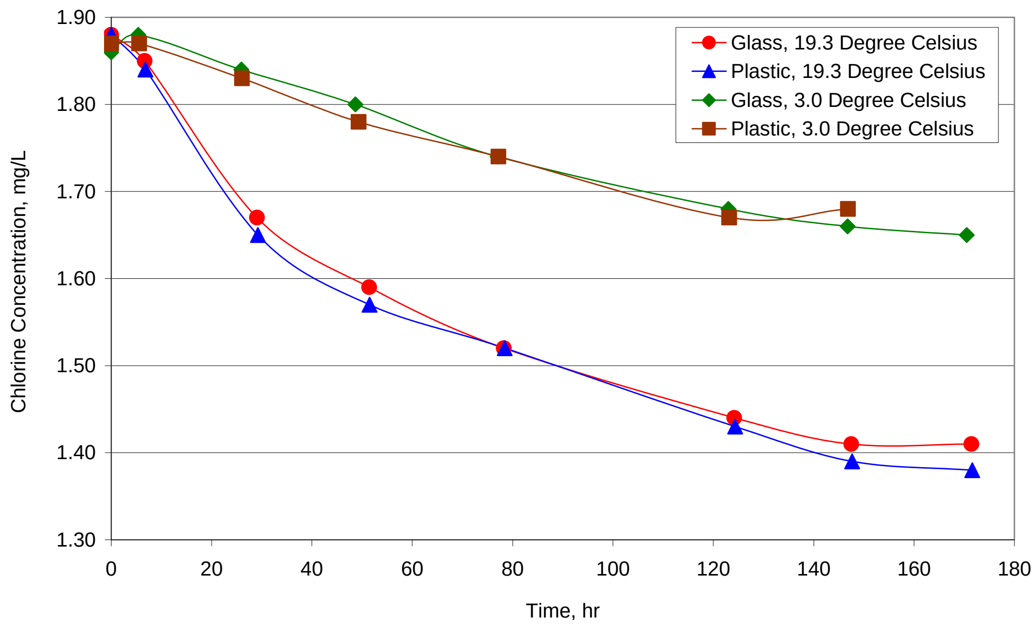

Figure 23 Chloramine concentration as a function of time for all bottle tests conducted for site 2.

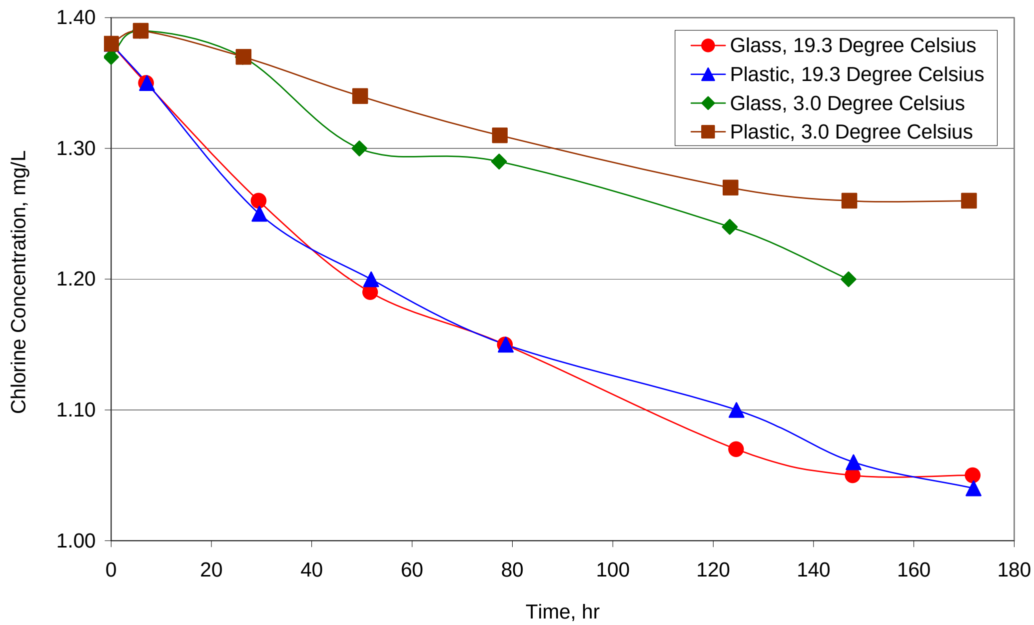

Figure 24 Chloramine concentration as a function of time for all bottle tests conducted for site 3.

All three figures show that chloramine concentrations decreased non-linearly with time. The decrease was more pronounced for water samples stored at the higher temperature (19.3°C) than at the lower temperature (3°C).

4.2.5 Determination of the Bulk Decay Coefficients

4.2.5.1 For Site 1

As the decrease of chloramine concentration showed a non-linear dependence on time, the first order and second order kinetic models were used to model the bulk decay process.

The differential equation for the first order reaction is shown by Equation 16:

$$\frac{dC}{dt} = -kC \qquad \text{Equation 16}$$

where C = Chlorine Concentration
t = Time
k = Reaction Rate Coefficient (Bulk Decay Coefficient)

The solution to Equation 16 is shown by Equation 17.

$$C = C_o \exp(-kt) \qquad \text{Equation 17}$$

where C_o = Initial Chlorine Concentration, and the rest are the same as above.

Equation 17 is changed into the form of a straight line, as defined by Equation 18, by taking the natural logarithm of the equation.

$$\ln C = -kt + \ln C_o \qquad \text{Equation 18}$$

By plotting ln C versus time t on a log-linear plot and applying the linear regression analysis, the bulk decay coefficient k and the initial chloramine concentration C_o can be determined from the slope of the regression line and the y-intercept of the line, respectively.

Table 21 lists the bulk decay coefficients, the initial chloramine concentrations and the coefficients of determination (R^2) of all bottle tests of site 1 using the first order model. The detailed data are listed in Appendix F. The linear regression analysis was performed using the built-in functions in Microsoft Office Excel 2003.

Table 21 The bulk decay coefficients and the initial chloramine concentrations of the bottle tests of site 1 for the first and the second order models.

Test Temperature (°C)	Bottle Type	First Order Model			Second Order Model		
		First Order k_b (hr^{-1})	C_o (mg/L)	R^2	Second Order k_b ($(mg*hr/L)^{-1}$)	C_o (mg/L)	R^2
19.3	Glass	2.27E-03	1.92	0.89	1.32E-03	1.93	0.91
	Plastic	2.92E-03	1.94	0.96	1.67E-03	1.94	0.97
3.0	Glass	1.25E-03	1.98	0.98	6.80E-04	1.98	0.98
	Plastic	9.58E-04	1.97	0.97	5.03E-04	1.97	0.98

The fit of the site 1 chloramine concentration data to the second order reaction model was also tested. The differential equation for the second order reaction is shown by Equation 19.

$$\frac{dC}{dt} = -kC^2 \qquad \text{Equation 19}$$

where C = Chlorine Concentration

t = Time

k = Reaction Rate Coefficient (Bulk Decay Coefficient)

The solution to Equation 19 is shown by Equation 20.

$$C = \left(kt + \frac{1}{C_o} \right)^{-1} \qquad \text{Equation 20}$$

where C_o = Initial Chlorine Concentration, and the rest are as above.

Equation 20 is changed into the form of a straight line by taking the reciprocal of both sides of the equation. Equation 21 shows the linearized form of Equation 20.

$$\frac{1}{C} = kt + \frac{1}{C_o} \qquad \text{Equation 21}$$

By plotting $1/C$ versus time t and then applying the linear regression analysis, the bulk decay coefficient and the initial chlorine concentration could be determined, as the slope of the regression line is k and the y-intercept of the line is $1/C_o$. The values for site 1 are also listed in Table 21 together with those of the first order modeling results, and the detailed data are shown in Appendix F.

Examination of the R^2 values shown in Table 21 indicates that for each bottle test, both the first and the second order reaction models fit fairly well to the test data. Using the obtained bulk decay coefficients, the chloramine concentrations of all bottle tests of site 1 can be calculated. The detailed calculation and calculated data are shown in Appendix F. The calculated values are compared with the actual measured values from Figure 25 to Figure 28. These four figures show that the chloramine concentration values predicted from the first and the second order models fit adequately with the measured chloramine concentrations. The figures also show that the calculated chloramine concentration values by the first order reaction model are essentially the same as those calculated by the second order model.

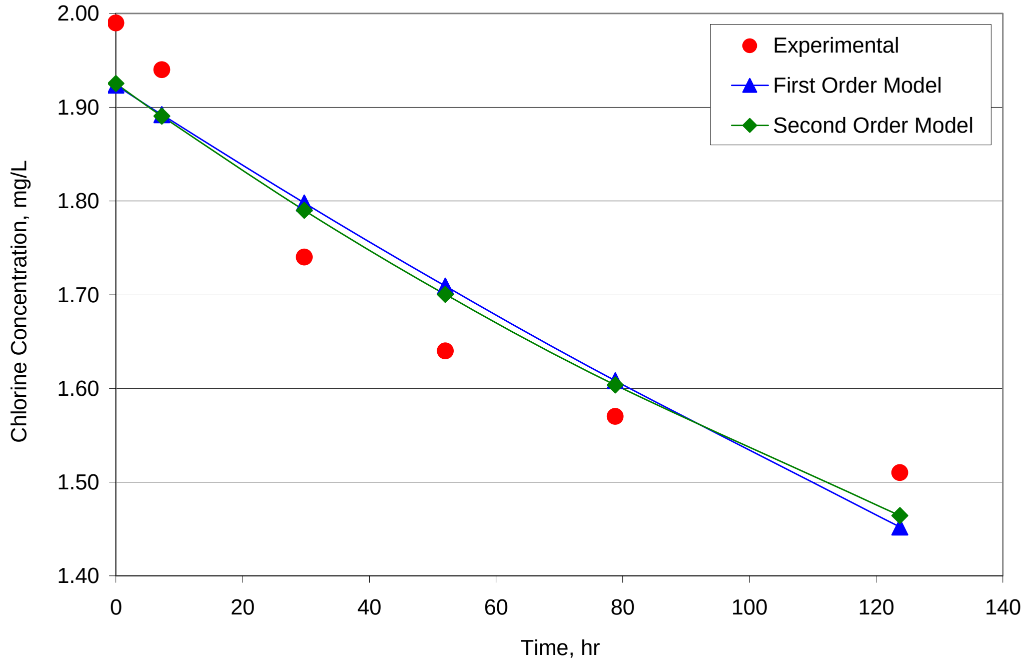

Figure 25 Comparison of the measured and predicted chloramine concentrations. Water bottle tests of site 1, glass bottles, 19.3°C.

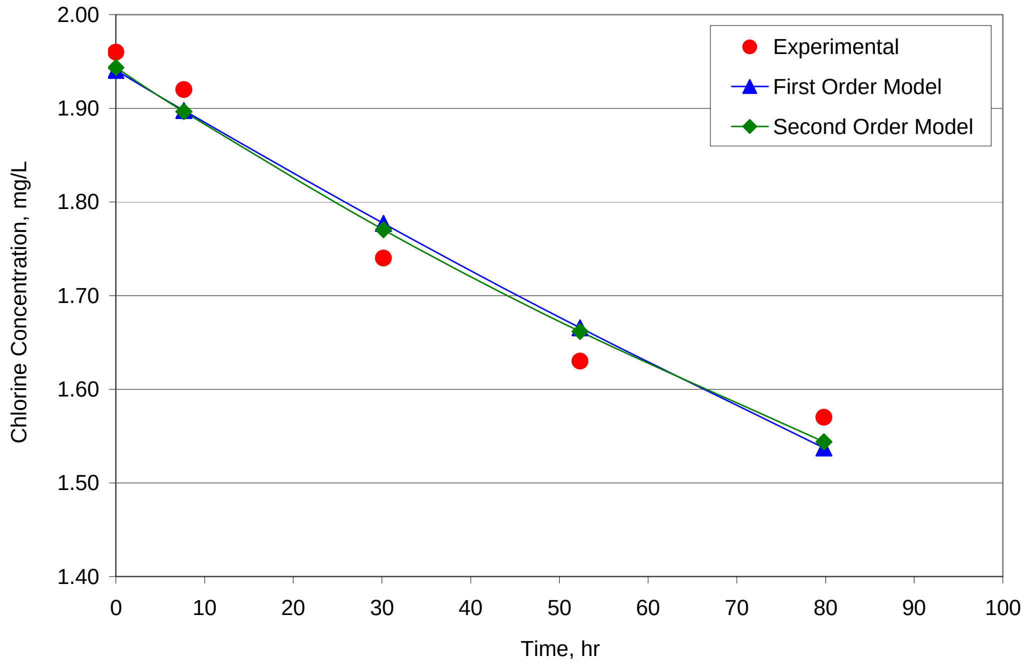

Figure 26 Comparison of measured and predicted chloramine concentrations. Water bottle tests of site 1, plastic (HDPE) bottles, 19.3°C.

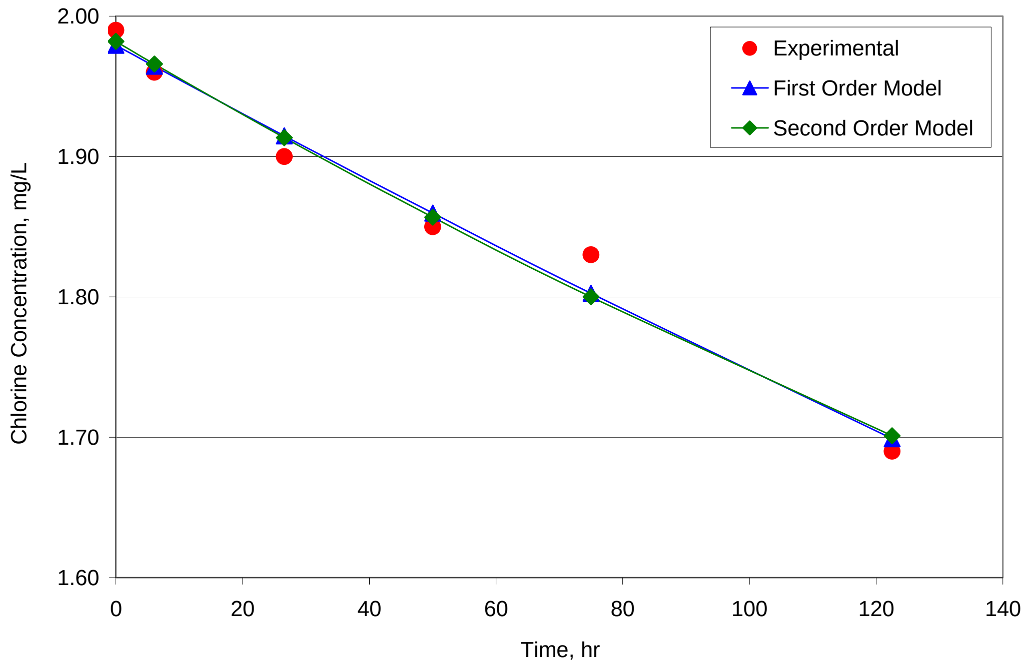

Figure 27 Comparison of measured and predicted chloramine concentrations. Water bottle tests of site 1, glass bottles, 3.0°C.

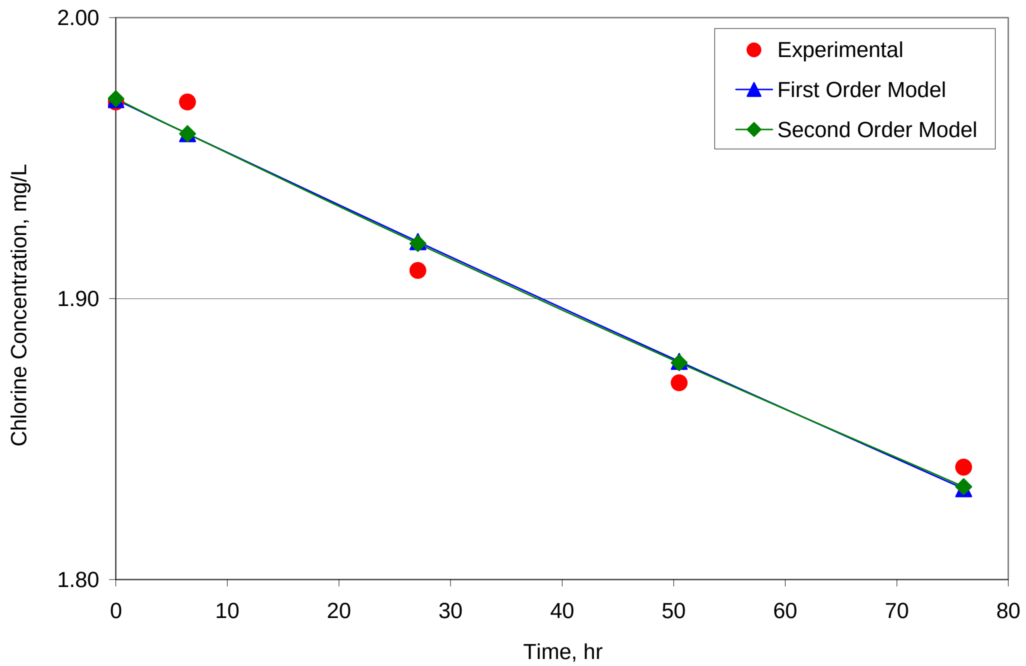

Figure 28 Comparison of measured and predicted chloramine concentrations. Water bottle tests of site 1, plastic (HDPE) bottles, 3.0°C.

4.2.5.2 For Sites 2 and 3

The same methodology was used to determine the bulk decay coefficients of the water samples collected from sites 2 and 3. The detailed calculations and data are listed in Appendix G and Appendix H, and the results are shown in Table 22, Table 23, Figure 29 and Figure 30. These tables and figures confirmed the observations of the bottle tests conducted for site 1, that is, the first order and second order model predictions are essentially the same, and that the predicted values are close to the measured values.

Table 22 The bulk decay coefficients and the initial chloramine concentrations of the bottle tests of site 2 for the first and the second order models.

Test Temperature (°C)	Bottle Type	First Order Model			Second Order Model		
		First Order k_b (hr^{-1})	C_o (mg/L)	R^2	Second Order k_b ($(mg*hr/L)^{-1}$)	C_o (mg/L)	R^2
19.3	Glass	1.69E-03	1.80	0.90	1.05E-03	1.81	0.92
	Plastic	1.76E-03	1.80	0.91	1.11E-03	1.80	0.93
3.0	Glass	8.00E-04	1.87	0.98	4.56E-04	1.87	0.98
	Plastic	8.15E-04	1.87	0.96	4.61E-04	1.87	0.97

4.2.6 Comparison of the Bulk Decay Coefficients

During the linear regression analyses, the lower and upper limits of the 95% confidence intervals were generated for the determined bulk decay coefficients. Table 24 and Table 25 present the bulk decay coefficients of all water bottle tests and associated lower and upper limits of the 95% confidence intervals for the first and the second order models, respectively. These confidence intervals are used to compare the bulk decay coefficients obtained from the different sites and different materials of construction for the bottles.

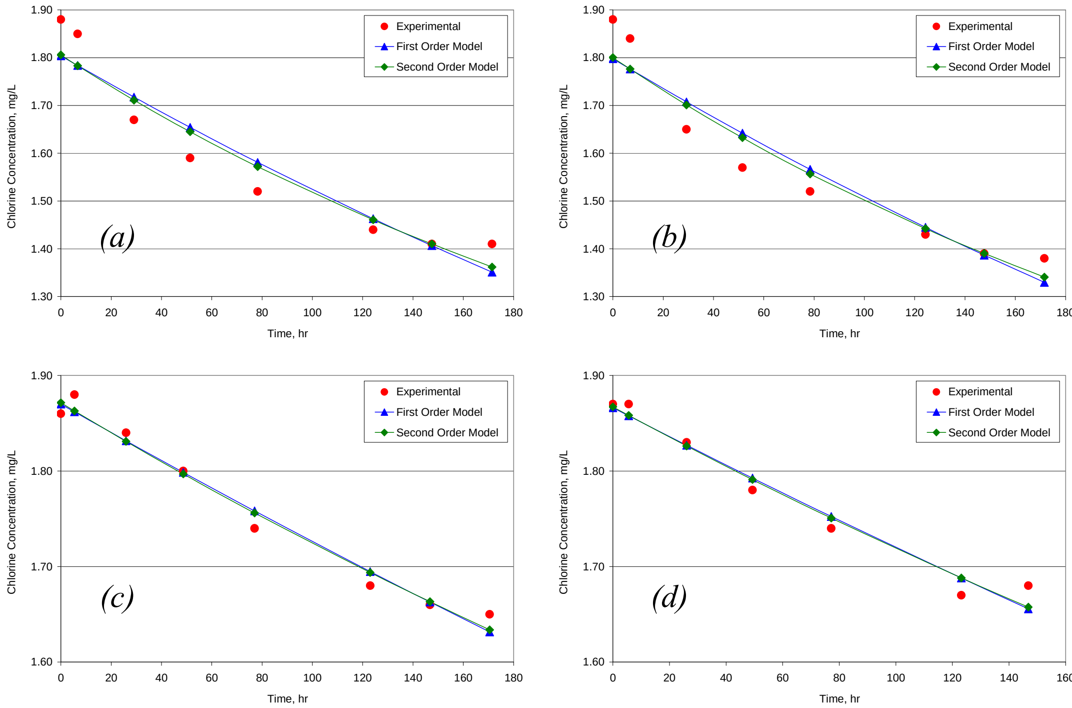

Figure 29 Comparison of the measured and predicted chloramine concentrations. Water bottle tests of site 2, (a) glass bottles, 19.3°C, (b) plastic (HDPE) bottles, 19.3°C, (c) glass bottles, 3.0°C and (d) plastic (HDPE) bottles, 3.0°C.

Table 23 The bulk decay coefficients and the initial chloramine concentrations of the bottle tests of site 3 for the first and the second order models.

Test Temperature (°C)	Bottle Type	First Order Model			Second Order Model		
		First Order k_b (hr^{-1})	C_o (mg/L)	R^2	Second Order k_b ($(mg*hr/L)^{-1}$)	C_o (mg/L)	R^2
19.3	Glass	1.63E-03	1.34	0.94	1.37E-03	1.34	0.95
	Plastic	1.59E-03	1.34	0.95	1.34E-03	1.34	0.97
3.0	Glass	9.50E-04	1.39	0.96	7.35E-04	1.39	0.96
	Plastic	6.23E-04	1.38	0.97	4.73E-04	1.39	0.97

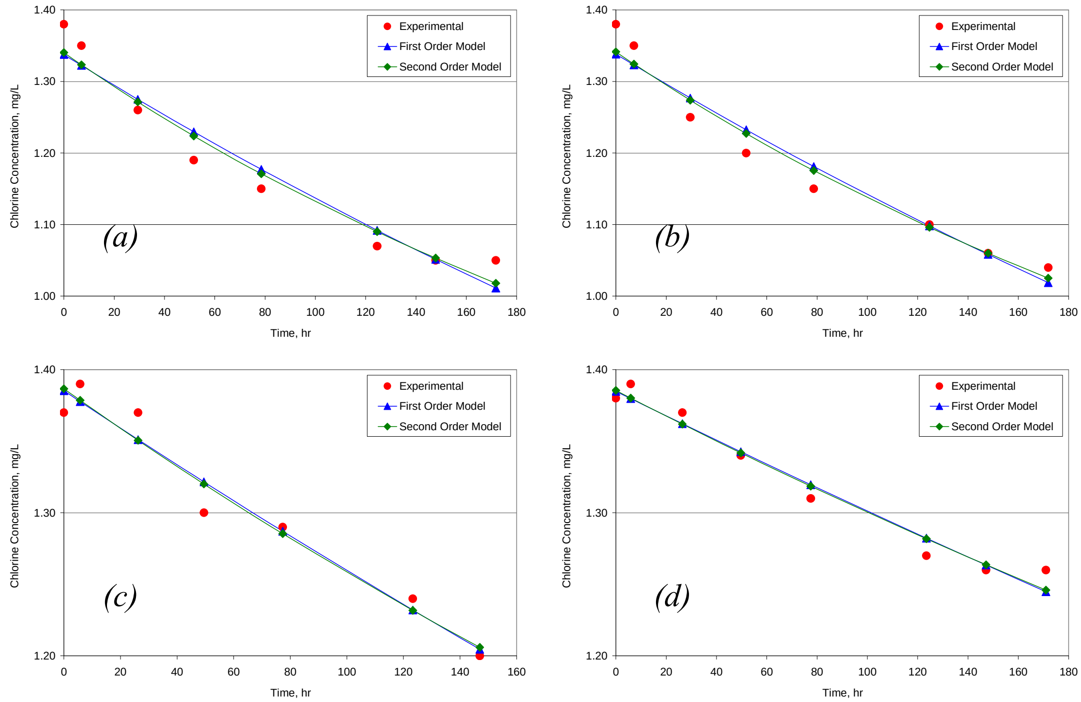

Figure 30 Comparison of the measured and predicted chloramine concentrations. Water bottle tests of site 3, (a) glass bottles, 19.3°C, (b) plastic (HDPE) bottles, 19.3°C, (c) glass bottles, 3.0°C and (d) plastic (HDPE) bottles, 3.0°C.

Table 24 The 95% confidence intervals of the bulk decay coefficients determined for the first order model.

Site Number	Test Temperature (°C)	Bottle Type	First Order k_b (hr^{-1})	Lower 95% CI (hr^{-1})	Upper 95% CI (hr^{-1})
1	19.3	Glass	2.27E-03	1.19E-03	3.35E-03
		Plastic	2.92E-03	1.80E-03	4.04E-03
	3.0	Glass	1.25E-03	9.87E-04	1.51E-03
		Plastic	9.58E-04	6.73E-04	1.24E-03
2	19.3	Glass	1.69E-03	1.14E-03	2.23E-03
		Plastic	1.76E-03	1.21E-03	2.30E-03
	3.0	Glass	8.00E-04	6.77E-04	9.23E-04
		Plastic	8.15E-04	6.36E-04	9.94E-04
3	19.3	Glass	1.63E-03	1.22E-03	2.04E-03
		Plastic	1.59E-03	1.24E-03	1.93E-03
	3.0	Glass	9.50E-04	7.29E-04	1.17E-03
		Plastic	6.23E-04	5.08E-04	7.38E-04

Table 25 The 95% confidence intervals of the bulk decay coefficients determined for the second order model.

Site Number	Test Temperature (°C)	Bottle Type	Second Order k_b $((mg*hr/L)^{-1})$	Lower 95% CI $((mg*hr/L)^{-1})$	Upper 95% CI $((mg*hr/L)^{-1})$
1	19.3	Glass	1.32E-03	7.60E-04	1.88E-03
		Plastic	1.67E-03	1.10E-03	2.24E-03
	3.0	Glass	6.80E-04	5.33E-04	8.28E-04
		Plastic	5.03E-04	3.60E-04	6.46E-04
2	19.3	Glass	1.05E-03	7.52E-04	1.36E-03
		Plastic	1.11E-03	8.16E-04	1.40E-03
	3.0	Glass	4.56E-04	3.90E-04	5.22E-04
		Plastic	4.61E-04	3.63E-04	5.60E-04
3	19.3	Glass	1.37E-03	1.07E-03	1.68E-03
		Plastic	1.34E-03	1.09E-03	1.58E-03
	3.0	Glass	7.35E-04	5.68E-04	9.02E-04
		Plastic	4.73E-04	3.88E-04	5.57E-04

4.2.6.1 Comparison between Glass and Plastic (HDPE) Bottles

Theoretically, if the 95% confidence intervals of two bulk decay coefficients overlap, then the two coefficients can be considered the same with 95% confidence.

In the two field sampling programs conducted in July and October 2011, plastic (HDPE) bottles were used to collect the water samples at all sample sites and all water samples were stored at 4±2°C until they were tested. It was assumed that the plastic (HDPE) bottles did not have any chlorine demand. This assumption could be checked by comparing the bulk decay coefficients for glass bottles with those determined for plastic (HDPE) bottles.

Figure 31, Figure 32 and Figure 33 show the comparison of the first order bulk decay coefficients for glass and plastic (HDPE) bottles for sites 1, 2 and 3, respectively. Figure 34, Figure 35 and Figure 36 show similar plots but for the second order bulk decay coefficients. Note that the first, second and third point (from left to right) in all plots represent the lower 95% confidence interval, the mean (i.e., the bulk decay coefficient) and the upper 95% confidence interval, respectively.

Examination of the six figures (twelve plots) indicates that the confidence intervals in each plot overlapped with each another, with the only exception of the plot in Figure 36(b), i.e., site 3 at a water temperature of 3°C. The exception was considered as an outlier to the general trend (one out of twelve) and was neglected.

Therefore, it can be concluded that the plastic (HDPE) bottles used for water sampling have no chlorine demand. Thus for the purpose of this study, the plastic (HDPE) bottles and glass bottles could be used interchangeably.

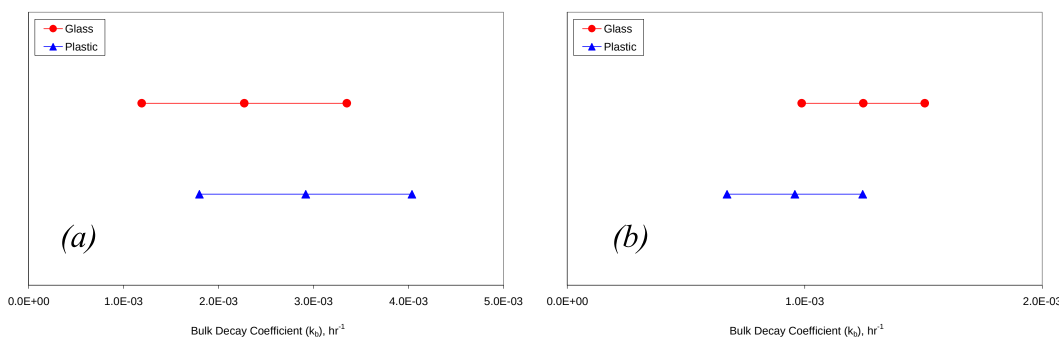

Figure 31 Confidence intervals of the first order bulk decay coefficients determined for glass and plastic (HDPE) water bottle tests at site 1 and stored at (a) 19.3°C and (b) 3.0°C.

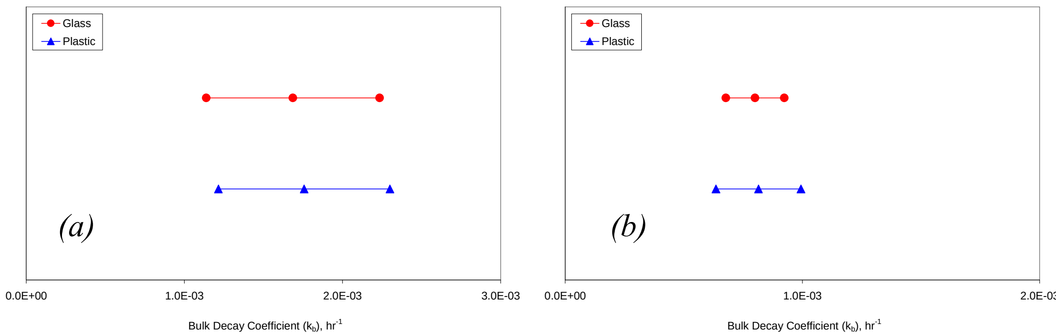

Figure 32 Confidence intervals of the first order bulk decay coefficients determined for glass and plastic (HDPE) water bottle tests conducted at site 2 and stored at (a) 19.3°C and (b) 3.0°C.

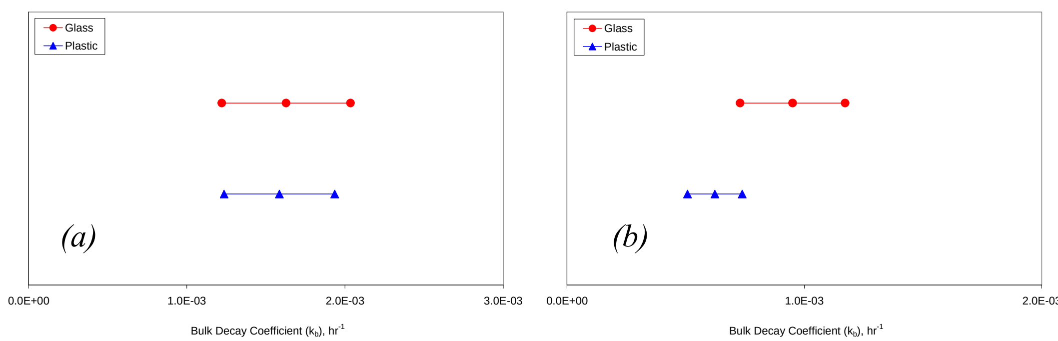

Figure 33 Confidence intervals of the first order bulk decay coefficients determined for glass and plastic (HDPE) water bottle tests conducted at site 3 and stored at (a) 19.3°C and (b) 3.0°C.

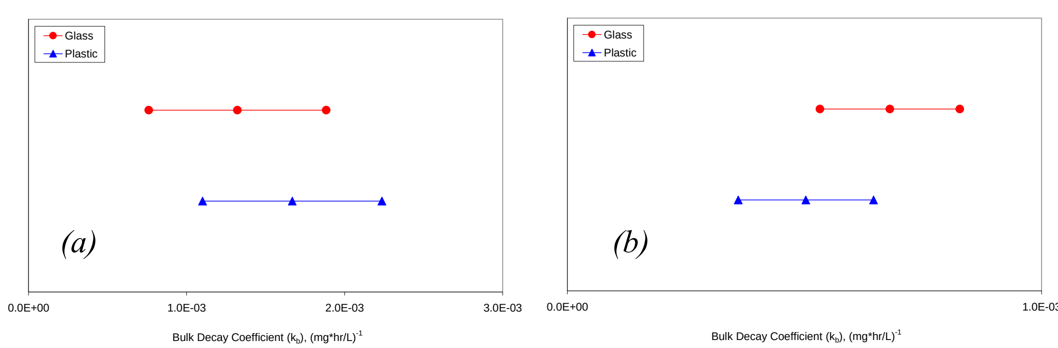

Figure 34 Confidence intervals of the second order bulk decay coefficients determined for glass and plastic (HDPE) water bottle tests conducted at site 1 and stored at (a) 19.3°C and (b) 3.0°C.

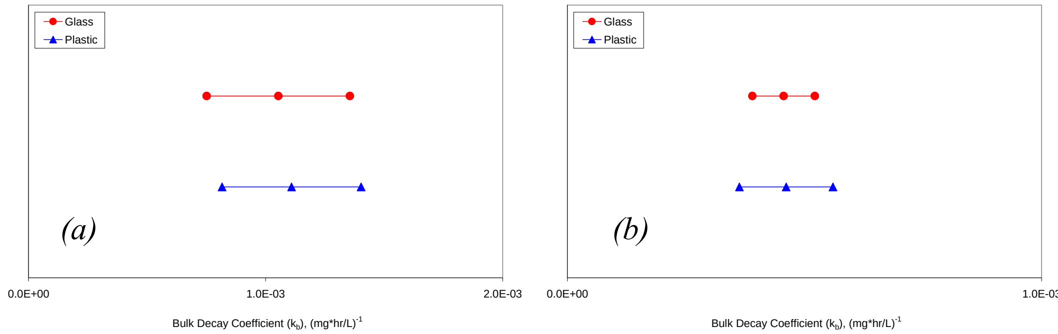

Figure 35 Confidence intervals of the second order bulk decay coefficients determined for glass and plastic (HDPE) water bottle tests conducted at site 2 and stored at (a) 19.3°C and (b) 3.0°C.

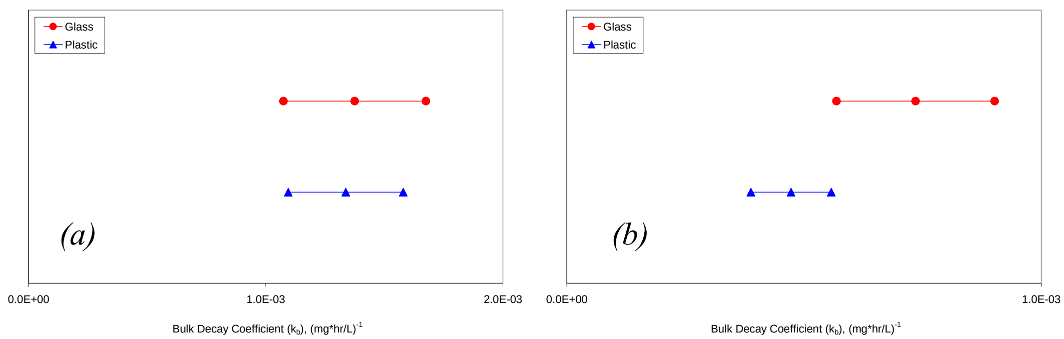

Figure 36 Confidence intervals of the second order bulk decay coefficients determined for glass and plastic (HDPE) water bottle tests conducted at site 3 and stored at (a) 19.3°C and (b) 3.0°C.

4.2.6.2 Comparison between Sites

The bulk decay coefficients are compared between the three sites to determine whether or not the bulk decay coefficient is constant throughout the Study Area. Figure 37 compares the first order bulk decay coefficients obtained from the three sites for the glass and plastic (HDPE) bottles stored at either 3°C or 19.3°C. Figure 38 shows similar plots for the second order bulk decay coefficients.

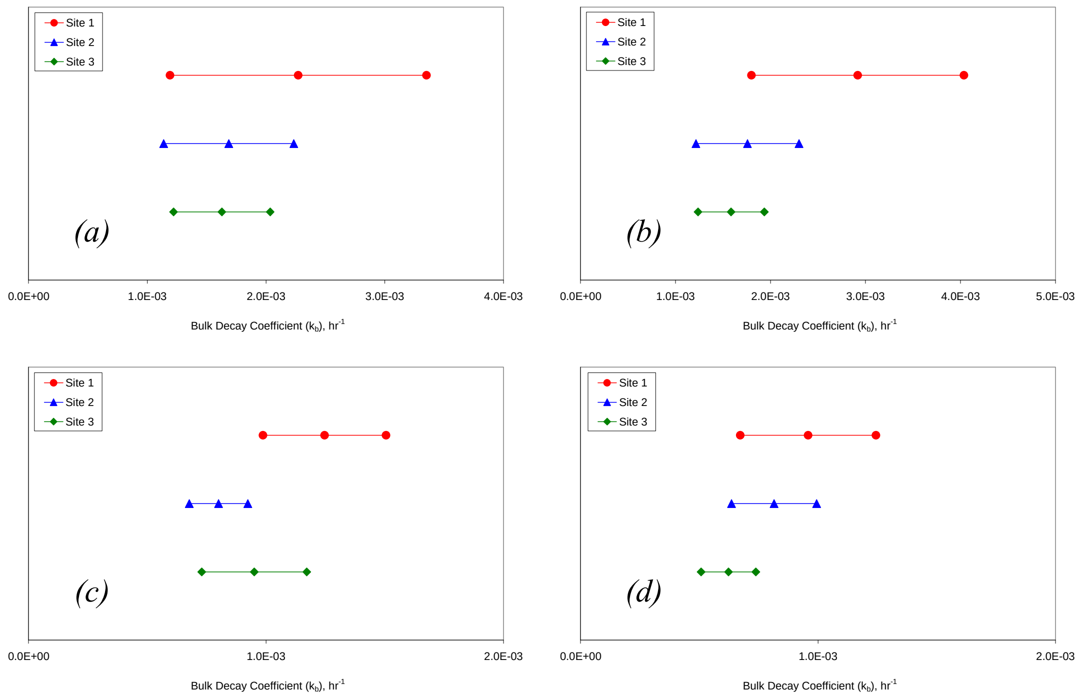

Figure 37 Confidence intervals of the first order bulk decay coefficients determined for the bottle tests of all three sites conducted using water samples that were collected (a) in glass bottles and stored at 19.3°C, (b) in plastic (HDPE) bottles and stored at 19.3°C, (c) in glass bottles and stored at 3.0°C and (d) in plastic (HDPE) bottles and stored at 3.0°C.

Figure 37 (b) and (d) are plots of the confidence intervals of the first order bulk decay coefficients for the water samples collected in plastic (HDPE) bottles and stored at 19.3°C and 3.0°C, respectively. Figure 38 (b) and (d) are plots of the confidence intervals of the second order bulk decay coefficients for the same water samples. On each of these plots, all three confidence intervals overlapped one another, which suggests that the bulk decay coefficients, determined using water samples collected in plastic (HDPE) bottles, are the same between the three sites for both the first and the second order models.

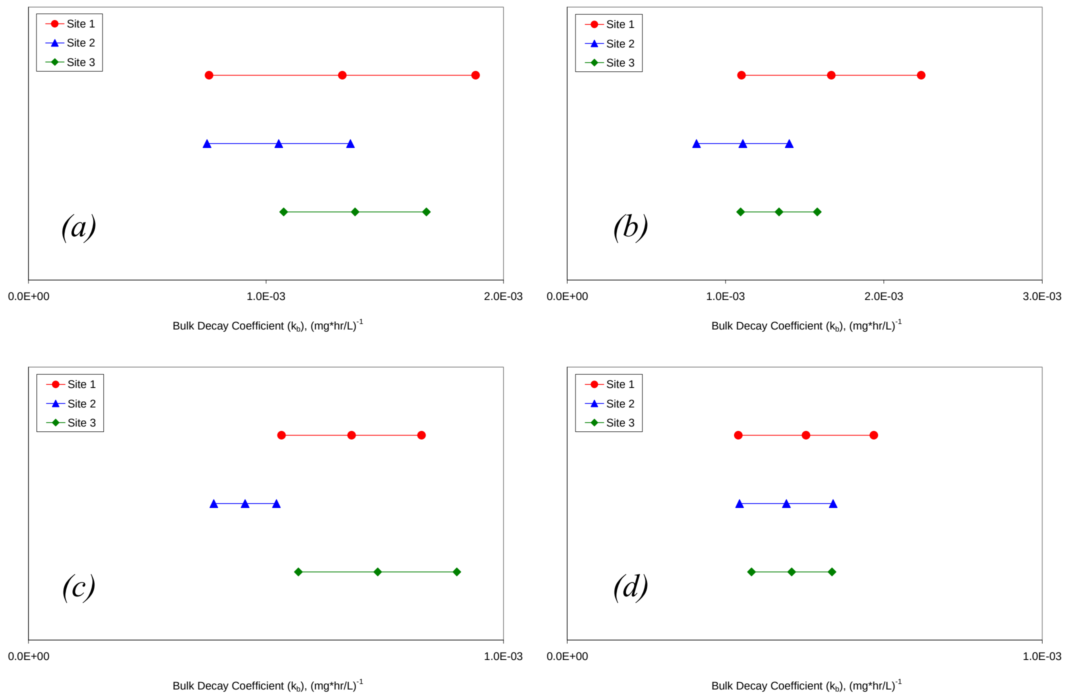

Figure 38 Confidence intervals of the second order bulk decay coefficients determined for the bottle tests of all three sites conducted using water samples that were collected (a) in glass bottles and stored at 19.3°C, (b) in plastic (HDPE) bottles and stored at 19.3°C, (c) in glass bottles and stored at 3.0°C and (d) in plastic (HDPE) bottles and stored at 3.0°C.

Figure 37 (a) and (c) are plots of the confidence intervals of the first order bulk decay coefficients for the water samples collected in glass bottles and stored at 19.3°C and 3.0°C, respectively. Figure 38 (a) and (c) are plots of the confidence intervals of the second order bulk decay coefficients for the same water samples. The three confidence intervals on each of Figure 37 (a) and Figure 38 (a) have overlapped one another, which suggests that the bulk decay coefficients, determined using water samples collected in glass bottles and stored at 19.3°C, are the same between the three sites for both the first and the second order model.

However, the confidence intervals for water samples collected with glass bottles and stored at 3°C from site 2 do not overlap with those of site 1 (Figure 37 (c), first order bulk decay coefficients), or with those from either site 1 or site 3 (Figure 38 (c), second order bulk decay coefficients). It is therefore not conclusive if the bulk decay coefficients determined from glass water bottles stored at 3°C is the same throughout the Study Area. However, such a conclusion does not affect the current study as the water samples were all collected with plastic (HDPE) bottles in the field sampling programs, which have been shown to be consistent in the foregoing discussion.

The bulk decay coefficients obtained from glass bottles were used in the extracted SynerGEE Water hydraulic model for the Study Area to calibrate the wall decay coefficients. The details are described in section 4.3.2.1.

4.3 Modeling Study

Through the bottle tests described in the previous section, the bulk decay coefficients for the water supplied to the Study Area were determined. These coefficients were used in the SynerGEE Water hydraulic model for the Study Area to calibrate the wall decay coefficient. Before such calibration could be conducted, model input parameters were selected.

Section 3.1 described in detail the methodologies used to extract the SynerGEE Water hydraulic model for the Study Area, and to update pipe material and demands in the extracted hydraulic model. In addition to those updates, valves in the water distribution system were not represented in the hydraulic models, which was equivalent to the state that all valves were open. The status of all valves in the Study Area on July 28 and 29, and October 5 and 6, 2011 were checked, and it was found that all valves were indeed open on the indicated dates. Thus, no changes regarding valves were made to the models.

4.3.1 Temperature Dependent Parameters

The average water temperatures in the July and October, 2011 field sampling programs were found to be 17.4°C and 12.9°C, respectively (section 4.1.3.3 and section 4.1.4.2). Thus, the hydraulic model was set to 17.4°C for the simulation of water samples for July 28 and 29, 2011, and to 12.9°C for October 5 and 6, 2011.

In the SynerGEE Water hydraulic model, there is no option to set the model temperature directly. Instead, the model requires the manual input of several parameters whose values are temperature dependent. The default model temperature in SynerGEE Water is 15.6°C (GL Industrial Services USA, Inc., 2010), so that all the values of the temperature dependent parameters in the model are default to values at this temperature. In order to set the July and the October models to their respective temperatures, the temperature dependent parameters were changed accordingly.

The following sections describe the method with which each temperature dependent parameter was determined for 12.9°C and 17.4°C. Linear interpolation was used when necessary.

4.3.1.1 Specific Gravity of Water

The SynerGEE model requires the input of the specific gravity of water. Table 26 lists the densities of water at temperatures from 0°C to 20°C. The water density at 12.9°C was interpolated using the water densities at 10°C and 15°C, and that at 17.4°C was interpolated using the water densities at 15°C and 20°C. The results are tabulated in Table 27. Next, the specific gravity of water at 12.9°C and 17.4°C are calculated by dividing the water density at each temperature by the water density at 5°C, which is 1000 kg/m^3 as shown in Table 26. The results are also tabulated in Table 27. The specific gravity was expressed to 4 decimal places as required in SynerGEE Water hydraulic model.

Table 26 Densities of water at temperatures from 0°C to 20°C (values taken from Appendix A of SynerGEE Water 4.5.1 User Guide).

Temperature (°C)	Density (kg/m^3)
0	999.9
5	1000.0
10	999.7
15	999.1
20	998.2

Table 27 The densities and the specific gravities of water at 12.9°C and 17.4°C.

Temperature (°C)	Density (kg/m^3)	Specific Gravity
12.9	999.4	0.9994
17.4	998.7	0.9987

4.3.1.2 Kinematic Viscosity of Water

Table 28 lists the kinematic viscosities of water at temperatures from 0°C to 20°C. The kinematic viscosity of water at 12.9°C was interpolated using the values at 10°C and 15°C, and that at 17.4°C was interpolated using the values at 15°C and 20°C. The results are tabulated in Table 29.

Table 28 The kinematic viscosities of water at temperatures from 0°C to 20°C (values taken from Appendix A of SynerGEE Water 4.5.1 User Guide).

Temperature (ºC)	Kinematic Viscosity (10^{-6} m^2/s)
0	1.792
5	1.519
10	1.308
15	1.141
20	1.007

Table 29 The kinematic viscosities of water at 12.9°C and 17.4°C.

Temperature (ºC)	Kinematic Viscosity (10^{-6} m^2/s)
12.9	1.211
17.4	1.077

4.3.1.3 Barometric Pressure Head

One standard atmosphere pressure is equal to 760 mmHg or Torr, which is the pressure exerted by a 760 mm mercury column given that the density of mercury is 13.5951 g/cm^3 (at 0°C), and that the gravitation constant is 9.80665 m/s^2 (Lide, 1997). The barometric pressure head required by SynerGEE Water hydraulic model is essentially the equivalent height of a column of water that exerts one standard atmosphere pressure when the density of water is at the specified model temperature. The barometric pressure heads of water at 12.9°C and 17.4°C were calculated and tabulated in Table 30. The water densities were taken from Table 27.

Table 30 The barometric pressure heads of water at 12.9°C and 17.4°C.

Temperature (°C)	Density (kg/m^3)	Barometric Pressure Head (m)
12.9	999.4	10.34
17.4	998.7	10.35

4.3.1.4 Molecular Diffusivity of Chloramine in Water

The SynerGEE model requires the molecular diffusivity of combined chlorine in water for water quality analysis. This parameter is temperature dependent. For this study, the values at 12.9°C and 17.4°C were required. An extensive search was performed to find the values at the two specified temperatures. It was found that there were very few values for free chlorine, and even less for combined chlorine. The values were only reported for 20°C and 25°C.

In this study, in order to improve the reliability of the wall decay coefficient, the values at the two specified temperatures were estimated and used in modeling. The values were estimated using the Hayduk and Laudie method as described in the Handbook of Chemical Property Estimation Methods. The following description draws heavily from this book.

The Hayduk and Laudie method is usually used to estimate the diffusivity of organic compounds in water. Nevertheless, it can be used to estimate the values for other chemicals as well (US EPA, 2012).

This method is expressed by Equation 22:

$$d = \frac{13.26 \times 10^{-5}}{\eta_W{}^{1.14} V_B'^{\,0.589}} \qquad \text{Equation 22}$$

Where d = molecular diffusivity of a chemical in water (cm^2/s)

η_W = dynamic viscosity of water (cp)

V_B' = LeBas molar volume of chemical (cm^3/mol)

Table 31 lists the dynamic viscosities of water at temperatures from 0°C to 20°C. The dynamic viscosity of water at 12.9°C was interpolated using the values at 10°C and 15°C and that at 17.4°C was interpolated using the values at 15°C and 20°C. The interpolated values are shown Table 33.

Table 31 The dynamic viscosities of water at temperatures from 0°C to 20°C (adapted from Lyman et al., 1990).

Temperature (°C)	Dynamic Viscosity (cp)
0	1.787
5	1.519
10	1.307
15	1.139
20	1.002

Table 32 The additive volume increments for calculating LeBas molar volume (adapted from Lyman et al., 1990).

Atom	Increment (cm^3/mol)
H	3.7
N (in primary amines)	10.5
Cl	24.6

Table 33 The LeBas molar volume of chloramine, the dynamic viscosities of water and the molecular diffusivity of chloramine in water at 12.9°C and 17.4°C.

Temperature (°C)	Dynamic Viscosity (cp)	LeBas Molar Volume (cm^3/mol)	Molecular Diffusivity (cm^2/s)
12.9	1.210	42.5	1.17E-05
17.4	1.073		1.34E-05

The most dominant form of combined chlorine is chloramine in the water distribution system of the City of Edmonton, as discussed earlier (EWSI, 2011). Thus, the LeBas molar volume of chloramine was calculated and assumed to be that for combined chlorine. Chloramine has the molecular formula NH_2Cl, and it was assumed to resemble a primary amine in which one of its hydrogen atoms is substituted by a chlorine atom (Petrucci et al., 2002). The data in Table 32 was used to calculate the LeBas molar volume of chloramine and the resulting value is shown in Table 33.

After the dynamic viscosities of water at 12.9°C and 17.4°C and the LeBas molar volume of chloramine were determined, the molecular diffusivity of chloramine in water at 12.9°C and 17.4°C were calculated using Equation 22. The results are shown in Table 33.

4.3.2 Bulk Decay Coefficients

4.3.2.1 Bulk Decay Coefficients at 12.9°C and 17.4°C

In this study, the bulk chloramine decay was accounted for in the calibration of the wall decay coefficient. The bulk decay coefficient is associated with the sources of water. All three boundaries in the Study Area act as inflows into the area in both the July and October, 2011 hydraulic models. Therefore, the bulk decay coefficients of all three boundaries were required as model inputs.

From the bulk chloramine decay experiments (section 4.2), the bulk decay coefficients at 3.0°C and 19.3°C were determined for both inflows 1 and 2 (note that inflow 3 is the same as inflow 1). The first order bulk decay coefficients of inflow 1 obtained from water samples collected in glass bottles, shown in Table 34, were used to calculate the bulk decay coefficients at 12.9°C and 17.4°C for inflow 1.

Table 34 The first order bulk decay coefficients of inflow 1 at 3.0°C and 19.3°C.

Temperature (°C)	Temperature (K)	First Order k_b (hr^{-1})
3.0	276.0	1.25E-03
19.3	292.3	2.27E-03

The Arrhenius equation (Equation 15, page 52) was transformed into the logarithmic form to eliminate the constant *A*, as shown in Equation 23.

$$\ln\frac{k_2}{k_1} = \frac{E_a}{R}\left(\frac{1}{T_1} - \frac{1}{T_2}\right) \qquad \text{Equation 23}$$

Where k_1 = Rate constant at T_1

k_2 = Rate constant at T_2

E_a = Activation energy (J/mol)

R = Gas constant (8.3145 J/(mol·K))

T_1 = Temperature of k_1 (K)

T_2 = Temperature of k_2 (K)

By substituting the data at two temperatures in Table 34 into Equation 23, the activation energy E_a is calculated to be 24,700 J/mol.

Next, using the activation energy obtained and the bulk decay coefficient at 3.0°C, the bulk decay coefficients at 12.9°C and 17.4°C were calculated by Equation 23. The calculated values were checked using the bulk decay coefficient at 19.3°C. The results are tabulated in Table 35.

Table 35 The calculated first order bulk decay coefficients of inflow 1 at 12.9°C and 17.4°C.

Temperature (°C)	Temperature (K)	First Order k_b* (hr^{-1})	First Order k_b Check** (hr^{-1})
12.9	285.9	1.81E-03	1.81E-03
17.4	290.4	2.13E-03	2.13E-03

*calculated using k_b at 3.0°C

**calculated using k_b at 19.3°C

The same procedure was used to calculate the second order bulk decay coefficients of inflow 1. The values in Table 36 are used for calculations and the results are tabulated in Table 37.

Table 36 The second order bulk decay coefficients of inflow 1 at 3.0°C and 19.3°C and the resulting activation energy.

Temperature (°C)	Temperature (K)	Second Order k_b ($(mg*hr/L)^{-1}$)	Activation Energy, E_a (J/mol)
3.0	276.0	6.80E-04	2.73E+04
19.3	292.3	1.32E-03	

Table 37 The calculated second order bulk decay coefficients of inflow 1 at 12.9°C and 17.4°C.

Temperature (°C)	Temperature (K)	Second Order k_b ($(mg*hr/L)^{-1}$)
12.9	285.9	1.03E-03
17.4	290.4	1.23E-03

The results in Table 35 and Table 37 were taken as the bulk decay coefficients of inflow 3 as well.

The bulk decay coefficients of inflow 2 were determined in the same way. The values in Table 38 are used for calculations and the results are tabulated in Table 39.

Table 38 The first and second order bulk decay coefficients of inflow 2 at 3.0°C and 19.3°C and the resulting activation energies.

Temperature (°C)	Temperature (K)	First Order Model		Second Order Model	
		First Order k_b (hr^{-1})	Activation Energy, E_a (J/mol)	Second Order k_b ($(mg*hr/L)^{-1}$)	Activation Energy, E_a (J/mol)
3.0	276.0	8.00E-04	3.07E+04	4.56E-04	3.45E+04
19.3	292.3	1.69E-03		1.05E-03	

Table 39 The calculated first and the second order bulk decay coefficients of inflow 2 at 12.9°C and 17.4°C.

Temperature (°C)	Temperature (K)	First Order k_b (hr^{-1})	Second Order k_b ($(mg*hr/L)^{-1}$)
12.9	285.9	1.27E-03	7.67E-04
17.4	290.4	1.55E-03	9.60E-04

4.3.2.2 Testing the Bulk Decay Coefficients in the Models

The first and second order bulk decay coefficients of inflows 1 and 2 were used to simulate the bulk chloramine decay in the extracted and updated SynerGEE Water hydraulic models for the Study Area prepared for the July and the October, 2011 datasets, prior to calibrating the wall decay coefficients. The July, 2011 model was run both with the first and second order bulk decay coefficients at 17.4°C and without any bulk decay coefficients. The simulated chloramine concentrations at all nodes and pipes from the three model runs are compared. The same process was carried out to the October, 2011 model, using the bulk decay coefficients at 12.9°C. The wall decay coefficient was set to zero in these simulations.

The calculated chloramine concentrations for all nodes and pipes from both the July and October model runs are presented in Appendix I. The results indicated that for each of the July and October, 2011 model runs, using first and second order bulk decay coefficients generated approximately the same results for almost all nodes and pipes. However, the results were different when no bulk decay was considered in the model runs.

Based on these observations, only the first order bulk decay coefficients were used in the model when calibrating the wall decay coefficients.

4.4 Determination of Wall Decay Coefficients

4.4.1 Modifying July and October 2011 Datasets

In both sampling programs carried out on July 28 and 29, and October 5 and 6, 2011, there were some delays in measuring the chloramine concentrations of the water samples due to the large number of samples collected and the availability of only one chlorine measurement kit. The measured chloramine concentrations of all water samples were therefore adjusted using the bulk decay coefficients to improve their accuracies.

All water samples in both sampling programs were collected in plastic (HDPE) bottles and stored at 4±2°C until testing. Therefore, the bulk decay coefficients obtained using water samples that were collected in plastic (HDPE) bottles and stored at 3.0°C were used to adjust the measured chloramine concentrations. Table 40 shows the first and the second order bulk decay coefficients of all three sites and their average values (plastic (HDPE) bottles, 3ºC). These values were obtained from Table 24 and Table 25 on page 94. The measured chloramine concentration of each water sample was “extrapolated” to the chloramine concentration at the time when the sample was collected using the average bulk decay coefficients and the elapsed time. The extrapolated chloramine concentration was used as the “true” chloramine concentration at the time of sample collection. The adjusted chloramine concentrations are shown together with the raw data of the July and the October, 2011 sampling programs, in Appendix D and Appendix E, respectively.

Table 40 The first and the second order bulk decay coefficients at 3.0°C (plastic (HDPE) bottles) and their average values.

Site Number	First Order Model		Second Order Model	
	First Order k_b (hr^{-1})	Average k_b (hr^{-1})	Second Order k_b ($(mg*hr/L)^{-1}$)	Average k_b ($(mg*hr/L)^{-1}$)
1	9.58E-04	7.99E-04	5.03E-04	4.79E-04
2	8.15E-04		4.61E-04	
3	6.23E-04		4.73E-04	

The adjusted chloramine concentrations using the first and the second order average bulk decay coefficients are about the same for all water samples. Therefore, only the values adjusted using the first order average bulk decay coefficient were used to calibrate the wall decay coefficients. Table 41 and Table 42 show the original and the adjusted average chloramine concentrations at all sample sites for the July and the October sampling programs, respectively.

All water samples in the July sampling program were tested within 24 hours after collection. From Table 41, it can be seen that the differences between the original and the extrapolated values range from 0 to 0.02 mg/L. This indicates that the chloramine in the water samples remained fairly stable within the 24-hour storage period. All modified chloramine concentrations of the July sampling program were used to calibrate the wall decay coefficients.

Table 41 The original and the modified average chloramine concentrations of the July field sampling program.

Inflow/Quadrant Number	Sampling Site Number	Thursday, July 28, 2011		Friday, July 29, 2011	
		Average Chloramine Concentration (mg/L)	Average Chloramine Concentration After Adjustment (mg/L)	Average Chloramine Concentration (mg/L)	Average Chloramine Concentration After Adjustment (mg/L)
Inflow 1	1	1.61	1.62	1.72	1.74
Inflow 2	2	1.35	1.36	1.45	1.45
Inflow 3	3	1.61	1.62	1.72	1.74
Quadrant 4 (West Side)	4	1.28	1.29	1.32	1.32
	5	1.59	1.61	-	
	6	1.51	1.52	-	
	7	-		1.55	1.55
	8	1.41	1.42	1.53	1.53
	9	1.33	1.34	-	
	10	1.19	1.20	-	
Quadrant 1 (West Side)	11	1.06	1.06	-	
	12	1.18	1.19	-	
	13	0.90	0.90	-	
	14	0.98	0.99	-	
	15	0.93	0.94	-	
	16	-		0.88	0.88
	17	-		1.55	1.56
Quadrant 3 (East Side)	18	-		1.72	1.73
	19	1.44	1.44	-	
	20	1.26	1.27	1.30	1.32
	21	1.29	1.30	-	
Quadrant 2 (East Side)	22	1.41	1.43	-	
	23	-		1.40	1.42
	24	1.44	1.46	1.55	1.57

Table 42 The original and the modified average chloramine concentrations of the October field sampling program.

Inflow/Route Number	Sampling Site Number	Wednesday, October 5, 2011		Thursday, October 6, 2011	
		Average Chloramine Concentration* (mg/L)	Average Chloramine Concentration After Adjustment** (mg/L)	Average Chloramine Concentration* (mg/L)	Average Chloramine Concentration After Adjustment** (mg/L)
Inflow 1	1	1.91	1.92	1.89	1.90
Inflow 2	2	1.75	1.76	1.75	1.76
Inflow 3	3	1.90	1.91	1.90	1.91
Route 2 (West Side)	4	1.84	1.87	*1.86*	1.89
	5	1.89	1.92	1.86	1.88
	6	1.88	1.89	-	
	7	1.84	1.85	1.68	1.70
	8	1.75	1.77	-	
	9	*1.72*	1.80	1.76	1.77
	10	-		*1.77*	1.82
	11	1.71	1.74	-	
	12	1.35	1.36	1.55	1.57
Route 1 (West Side)	13	1.63	1.64	1.64	1.65
	14	-		*1.67*	1.72
	15	1.66	1.68	1.66	1.68
	16	1.60	1.61	-	
	17	-		1.61	1.62
	18	1.47	1.49	1.53	1.55
	19	1.43	1.44	-	
	20	-		*1.48*	1.51
	21	1.30	1.31	1.43	1.44
	22	1.22	1.23	1.34	1.36
	23	1.20	1.21	-	
	24	1.16	1.17	*1.33*	1.35
	25	1.12	1.14	*1.29*	1.32
	26	1.11	1.13	-	
	27	1.11	1.12	1.17	1.18
Route 3 (East Side)	28	-		*1.88*	1.92
	29	-		*1.86*	1.90
	30	1.81	1.83	-	
	31	1.72	1.74	-	
	32	1.73	1.75	1.78	1.79
	33	1.53	1.55	1.51	1.53
	34	1.36	1.37	-	
	35	1.54	1.56	*1.55*	1.58
	36	1.65	1.67	-	

Note:
*regular font: water samples were tested within 24 hours after collection
*italicized font: water samples were tested longer than 24 hours after collection
**regular font: data included in calibration
**red font: data excluded from calibration

From Table 42, it can be seen that the differences between the original and the modified values range from 0 to 0.08 mg/L. While most of the water samples in the October sampling program were tested within 24 hours after collection, some of the samples were tested after a 24-hour storage period. The chloramine concentrations for these samples are marked with italicized fonts in Table 42. All modified chloramine concentrations of the October sampling program were used to calibrate the wall decay coefficients, except for the three values marked in red, as shown in Table 42. The first value is the chloramine concentration at site 9 on October 5. Site 8 to 11 were located on one pipe, as shown in Figure 39. Thus, the concentration at site 9 should be between those at site 8 and 11. However, the actual value was higher than the values at both site 8 and 11, which makes it questionable. As a result, it was excluded from calibration. The second value is the chloramine concentration at site 10 on October 6. Figure 39 shows that site 9 and 10 were at the same point in the water distribution system. However, their chloramine concentrations were somewhat different. Since the samples of site 9 was tested within 24 hours and the samples of site 10 was tested after 24 hours, the concentration at site 9 should be more reliable. Thus, the value at site 10 was excluded from calibration. The third value is the chloramine concentration at site 28 on October 6. Site 28 was close to inflows 1 and 3, as shown in Figure 40. The chloramine concentration at site 28 was higher than those at inflow 1 and 3, which is possible due to measurement variability. However, in modeling, the concentrations at the inflows would be the highest in the area. As a result, the value at site 28 was excluded from calibration.

To avoid confusion, although the adjusted chloramine concentrations were used in the wall decay coefficient calibration, in the following description, the phrase “measured chloramine concentrations” was used rather than “adjusted chloramine concentrations”.

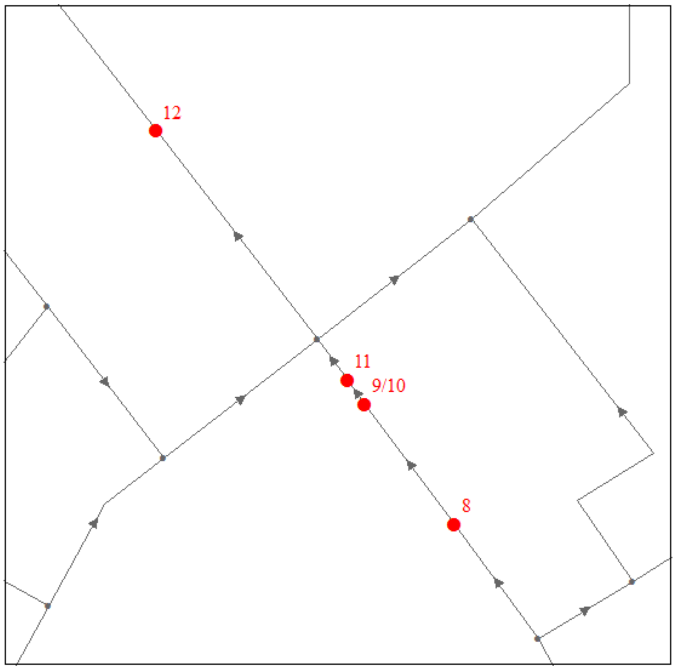

Figure 39 Map of Site 8 to 12 of October 2011 field sampling program.

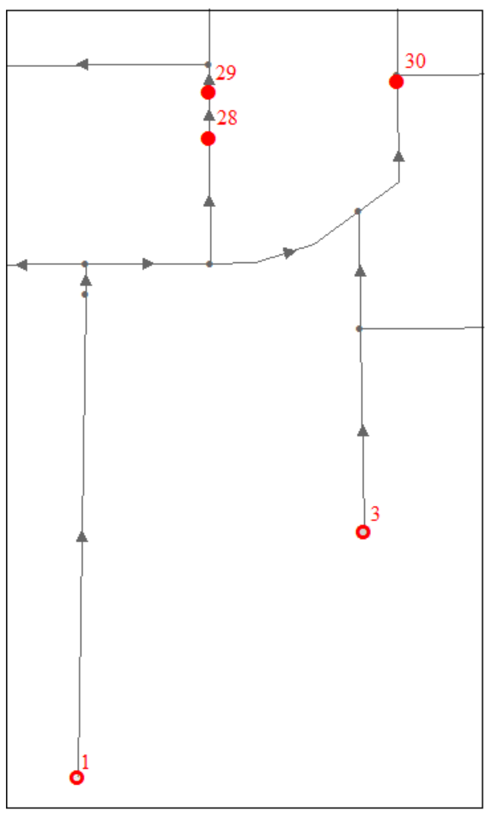

Figure 40 Map of Site 1, 3, 28, 29 and 30 of October 2011 field sampling program.

4.4.2 Determining the Wall Decay Coefficient at 12.9°C

4.4.2.1 Determining the Wall Decay Coefficient using October 5 Data

The measured chloramine concentrations from the October 5, 2011 field sampling were used to calibrate a wall decay coefficient for the Study Area. Since the average water temperature on October 5, 2011 was 12.9°C, the calibrated coefficient was for this temperature. The measured chloramine concentrations from the October 6, 2011 field sampling were used to validate the calibrated wall decay coefficient.

Prior to calibration, the October model was set up for water quality modeling. There were thirty-six sampling sites in the October sampling program with twenty-nine sites on October 5, 2011 and twenty-three sites on October 6, 2011. In the October model, the chloramine concentrations of the three sites at the inflows were entered and the locations of the other thirty-three sites were geo-coded. All sites were represented as nodes in the model. The initial chloramine concentrations and the initial water ages at all nodes and pipes were set to zero. Also, the bulk decay coefficient was set to be associated with sources and the first order bulk decay coefficients at all three inflows (Table 37 and Table 39, page 108) were entered into the model. The wall decay coefficient was set to first order.

The wall decay coefficient was assumed to be the same for all pipes in the Study Area, regardless of their material types. The calibration was "manual", which involved entering a trial wall decay coefficient into the model, running the water quality model simulation, exporting the predicted chloramine concentrations of the twenty-six sites out of the model, and comparing these values to the measured values using the least squares criteria. The value that resulted in the least sum of squared residuals (SSR) between the predicted and the measured chloramine concentrations was the wall decay coefficient. When such a wall decay coefficient was identified, the model calculation was considered "converged".

The model was tested for convergence by assuming a total of forty-three wall decay coefficient values, ranging from 0 to 100 m/d. The model calculation results are summarized in Table 43 and plotted from Figure 41 to Figure 44. From the table and the figures, it can be seen that using the least squares criteria, the calibration had an absolute minimum, or a unique solution, which gave a unique wall decay coefficient. In this case, the model converged at the value of 0.0382 m/d. The wall decay coefficient was calibrated to 3 significant figures, since the measured chloramine concentrations were only accurate to 2 decimal places. Note that the units for all sum of squared residuals (SSR) values in this thesis is mg^2/L^2.

Table 43 The wall decay coefficients from 0 to 100 m/d and their associated sum of squared residuals (SSR).

Left of Convergence		Convergence		Right of Convergence	
k_w (m/d)	SSR	k_w (m/d)	SSR	k_w (m/d)	SSR
0	3.47	0.038	0.3302006	0.0386	0.3303
0.0001	3.44	0.0381	0.3301689	0.039	0.3307
0.0005	3.34	0.0382	0.3301565	0.04	0.3330
0.001	3.21	0.0383	0.3301629	0.042	0.3426
0.005	2.36	0.0384	0.3301872	0.045	0.37
0.01	1.62	0.0385	0.3302304	0.05	0.44
0.02	0.76			0.06	0.65
0.03	0.40			0.07	0.92
0.035	0.3403			0.08	1.24
0.037	0.3316			0.09	1.57
0.0375	0.3306			0.1	1.92
0.0376	0.3305			0.5	10.20
0.0377	0.3304			1	13.43
0.0378	0.3303			1.5	14.86
0.0379	0.3303			2	15.67
				3	16.55
				5	17.33
				10	17.95
				20	18.28
				50	18.48
				70	18.52
				100	18.55

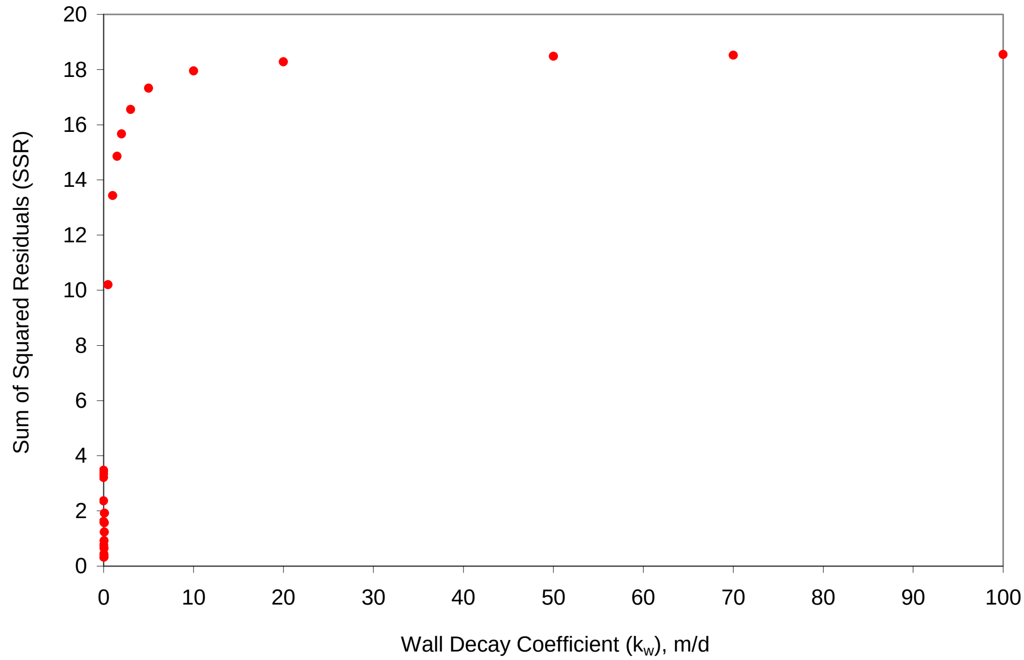

Figure 41 The SSR versus the wall decay coefficients from 0 to 100 m/d.

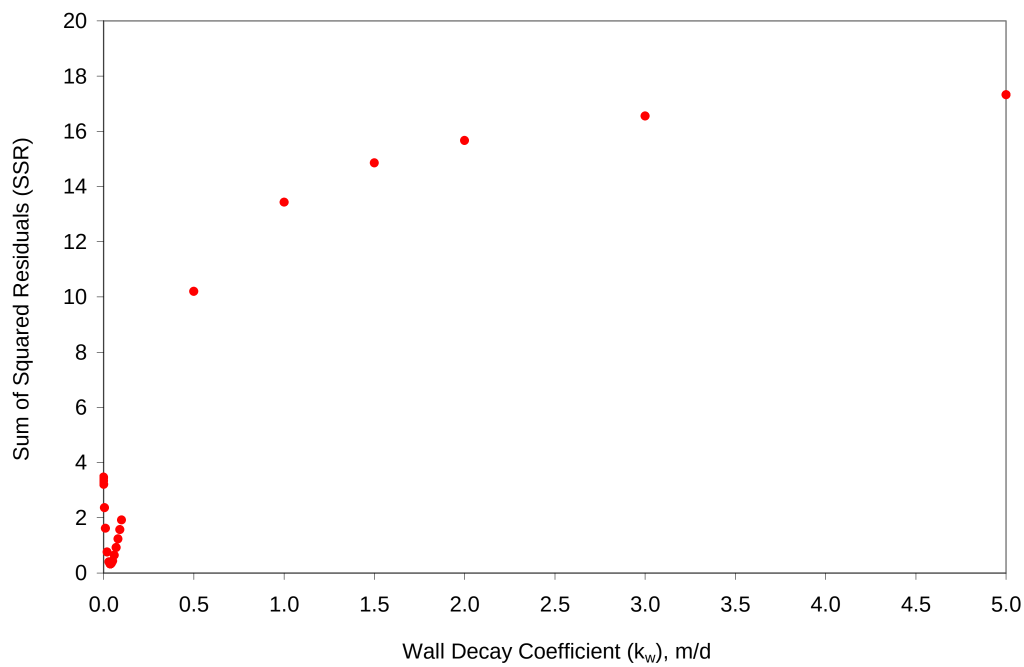

Figure 42 The SSR versus the wall decay coefficients from 0 to 5 m/d.

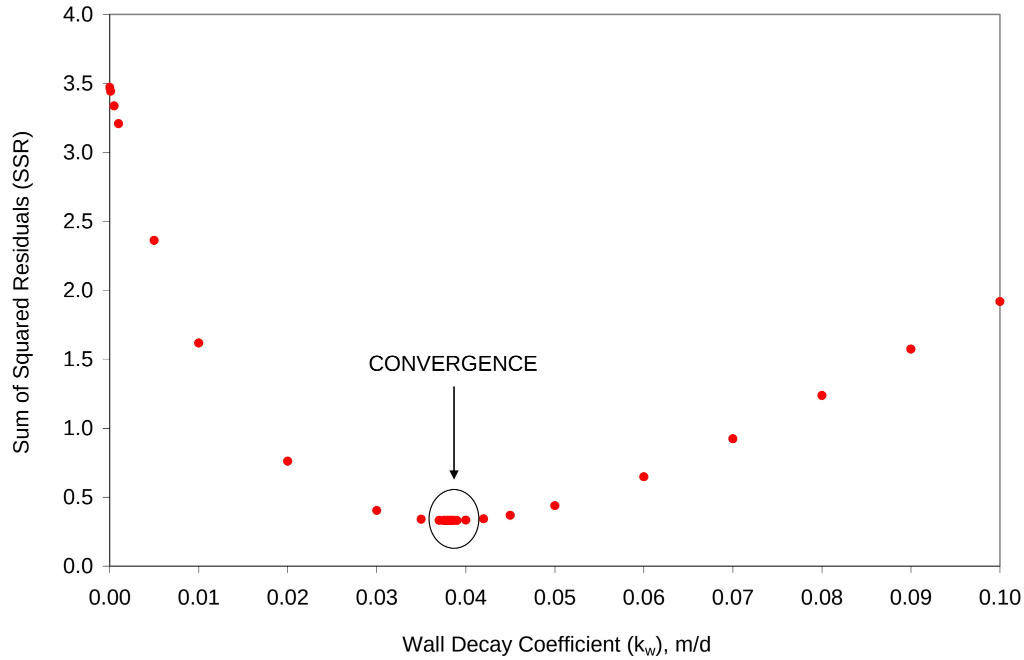

Figure 43 The SSR versus the wall decay coefficients from 0 to 0.1 m/d.

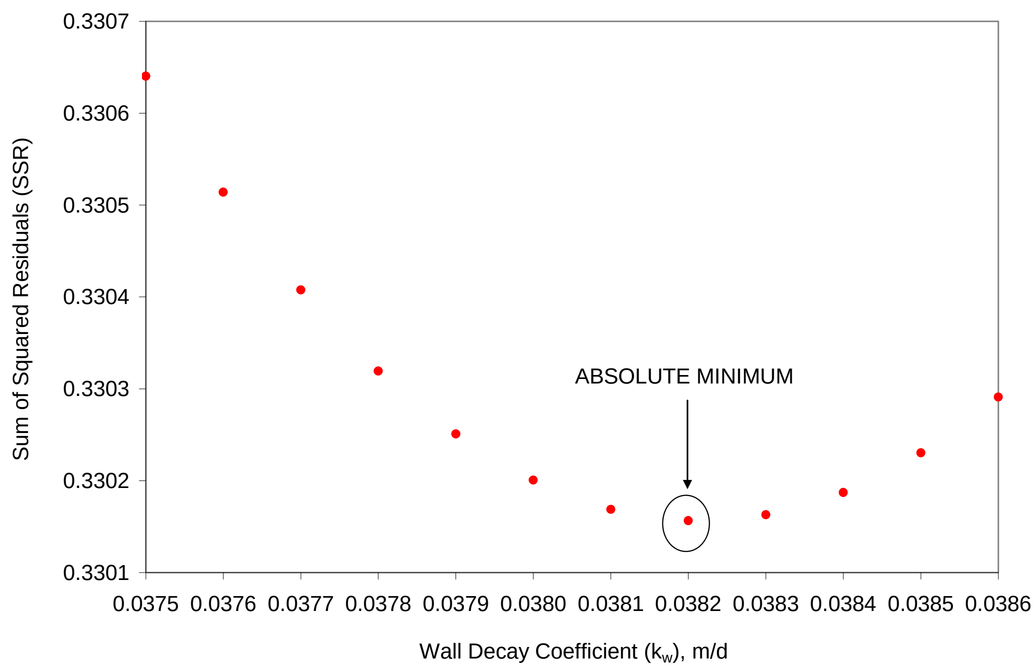

Figure 44 The SSR versus the wall decay coefficients from 0.0375 to 0.0386 m/d.

The final results of the calibration of the wall decay coefficient using the October, 2011 dataset are summarized in Table 44.

Table 44 The results of the calibration using the October 5, 2011 dataset.

Date of Field Data Used	Number of Known Chlorine Concentration Points	Global k_w (m/d)	SSR for Global k_w
October 5, 2011	26	0.0382	0.3302

Next, the residuals for the individual sampling site are calculated to examine how well the model prediction fits the field sampling data. The measured and the predicted chloramine concentrations, and their differences (i.e., residuals, which are equal to the measured chloramine concentration minus the model predicted chloramine concentration) are shown in Table 45. The residuals are plotted against the locations of the sample sites as well as the measured chloramine concentrations in Figure 45 and Figure 46, respectively. Note that the units of all residual values in this thesis is mg/L.

Visual inspection of the residuals data shown in Figure 45 illustrates that the residuals are scattered reasonably randomly among the sampling sites. Note that although it appears that the residuals between sites 12 and 31 were negative, it cannot be concluded that the residuals for sites 12 to 31 were all negative as some of the sites were not measured on the sampling day as they were unavailable.

Close inspection of the data points of the residuals in Figure 46 indicate that for the low chloramine concentration range (< 1.5 mg/L), all data points are negative, that is, the model predicted values are larger than the measured values. On the other hand, for the high chloramine concentration range (> 1.5 mg/L), nine data points of residuals are positive and six data points are negative, indicating that for the high chloramine concentrations, the majority of the model predicted values are smaller than the measured values. Furthermore, the six negative values are all very close to zero.

Table 45 The measured and the predicted chloramine concentrations, and their differences (residuals).

Inflow/Route Number	Sample Site Number	Average Chlorine Concentration (After Adjustment) on October 5, 2011 (mg/L)	Simulated Chlorine Concentration (mg/L)	Residual
Inflow 1	1	1.92	1.92	0.00
Inflow 2	2	1.76	1.76	0.00
Inflow 3	3	1.91	1.91	0.00
Route 2 (West Side)	4	1.87	1.89	-0.03
	5	1.92	1.89	0.03
	6	1.89	1.86	0.04
	7	1.85	1.75	0.11
	8	1.77	1.68	0.09
	11	1.74	1.64	0.09
	12	1.36	1.46	-0.10
Route 1 (West Side)	13	1.64	1.66	-0.02
	15	1.68	1.69	-0.01
	16	1.61	1.63	-0.01
	18	1.49	1.55	-0.06
	19	1.44	1.53	-0.09
	21	1.31	1.44	-0.13
	22	1.23	1.39	-0.16
	23	1.21	1.32	-0.11
	24	1.17	1.24	-0.06
	25	1.14	1.18	-0.04
	26	1.13	1.16	-0.03
	27	1.12	1.15	-0.04
Route 3 (East Side)	30	1.83	1.87	-0.05
	31	1.74	1.76	-0.02
	32	1.75	1.55	0.20
	33	1.55	1.50	0.04
	34	1.37	1.52	-0.15
	35	1.56	1.28	0.28
	36	1.67	1.42	0.25

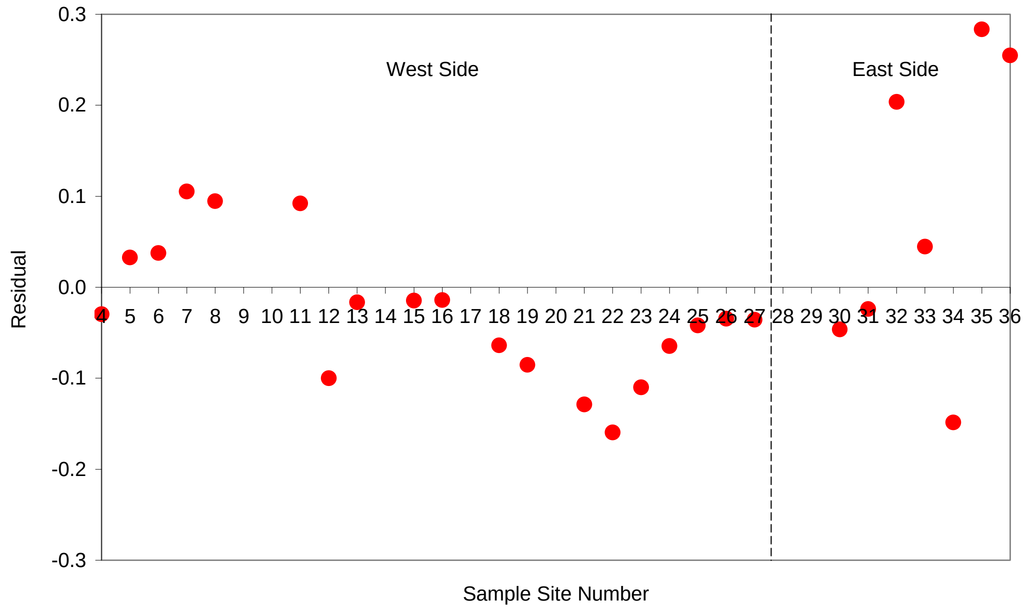

Figure 45 The residuals versus the locations of the sampling sites (October 5, 2011 dataset).

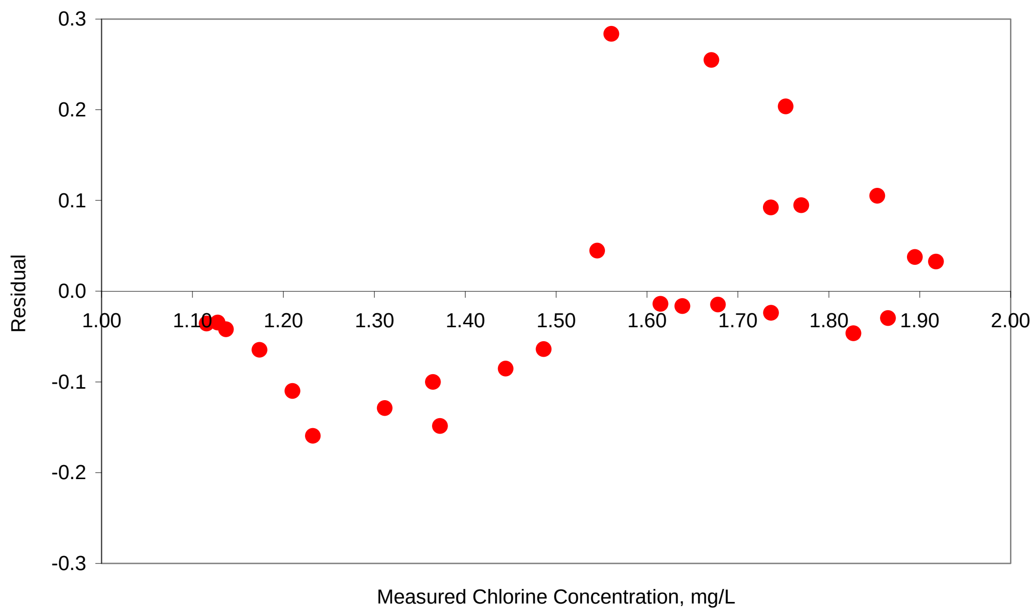

Figure 46 The residuals versus the measured chloramine concentrations (October 5, 2011 dataset).

Such a discrepancy is reasonable considering how the wall chloramine decay coefficient was obtained. The Study Area consists of pipes that were made of different materials and with different ages. They are likely to have different wall chloramine decay coefficients. When only one global wall decay coefficient was obtained by using the least squares analysis method, such a global value is likely close to some sort of an “average” value. Obviously, using such an “average” wall chloramine decay coefficient to calculate the chloramine concentration, the model would tend to predict higher chloramine concentrations for regions with higher wall decay coefficients (e.g., cast iron pipes, which should lead to lower chloramine concentrations), leading to negative residuals. Conversely, the model would predict lower chloramine concentrations for regions with lower wall decay coefficients (such as renewed pipes or PVC pipes, which should lead to higher chloramine concentrations), resulting in positive residuals[*].

4.4.2.2 Validating the Wall Decay Coefficient using the October 6 Data

The calibrated wall decay coefficient using measured chloramine concentration data on October 5, 2011 was validated using measured chloramine concentration data on October 6, 2011. The results of the validation are shown in Table 46.

The calibrated wall decay coefficient, 0.0382 m/d, was considered validated as the calculated SSR (0.2325) for the October 6, 2011 data was even lower than the SSR (0.3302) for the October 5, 2011 data.

[*] The slight negative residuals for some of the sites with high chloramine concentrations was probably because the sites were close to the inflows and/or because of random errors.

Table 46 The measured and the model predicted chloramine concentrations for October 6, 2011. The wall decay coefficient was developed from the measured chloramine concentrations on October 5, 2011.

Inflow/Route Number	Sample Site Number	Average Chlorine Concentration (After Adjustment) on October 6, 2011 (mg/L)	Simulated Chlorine Concentration (mg/L)	Squared Residual
Inflow 1	1	1.90	1.90	0.0000
Inflow 2	2	1.76	1.76	0.0000
Inflow 3	3	1.91	1.91	0.0000
Route 2 (West Side)	4	1.89	1.87	0.0004
	5	1.88	1.87	0.0003
	7	1.70	1.73	0.0010
	9	1.77	1.63	0.0203
	12	1.57	1.45	0.0140
Route 1 (West Side)	13	1.65	1.64	0.0002
	14	1.72	1.72	0.0000
	15	1.68	1.69	0.0001
	17	1.62	1.62	0.0000
	18	1.55	1.55	0.0000
	20	1.51	1.49	0.0001
	21	1.44	1.44	0.0000
	22	1.36	1.39	0.0011
	24	1.35	1.24	0.0138
	25	1.32	1.18	0.0200
	27	1.18	1.15	0.0013
Route 3 (East Side)	29	1.90	1.87	0.0007
	32	1.79	1.54	0.0621
	33	1.53	1.49	0.0014
	35	1.58	1.27	0.0958
			SSR =	0.2325

4.4.3 Determining the Wall Decay Coefficient at 17.4°C

4.4.3.1 Determining the Wall Decay Coefficient using the July 28 Data

The chloramine concentrations obtained on July 28, 2011 were used to calibrate a wall decay coefficient for the Study Area. Since the average measured water temperature on July 28, 2011 was 17.4°C, the calibrated wall decay coefficient was at this temperature. The chloramine concentrations measured on July 29, 2011 were used to validate the calibrated wall decay coefficient.

The setup of the July, 2011 model for water quality modeling was the same as the setup of the October, 2011 model except that the temperature dependent variables were set to 17.4ºC. There were twenty-three sampling sites in the July sampling program with eighteen sites on July 28 and eleven sites on July 29 (the data for inflow 3 were assumed to be the same for inflow 1).

All pipes in the study area were assumed to have the same wall decay coefficient. The wall decay coefficient at 17.4°C was calibrated using the same methodology as that used to calibrate the coefficient at 12.9°C. The calibration was done manually, using the least squares criteria to compare the measured and the predicted chloramine concentrations to find a unique wall decay coefficient that results in the least SSR.

The final results of the calibration of the wall decay coefficient using the July, 2011 dataset are summarized in Table 47. In this calibration, the model converged at the value of 0.0295 m/d, which results in the least SSR.

Table 47 The results of the calibration using the July 28, 2011 dataset.

Date of Field Data Used	Number of Known Chlorine Concentration Points	Global k_w (m/d)	SSR for Global k_w
July 28, 2011	16	0.0295	0.2303

Next, the residuals were calculated to examine how well the model prediction fits the field sampling data. The measured and the predicted chloramine concentrations of the calibration and the residuals are shown in Table 48. The residuals are obtained by subtracting the predicted values from the measured ones.

The residuals are plotted versus the locations of the sample sites as well as the measured chloramine concentrations in Figure 47 and Figure 48, respectively.

Table 48 The measured and the predicted chloramine concentrations of the calibration and the residuals for the July 28, 2011 data set.

Inflow/Quadrant Number	Sample Site Number	Average Chlorine Concentration (After Adjustment) on July 28, 2011 (mg/L)	Simulated Chlorine Concentration (mg/L)	Residual
Inflow 1	1	1.62	1.62	0.00
Inflow 2	2	1.36	1.36	0.00
Inflow 3	3	1.62	1.62	0.00
Quadrant 4 (West Side)	4	1.29	1.34	-0.05
	5	1.61	1.60	0.00
	6	1.52	1.50	0.01
	8	1.42	1.51	-0.09
	9	1.34	1.35	-0.01
	10	1.20	1.17	0.03
Quadrant 1 (West Side)	11	1.06	1.21	-0.14
	12	1.19	1.21	-0.02
	13	0.90	1.20	-0.30
	14	0.99	1.11	-0.12
	15	0.94	1.00	-0.06
Quadrant 3 (East Side)	19	1.44	1.27	0.17
	20	1.27	1.16	0.11
	21	1.30	1.27	0.02
Quadrant 2 (East Side)	22	1.43	1.27	0.16
	24	1.46	1.30	0.15

Figure 47 illustrates that the residuals are scattered randomly in the west side of the study area, with the exception of the negative residual at site 13 that is noticeably larger than the other negative residuals on this side of the area. The random scatter of the residuals indicates that the model fits the data fairly well on the west side of the area. On the east side, all five residuals were positive numbers, which indicates that the model predicted lower chloramine concentrations than the measured values on this side of the Study Area.

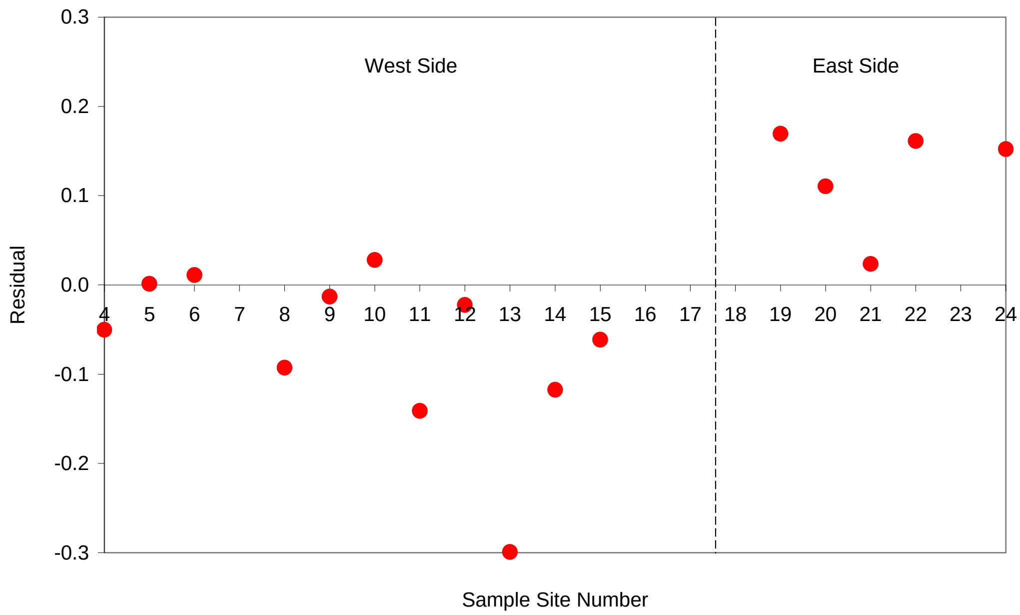

Figure 47 The residuals versus the locations of the sample sites (July 28, 2011 data set).

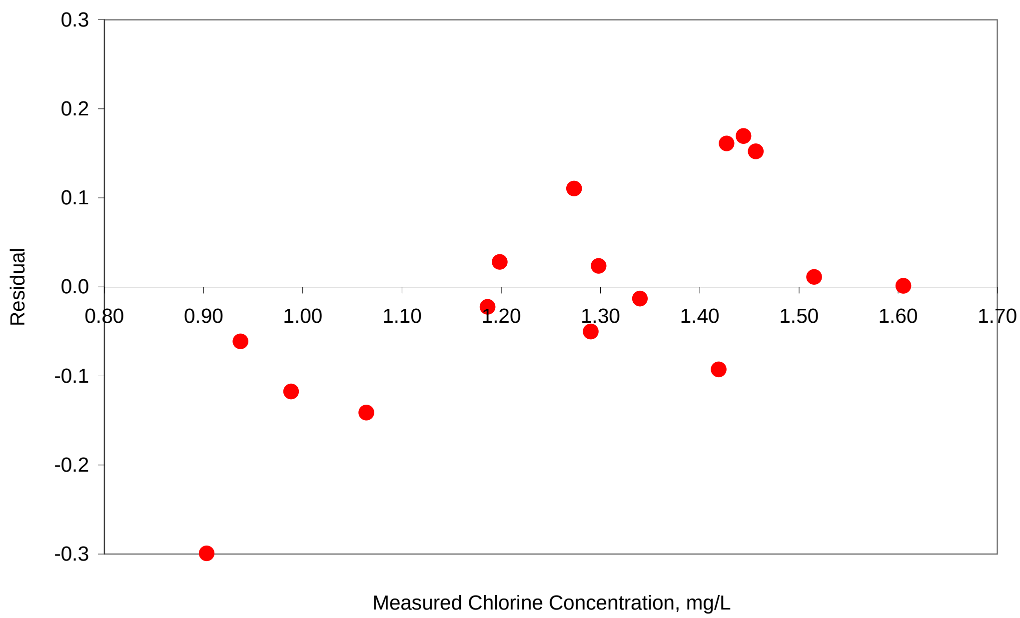

Figure 48 The residuals versus the measured chloramine concentrations (July 28, 2011 dataset).

Examination of Figure 48 indicates a similar trend as observed for the October 2011 data, that is, in the low chloramine concentration region the model tends to predict higher chloramine concentrations (thus negative residual), and in the high chloramine concentration region the model tends to predict lower chloramine concentrations (thus positive residual). In fact, as can be seen from Figure 48, all five residuals below a chloramine concentration of 1.2 mg/L are negative, and seven residual points at chloramine concentrations of > 1.2 mg/L are positive with only three slightly negative.

4.4.3.2 Validating the Wall Decay Coefficient using the July 29 Data

The calibrated wall decay coefficient using data on July 28 was validated using data on July 29. The results of the validation are shown in Table 49.

Table 49 The measured and the predicted chloramine concentrations of the validation and the squared residuals (July 29, 2011 data set).

Inflow/Quadrant Number	Sample Site Number	Average Chlorine Concentration (After Adjustment) on July 29, 2011 (mg/L)	Simulated Chlorine Concentration (mg/L)	Squared Residual
Inflow 1	1	1.74	1.74	0.0000
Inflow 2	2	1.45	1.45	0.0000
Inflow 3	3	1.74	1.74	0.0000
Quadrant 4 (West Side)	4	1.32	1.43	0.0116
	7	1.55	1.63	0.0056
	8	1.53	1.62	0.0082
Quadrant 1 (West Side)	16	0.88	1.06	0.0332
	17	1.56	1.51	0.0023
Quadrant 3 (East Side)	18	1.73	1.66	0.0050
	20	1.32	1.25	0.0048
Quadrant 2 (East Side)	23	1.42	1.12	0.0855
	24	1.57	1.40	0.0283
			SSR =	0.1846

The calibrated wall decay coefficient, 0.0295 m/d, was considered validated as the calculated SSR (0.1846) for the July 29, 2011 data was even lower than the SSR (0.2303) for the July 28, 2011 dataset.

4.5 Applications of the Developed Methodology

In this research, field water sampling was carried out in conjunction with SynerGEE Water model simulation to calibrate the chloramine wall decay coefficient in the Study Area. Although similar methodologies were reported in literature (as summarized in section 2.5.2, page 24), those reported methodologies were all used in the study of free chlorine, and the author did not find any paper in which researchers had used the field sampling – model simulation to determine the chloramine wall decay coefficients.

The developed methodology was applied in the following several case scenarios to test its usability.

4.5.1 The Variation of the Wall Decay Coefficient with Temperature

The wall decay coefficients calibrated for the Study Area using both the July and the October 2011 datasets are tabulated in Table 50. Theoretically, the wall decay coefficient should increase as temperature increases. However, Table 50 shows that the wall decay coefficient at 12.9°C is actually higher than at 17.4°C. One explanation for this observation is that the number and the locations of sampling sites for the two sampling programs were too different to yield wall decay coefficients that could be compared directly. In other words, if the wall decay coefficients at different temperatures are to be compared, field data from the exact same sample locations should be used, which may yield correct information about the effect of temperature provided that other conditions remain the same.

Table 50 The chloramine wall decay coefficients at 12.9°C and 17.4°C.

Temperature (°C)	Date of Field Data Used	Number of Known Chlorine Concentration Points	Global k_w (m/d)	SSR for Global k_w
12.9	October 5, 2011	26	0.0382	0.3302
17.4	July 28, 2011	16	0.0295	0.2303

4.5.2 The Variation of the Wall Decay Coefficient with Location

Using the field sampling data on July 28, 2011, a wall decay coefficient was calibrated for the west side of the Study Area, by using the least squares criteria to compare the measured and the predicted chloramine concentrations of the sample sites that are on this side only. Similarly, a wall decay coefficient was calibrated for the east side of the Study Area. The results are tabulated in Table 51. Also, using the field data on October 5, 2011, a wall decay coefficient was calibrated for the west and the east side of the Study Area. The results are tabulated in Table 52.

Table 51 The west and the east side wall decay coefficients calibrated using the July 28, 2011 dataset.

Part of Study Area	Date of Field Data Used	Number of Known Chlorine Concentration Points	k_w (m/d)	SSR for k_w
West Side	July 28, 2011	11	0.0455	0.0711
East Side	July 28, 2011	5	0.0160	0.0155

Table 52 The west and the east side wall decay coefficients calibrated using the October 5, 2011 dataset.

Part of Study Area	Date of Field Data Used	Number of Known Chlorine Concentration Points	k_w (m/d)	SSR for k_w
West Side	October 5, 2011	19	0.0454	0.0851
East Side	October 5, 2011	7	0.0221	0.1278

It is known that in the water distribution system for the Study Area, the pipes on the west side remain predominantly cast iron, whereas the pipes on the east side have been extensively lined with epoxy or renewed with PVC (Figure 4, page 40). As can be seen from both Table 51 and Table 52, the wall decay coefficients for the west side are larger than those for the east side. This suggests that pipe linings and renewals do cause slower chloramine wall decay and positively impact water quality in the area. The results also indicate that narrowing the study area will generate more accurate results for the wall decay coefficients and more accurate water quality predictions.

The residuals, obtained by subtracting the predicted chloramine concentrations from the measured chloramine concentrations, are plotted against the sampling sites and the measured chloramine concentrations for the west side (Figure 49) and east side (Figure 50) of the July 28, 2011 dataset. Similar plots are generated for the October 5, 2011 dataset in Figure 51 (west side) and Figure 52 (east side).

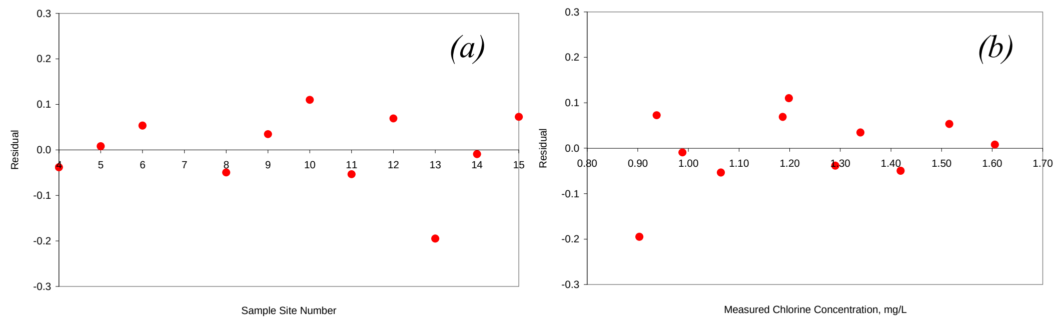

Figure 49 The residuals versus (a) the sample sites and (b) the measured chloramine concentrations (July 28, 2011 dataset, west side only).

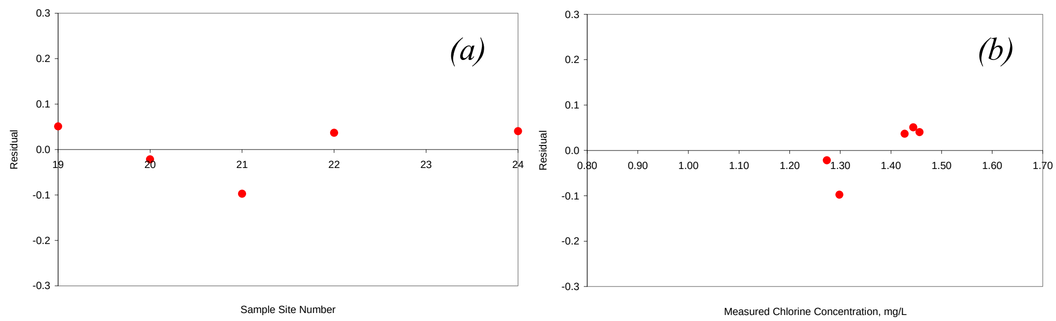

Figure 50 The residuals versus (a) the sample sites and (b) the measured chloramine concentrations (July 28, 2011 dataset, east side only).

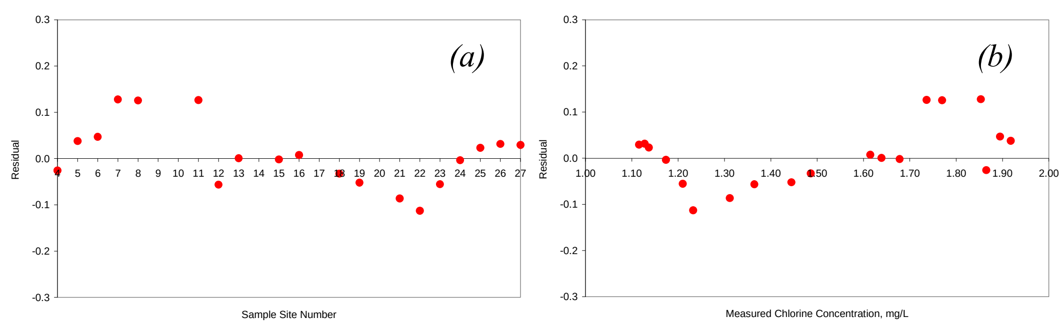

Figure 51 The residuals versus (a) the sample sites and (b) the measured chloramine concentrations (October 5, 2011 dataset, west side only).

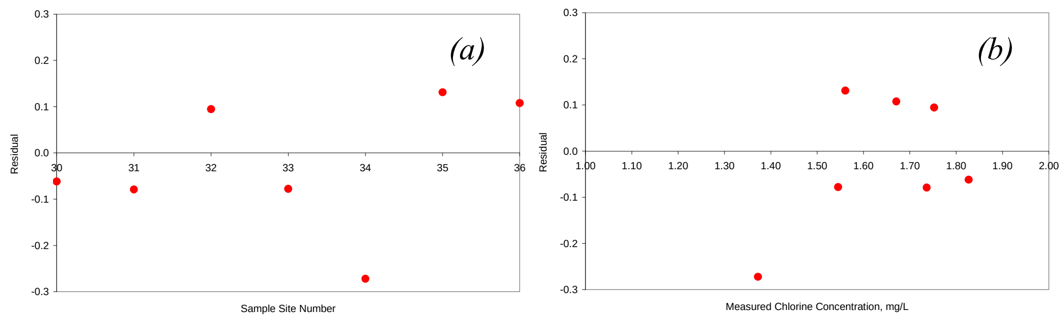

Figure 52 The residuals versus (a) the sample sites and (b) the measured chloramine concentrations (October 5, 2011 dataset, east side only).

As can be seen from Figure 49, the distribution of the residuals for the July 28, 2011 dataset for the west side of the Study Area is random with respect to both the sampling sites and the measured chloramine concentrations. The trend that was observed for the residuals for the July 28, 2011 dataset for the entire Study Area (Figure 48, page 127), i.e., that the model tends to over-predict chloramine concentrations for sites with low chloramine concentrations and under-predict chloramine concentrations for sites with high chloramine concentrations, did not appear when only the data from the west side were considered. This implies that the pipes at the sampling sites on the west side of the Study Area on July 28, 2011 had similar chloramine wall decay coefficients so that the data did not show any systematic bias and the residuals were random.

The data points for the east side of the Study Area of the July 28, 2011 dataset (Figure 50) are too few to draw any conclusions, although the plot of the residuals versus the sampling sites (Figure 50a) does show a random distribution.

However, although the data points for the east side of the Study Area of the October 5, 2011 dataset also show a random distribution (Figure 52), those for the west side (Figure 51) still show a bias that was observed when the data of October 5, 2011 for the entire Study Area were considered (compare with Figure 45 and Figure 46 on page 122). As can be seen from Figure 51b, excluding the eight data points on or very close to the horizontal axis, the remaining eleven data points show that they are either negative at low chloramine concentrations (six data points), or positive at high chloramine concentrations (five data points). This indicates that the model tends to over-predict chloramine concentrations for sites with low chloramine concentrations, and under-predict chloramine concentrations for sites with high chloramine concentrations. This is the same behavior observed earlier when the October 5, 2011 dataset for the entire Study Area were considered (Figure 46, page 122).

It is interesting to note that for the west side of the Study Area, the residuals of the July 28, 2011 dataset showed random distributions with respect to sampling sites and measured chloramine concentrations, whereas the October 5, 2011 dataset showed a bias. This was probably caused by the non-random sampling of the October 5, 2011 samples.

4.5.3 The Variation of the Wall Decay Coefficient with Bulk Decay

Using the field data on July 28, 2011, a wall decay coefficient was calibrated by using the least squares criteria to compare the measured and the predicted chloramine concentrations of all sample sites, without entering a bulk decay coefficient in the model. The results are shown in Table 53. Also, using the data on October 5, 2011, a wall decay coefficient was calibrated without entering a bulk decay coefficient in the model. The results are shown in Table 54.

Table 53 The wall decay coefficients calibrated with and without the effects of bulk decay using the July 28, 2011 dataset.

Accounted for Bulk Chlorine Decay?	Date of Field Data Used	Number of Known Chlorine Concentration Points	Global k_w (m/d)	SSR for Global k_w
Yes	July 28, 2011	16	0.0295	0.2303
No	July 28, 2011	16	0.0328	0.2225

Table 54 The wall decay coefficients calibrated with and without the effects of bulk decay using the October 5, 2011 dataset.

Accounted for Bulk Chlorine Decay?	Date of Field Data Used	Number of Known Chlorine Concentration Points	Global k_w (m/d)	SSR for Global k_w
Yes	October 5, 2011	26	0.0382	0.3302
No	October 5, 2011	26	0.0418	0.3126

Both Table 53 and Table 54 show that the wall decay coefficient calibrated without bulk decay is larger than that calibrated with bulk decay. This suggests that bulk decay does have a measurable contribution to the overall chloramine decay in the area and thus, it should be included in the modeling of chloramine decay.

4.6 The Determined Wall Decay Coefficient for the Study Area

As two field sampling programs were carried out (i.e., July and October 2011) and two wall decay coefficients were obtained, the question arose as to which value could be considered as the chloramine wall decay coefficient for the Study Area. There were pros and cons of picking either value, but eventually the chloramine wall decay coefficient determined from the July 28, 2011 sampling program was chosen as the value for the Study Area. This was mainly because the July 28, 2011 sampling sites were more randomly scattered in the Study Area, and that the data were more representative of the entire area. Furthermore, as discussed in section 4.4.3 and section 4.5.2, when using a wall decay coefficient that was calibrated using the July 28, 2011 data for the entire Study Area, the model showed a bias in that it over-predicted chloramine concentration for sites with low chloramine concentrations, and under-predicted chloramine concentrations for sites with high chloramine concentrations. However, such a bias disappeared when only the data from a sub-section of the Study Area (e.g., the west side) were used to calibrate the wall decay coefficient, and the residuals were random. The water distribution system in the west side of the Study Area is predominantly made of cast iron so the pipe material is more uniform. This shows the validity of the developed methodology, i.e., to combine field sampling with model calculation, to find a representative wall decay coefficient for a sub-section of a water distribution system where the pipe materials are uniform. On the other hand, the dataset for the October 2011 sampling program showed systematic errors of over-predicting low chloramine concentrations and under-predicting high chloramine concentrations, whether the dataset for the entire Study Area or only for the west side were used. The October 2011 dataset is thus biased, possibly due to the non-random sampling.

Therefore, the chloramine wall decay coefficient for the Study Area was determined to be 0.0295 m/d. Furthermore, the chloramine wall decay coefficient for the west side of the Study Area (where the dominant pipe material is cast iron) was determined to be 0.0455 m/d, and that for the east side of the Study Area (where extensive pipe renewal has been done) was determined to be 0.0160 m/d.

4.7 Comparison of the Determined Wall Decay Coefficients with Literature

The author was not able to find from literature any data on wall chloramine decay using the hydraulic model – field sampling methodologies used in this work. The wall chloramine decay coefficients reported in the literature were determined using laboratory procedures (see section 2.5.1 on page 20). However, the wall chloramine decay coefficients obtained from this work are compared with those from the literature anyway.

As shown from the previous section, the chloramine wall decay coefficient for the Study Area was determined to be 0.0295 m/d. For the west side of the Study Area, where the predominant pipe material is cast iron, this coefficient was found to be 0.0455 m/d, whereas for the east side of the Study Area, where significant pipe renewal has occurred in which some of the cast iron pipes have been epoxy-lined or replaced with PVC pipes, the wall decay coefficient was found to be 0.0160 m/d. The results indicated that the wall decay coefficient was indeed much higher for the west side where cast iron pipes dominate.

Mutoti et al. (2007) built pilot water distribution systems using different pipe materials. They had determined that at 20ºC, the wall chloramine decay coefficient was 0.015 m/d for cast iron pipes. This value is lower than the values determined in this study. Moreover, Westbrook and Digiano (2009) built a PSR and determined the wall chloramine decay coefficient for cast iron pipes as well. They obtained a value of 0.67 m/d at 23.5ºC, which is higher than the values determined in this study.

Overall, the wall decay coefficients determined in this study are in-between the available literature values. Since the values determined are comparable to those in literature, the author is confident in the reliability of the values.

4.8 Applications and Limitations of the Determined Chloramine Wall Decay Coefficient

Through the systematic study carried out in this project, the chloramine wall decay coefficient for the Study Area was determined to be 0.0295 m/d. Such a wall decay coefficient, together with chloramine bulk decay coefficient and other model input parameters (section 4.3, page 100), can be used in SynerGEE Water hydraulic model to calculate the chloramine concentrations at all nodes and pipes in the Study Area, thus serving the purpose of quickly predicting the water quality in the water distribution system in the area. Such predictions are deemed to have reasonable accuracy as other influencing parameters, such as water temperature and demand which may affect model predictions, are not expected to vary significantly for the Study Area.

As has been pointed out earlier (sections 4.4.2.1, 4.4.3.1, and 4.5.2, on pages 116, 124 and 130), the determined chloramine wall decay coefficient is a global value for the entire Study Area which encompasses different pipe materials. With one global chloramine wall decay coefficient the model therefore tends to over-predict the chloramine concentrations for regions with mostly cast iron pipes (which should have higher wall decay coefficients), and under-predict the chloramine concentrations for regions with mostly epoxy-lined cast iron and PVC pipes (which have lower wall decay coefficients). Clearly, selecting a smaller area where the pipe materials are more uniform (section 4.5.2, page 130) would give more representative chloramine wall decay coefficient and more accurate water quality predictions.

As the chloramine wall decay coefficient (0.0295 m/d) was determined for the Study Area, it is not advisable to use it directly in other areas of the water distribution system of the City of Edmonton. This is because the pipe materials, demands, and other conditions may be very different. It is conceivable that sub-sections of the water distribution system at the City of Edmonton can be selected, and the developed methodologies from this work can be used to calibrate a unique chloramine wall decay coefficient for the individual sub-sections. The wall decay coefficient determined in this work (0.0295 m/d) can be used as a starting point in the model calculations for these sub-sections to minimize the amount of simulation work required to make the model to converge.

5 CONCLUSIONS AND RECOMMENDATIONS

A comprehensive study was carried out with the objective of turning the SynerGEE Water hydraulic model of EPCOR Water Services Inc into a working model to monitor the water quality for a selected Study Area of the water distribution system of the City of Edmonton.

The general methodologies that were adopted and refined through this study program were to extract an independent hydraulic model for the Study Area from the SynerGEE Water hydraulic model, and to update the pipe materials and water demands for the extracted model. Field water sampling campaigns were then carried out to take water samples from selected locations in the Study Area and measure chloramine concentrations in the water samples. The field sampling data were used to calculate the bulk decay coefficients in the Study Area, which were used as model input to the extracted hydraulic model together with other required model input parameters. A wall decay coefficient was then assumed and entered into the extracted hydraulic model, to calculate the chloramine concentrations at all addresses in the Study Area. The calculated values were compared with measured values from the field sampling programs, and the differences were taken as residuals. By minimizing the sum of the squared residuals using the least squares method, a unique wall decay coefficient was identified for the Study Area, which could be used to predict water quality (chloramine concentration) for the Study Area.

5.1 Conclusions

The major findings and conclusions of this study are:

1) The adopted and refined methodology of combining field sampling with SynerGEE Water model calculation to determine the chloramine wall decay coefficient through least squares analysis is applicable to the selected Study

Area of the water distribution system of the City of Edmonton. The model calculations converged which led to a unique chloramine wall decay coefficient for the Study Area.

2) The chloramine wall decay coefficient for the Study Area was determined to be 0.0295 m/d. The chloramine wall decay coefficient for the west side of the Study Area, where the predominant pipe material was cast iron, was 0.0455 m/d. On the other hand, the chloramine wall decay coefficient for the east side of the Study Area, where significant pipe renewals were done in which the cast iron pipes were lined with epoxy and/or replaced with PVC pipes, was 0.0160 m/d. The results indicated that the wall decay coefficient was indeed much higher for the west side where cast iron pipes predominate.

3) Since only one global wall decay coefficient was determined for the entire Study Area, and since the Study Area had regions with different types of pipes, it was observed that the hydraulic model, using the determined wall decay coefficient, tend to over-predict the chloramine concentrations for regions and sections with primarily cast iron pipes, and under-predict chloramine concentrations for regions and sections with epoxy-lined cast iron or PVC pipes.

4) Therefore, accurate model prediction of water quality requires that the entire water distribution system be divided into sub-sections with pipe materials and other parameters as consistent within the sub-section as possible. Then the calibrated wall decay coefficient, using the methodologies developed in this work, can accurately represent the sub-section. When the wall decay coefficients for all the sub-sections in a water distribution system are identified, the SynerGEE Water hydraulic model can be used as a working model to quickly provide accurate predictions of the water quality in the entire water distribution system.

5.2 Contributions

The contributions of this study to the field of water resources engineering are:

1) The adoption and refinement of a methodology for identifying chloramine wall decay coefficient for a sub-section of the water distribution system using field sampling, SynerGEE Water hydraulic model, and least squares analysis, to make accurate model predictions of water quality in a sub-section of the water distribution system of the City of Edmonton.

2) The identification of chloramine bulk decay and wall decay coefficients for the Study Area.

5.3 Recommendations

The following are the recommendations for further work:

1) To obtain more accurate water quality model predictions, time-varying SynerGEE Water hydraulic model needs to be used rather than the steady-state average day demand (ADD) model.

2) To test the developed methodology in other sub-sections of the water distribution system of the City of Edmonton to verify its validity and usefulness. When choosing other sub-sections, it is advised that each sub-section is selected such that the pipe materials in the sub-section are uniform (e.g. all cast iron or all PVC pipes), so that a more representative chloramine wall decay coefficient can be determined to provide more accurate water quality predictions for the sub-section.

3) To systematically study the effects of water temperature and demand on chloramine wall decay coefficients using the developed methodology. In order

to rule out complications, other conditions need to be maintained the same as much as possible during these studies.

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APPENDIX A

Status of Existing Hydraulic Models at EWSI

Back in the year 2002, EWSI had built and calibrated a set of hydraulic models for the WDS of the City of Edmonton. Constructions, such as pipe repairs and replacements, as well as expansions are constantly being done in the WDS over the last decade. As a result, there are large discrepancies between the set of hydraulic models and the real WDS, both in terms of infrastructures in the WDS, such as pipes, tanks and pumps, as well as hydraulic conditions of the WDS, such as flows and pressures. In recent years, EWSI has built several new hydraulic models for the WDS of the City to account for changes that had occurred in the WDS over the last decade. However, these models are still being calibrated. The set of hydraulic models from 2002 was used in the last decade and it is still the dominant set of models being used by EWSI today.

EWSI uses the modeling software SynerGEE Water for all of its modeling work. In general, one of the first steps in building a hydraulic model is to import the infrastructures of the WDS into the model to obtain a model representation of the WDS. At EWSI, all data associated with the WDS infrastructures is stored in its geographic information system (GIS). When building the set of hydraulic models in 2002, the infrastructure data was extracted from the GIS and imported into SynerGEE Water to obtain a model representation of the actual WDS. In the hydraulic models, components in the actual WDS were represented using symbols such as dots, lines, circles and polygons. For example, a line in the models was to indicate a pipe in the WDS and a particular pre-defined polygon in the models was assigned to indicate a tank in the WDS. An important aspect of building the models was the use of nodes in the models. Nodes were used in the models to represent a number of things in the actual WDS. For the most part, a node was used to represent the intersection of two or more pipes. It was also used to represent a change, such as a change in pipe diameter, material or direction. In the models, a line between two nodes was considered as a single pipe, and this pipe had uniform diameter, material and extended in only one direction. This implies that pipes in the models could have been much longer than that in the actual WDS. For instance, assuming that in the WDS there were several pipes, with the same diameter, material and direction that were installed in one long line. In the models, this line of several pipes would have been considered as a single pipe, with a node at each of its end indicating the start and the end of this long line of pipes. The length of this single pipe in the models would have been equal to the sum of the lengths of all the individual pipes in the WDS.

Generally, the degree of detail in which the WDS should be represented in a hydraulic model is dependent on the purpose of the model. For the hydraulic models at EWSI, not all infrastructures in the WDS of the City were imported into the models. In regards to the Study Area which is the focus of this study, the infrastructures that were missing in the hydraulic models for this area that could potentially affect this study were valves and hydrants, and their associated components.

For hydraulic modeling in general, the water usages of customers are considered as demands in the WDS. The demands are added to the hydraulic model as base flows to "load" the model. This is usually done after the model representation of the WDS is completely set up. Usually, demands are assigned to nodes in the model. Every address that has a water service connected to the WDS is a demand. Thus, for a single pipe in the WDS, there could be a number of addresses that draw water from it. In the hydraulic model, to account for the demands for each address, a node would have to be set up on this pipe for each address. If this is to be done for all pipes in the model, it would require a lot of computing resources. For simplification, EWSI used nodes in its hydraulic models as discussed previously and the demand of each address was assigned to its nearest node. This indicates that each node in the models had a particular "zone of influence".

It is very difficult, if not impossible, to obtain the exact amount of water being used at each address at any given time. Thus, some assumptions have to be made in obtaining the demands that are to be assigned to the nodes in the hydraulic model. In general, the method in which demands is to be estimated depends on the purpose of the hydraulic model. At EWSI, the set of hydraulic models that were built and calibrated in 2002 were the Average Day Demand (ADD), Max Day Demand (MDD) and Peak Hour Demand (PHD) models. These three models had the same model representation of the WDS for the City. In other words, infrastructures imported into these models were exactly the same. These models differ in terms of the demands that were assigned. In the ADD model, demands were calculated based on the amount of water used as recorded in the customer billing statements. Essentially, for each address in the City, its monthly billing statement shows the total amount of water in cubic meters it has used for the month in consideration. Since the ADD model was built and calibrated in 2002, it could be deduced that monthly billing statements from 2001 were used to calculate demands. For each address, EWSI calculated its total water consumption for the year 2001 by summing up all of its monthly water consumptions in 2001, and dividing this total water consumption by 365 days to obtain an average day demand for the address. This average day demand was then assigned to the node in the model that was nearest to the address. At each node in the model, the average day demand of all the addresses within its "zone of influence" were summed to obtain the average day demand for the node. This was the method in which demands were estimated for the ADD hydraulic model.

As for the MDD hydraulic model, its demands were estimated based on a single day in 2001 that had the highest water consumption for the City. Evidently, the demands for the PHD model were estimated based on a single hour in 2001 that had the highest water consumption for the City. Since this study only used the ADD hydraulic model, the method in which demands were estimated for the MDD and PHD hydraulic models will not be discussed in detail in this thesis.

After the hydraulic models were built, they were calibrated by EWSI. Unfortunately, considering the fact that these models were calibrated a decade ago, the details in which the calibration was done could not be retrieved as individuals who were involved in the calibration process had left and no documents regarding the calibration could be found at EWSI either. However, since EWSI had used these hydraulic models for the last decade and it still uses these models, the calibration should have been done such that the results from the models agreed with the hydraulic data collected from the WDS to a reasonable degree, or to a degree as deemed acceptable by EWSI at the time the models were calibrated.

It is important to note that the hydraulic models of 2002 were built and calibrated to be steady state models, that is, the results from the models do not change with time. EWSI does not have any time varying hydraulic models for the WDS of the City or for the WDS of the Study Area.

APPENDIX B

Raw Data of Preliminary Field Sampling at the Author's Residence

Table 1 Raw data of the preliminary field sampling conducted at the author's residence on Tuesday, June 14, 2011.

Date:	Tuesday, June 14, 2011
Weather:	Mostly cloudy with rain, occasional sunshine
Sample Collection Location:	At the kitchen tap in the residence of the M.Sc. student
Sample Testing Location:	On the kitchen counter in the residence of the M.Sc. student
Sample Testing Method:	Using the chlorine field kit

Sample Number	Sample Collection Date (mm/dd/yr)	Sample Collection Time (24 Hours)	Sample Collection Time (AM/PM)	Water Temperature (°C)	Sample Testing Time	Chlorine Concentration (mg/L)
1	6/14/2011	12:10:00	12:10:00 PM	12.0	Immediately after collection	1.83
2	6/14/2011	13:00:00	01:00:00 PM	12.0	Immediately after collection	1.82
3	6/14/2011	14:02:00	02:02:00 PM	12.0	Immediately after collection	1.82
4	6/14/2011	15:20:00	03:20:00 PM	12.0	Immediately after collection	1.81
5	6/14/2011	16:27:00	04:27:00 PM	12.0	Immediately after collection	1.82
6	6/14/2011	17:27:00	05:27:00 PM	12.0	Immediately after collection	1.82
7	6/14/2011	18:22:00	06:22:00 PM	12.0	Immediately after collection	1.81
8	6/14/2011	19:36:00	07:36:00 PM	12.0	Immediately after collection	1.85
9	6/14/2011	20:51:00	08:51:00 PM	12.0	Immediately after collection	1.83
10	6/14/2011	21:54:00	09:54:00 PM	12.0	Immediately after collection	1.80
11	6/14/2011	22:58:00	10:58:00 PM	12.0	Immediately after collection	1.81

Table 2 Raw results of the preliminary field sampling conducted at the author's residence on Tuesday, June 21 and Wednesday, June 22, 2011.

Date:	Tuesday, June 21, 2011 and Wednesday, June 22, 2011
Weather:	Sunny, partly cloudy
Sample Collection Location:	At the kitchen tap in the residence of the M.Sc. Student
Sample Testing Location:	On the kitchen counter in the residence of the M.Sc. Student
Sample Testing Method:	Using the chlorine field kit

Sample Number	Sample Collection Date (mm/dd/yr)	Sample Collection Time (24 Hours)	Sample Collection Time (AM/PM)	Water Temperature (°C)	Sample Testing Time	Chlorine Concentration (mg/L)
1	6/21/2011	07:49:00	07:49:00 AM	12.0	Immediately after collection	1.71
2	6/21/2011	09:08:00	09:08:00 AM	12.0	Immediately after collection	1.68
3	6/21/2011	10:05:00	10:05:00 AM	12.0	Immediately after collection	1.72
4	6/21/2011	11:00:00	11:00:00 AM	12.0	Immediately after collection	1.73
5	6/21/2011	12:02:00	12:02:00 PM	12.0	Immediately after collection	1.73
6	6/21/2011	13:07:00	01:07:00 PM	12.0	Immediately after collection	1.73
7	6/21/2011	14:09:00	02:09:00 PM	12.0	Immediately after collection	1.76
8	6/21/2011	15:09:00	03:09:00 PM	12.0	Immediately after collection	1.74
9	6/21/2011	16:01:00	04:01:00 PM	12.0	Immediately after collection	1.75
10	6/21/2011	17:00:00	05:00:00 PM	12.0	Immediately after collection	1.76
11	6/21/2011	18:00:00	06:00:00 PM	12.0	Immediately after collection	1.76
12	6/21/2011	19:07:00	07:07:00 PM	12.0	Immediately after collection	1.77
13	6/21/2011	20:05:00	08:05:00 PM	12.0	Immediately after collection	1.80
14	6/21/2011	21:06:00	09:06:00 PM	12.0	Immediately after collection	1.81
15	6/21/2011	22:07:00	10:07:00 PM	12.0	Immediately after collection	1.82
16	6/21/2011	23:05:00	11:05:00 PM	11.5	Immediately after collection	1.79
17	6/22/2011	00:07:00	12:07:00 AM	11.5	Immediately after collection	1.80
18	6/22/2011	01:02:00	01:02:00 AM	11.5	Immediately after collection	1.78
19	6/22/2011	02:08:00	02:08:00 AM	11.0	Immediately after collection	1.79
20	6/22/2011	03:05:00	03:05:00 AM	12.0	Immediately after collection	1.80
21	6/22/2011	04:04:00	04:04:00 AM	11.0	Immediately after collection	1.76
22	6/22/2011	05:05:00	05:05:00 AM	11.5	Immediately after collection	1.76
23	6/22/2011	06:05:00	06:05:00 AM	12.0	Immediately after collection	1.79
24	6/22/2011	07:05:00	07:05:00 AM	11.5	Immediately after collection	1.74
25	6/22/2011	08:01:00	08:01:00 AM	11.5	Immediately after collection	1.78
26	6/22/2011	09:01:00	09:01:00 AM	12.0	Immediately after collection	1.80
27	6/22/2011	10:53:00	10:53:00 AM	12.0	Immediately after collection	1.79

APPENDIX C

Raw Data of Preliminary Field Sampling in the Study Area

Table 1 Raw results of site 1 from the preliminary field sampling conducted in the study area on Thursday, June 16, 2011.

Date:	Thursday, June 16, 2011
Weather:	Mostly cloudy with rain, occasional sunshine
Sample Collection Location:	In the women's washroom at site 1
Sample Testing Location:	In own vehicle parked at the parking lot of site 1
Sample Testing Method:	Using the chlorine field kit

Sample Collection and Testing Time (24 Hours)	Sample Collection and Testing Time (AM/PM)	Water Temperature (°C)	Chlorine Concentration (mg/L)
08:50:00	08:50:00 AM	15.0	1.88
10:05:00	10:05:00 AM	13.0	1.85
11:20:00	11:20:00 AM	13.5	1.85
12:40:00	12:40:00 PM	13.5	1.85
14:20:00	02:20:00 PM	14.0	1.92
15:40:00	03:40:00 PM	14.0	1.89
17:05:00	05:05:00 PM	13.0	1.83
18:35:00	06:35:00 PM	14.0	1.87
19:50:00	07:50:00 PM	14.0	1.84

Table 2 Raw results of site 2 from the preliminary field sampling conducted in the study area on Thursday, June 16, 2011.

Date: Thursday, June 16, 2011
Weather: Mostly cloudy with rain, occasional sunshine
Sample Collection Location: In the women's washroom at site 2
Sample Testing Location: In own vehicle parked at the parking lot of site 2
Sample Testing Method: Using the chlorine field kit

Sample Collection and Testing Time (24 Hours)	Sample Collection and Testing Time (AM/PM)	Water Temperature (°C)	Chlorine Concentration (mg/L)
09:10:00	09:10:00 AM	13.0	1.79
10:30:00	10:30:00 AM	13.5	1.82
11:45:00	11:45:00 AM	13.0	1.83
13:15:00	01:15:00 PM	13.0	1.79
14:40:00	02:40:00 PM	13.0	1.83
16:10:00	04:10:00 PM	13.0	1.82
17:30:00	05:30:00 PM	13.0	1.83
18:55:00	06:55:00 PM	13.0	1.79
20:15:00	08:15:00 PM	13.0	1.80

Table 3 Raw results of site 3 from the preliminary field sampling conducted in the study area on Thursday, June 16, 2011.

Date: Thursday, June 16, 2011
Weather: Mostly cloudy with rain, occasional sunshine
Sample Collection Location: At the water drinking fountain in the public washroom building located at site 3
Sample Testing Location: In own vehicle parked at the parking lot of site 3
Sample Testing Method: Using the chlorine field kit

Sample Collection and Testing Time (24 Hours)	Sample Collection and Testing Time (AM/PM)	Water Temperature (°C)	Chlorine Concentration (mg/L)
09:35:00	09:35:00 AM	10.0	1.15
10:55:00	10:55:00 AM	8.5	1.08
12:10:00	12:10:00 PM	12.0	1.16
13:40:00	01:40:00 PM	8.0	1.29
14:00:00	02:00:00 PM	8.0	1.33
15:05:00	03:05:00 PM	11.0	1.35
16:35:00	04:35:00 PM	12.0	1.32
18:00:00	06:00:00 PM	12.0	1.33
19:20:00	07:20:00 PM	7.0	1.44
20:35:00	08:35:00 PM	11.0	1.38

APPENDIX D

Raw and Processed Data for First Field Sampling (July 2011)

The data are sorted by sampling sites.

Site 1/3 Sample Number	Sample Collection				Sample Testing				Time Elapsed from Collection until Testing (hr)	Adjusted Chlorine Concentration (mg/L)	
	Sample Collection Date (mm/dd/yr)	Sample Collection Time (24 Hours)	Sample Collection Time (AM/PM)	Water Temperature (°C)	Sample Testing Date (mm/dd/yr)	Sample Testing Time (24 Hours)	Sample Testing Time (AM/PM)	Chlorine Concentration (mg/L)		First Order Model	Second Order Model
1	7/28/2011	08:39:00	08:39:00 AM	16.6	7/28/2011	09:50:00	09:50:00 AM	1.61	1.18	1.61	1.61
2	7/28/2011	10:41:00	10:41:00 AM	17.8	7/28/2011	13:17:00	01:17:00 PM	1.67	2.60	1.67	1.67
3	7/28/2011	12:52:00	12:52:00 PM	18.1	7/28/2011	16:20:00	04:20:00 PM	1.58	3.47	1.58	1.58
4	7/28/2011	14:47:00	02:47:00 PM	16.9	7/28/2011	22:00:00	10:00:00 PM	1.56	7.22	1.57	1.57
5	7/28/2011	16:39:00	04:39:00 PM	17.8	7/29/2011	11:35:00	11:35:00 AM	1.65	18.93	1.68	1.68
6	7/28/2011	19:00:00	07:00:00 PM	17.0	7/29/2011	11:45:00	11:45:00 AM	1.60	16.75	1.62	1.62
7	7/29/2011	08:46:00	08:46:00 AM	17.9	7/30/2011	07:11:00	07:11:00 AM	1.71	22.42	1.74	1.74
8	7/29/2011	10:38:00	10:38:00 AM	17.0	7/30/2011	07:20:00	07:20:00 AM	1.70	20.70	1.73	1.73
9	7/29/2011	12:34:00	12:34:00 PM	16.9	7/30/2011	07:30:00	07:30:00 AM	1.66	18.93	1.69	1.69
10	7/29/2011	14:38:00	02:38:00 PM	17.9	7/30/2011	07:40:00	07:40:00 AM	1.78	17.03	1.80	1.81
11	7/29/2011	16:46:00	04:46:00 PM	16.9	7/30/2011	07:48:00	07:48:00 AM	1.69	15.03	1.71	1.71
12	7/29/2011	19:06:00	07:06:00 PM	17.8	7/30/2011	07:55:00	07:55:00 AM	1.78	12.82	1.80	1.80

Site 2 Sample Number	Sample Collection			Sample Testing				Time Elapsed from Collection until Testing (hr)	Adjusted Chlorine Concentration (mg/L)	
	Sample Collection Date (mm/dd/yr)	Sample Collection Time (24 Hours)	Sample Collection Time (AM/PM)	Sample Testing Date (mm/dd/yr)	Sample Testing Time (24 Hours)	Sample Testing Time (AM/PM)	Chlorine Concentration (mg/L)		First Order Model	Second Order Model
1	7/28/2011	08:10:00	08:10:00 AM	7/28/2011	12:45:00	12:45:00 PM	1.21	4.58	1.21	1.21
2	7/28/2011	10:08:00	10:08:00 AM	7/28/2011	14:15:00	02:15:00 PM	1.28	4.12	1.28	1.28
3	7/28/2011	12:07:00	12:07:00 PM	7/28/2011	17:00:00	05:00:00 PM	1.39	4.88	1.40	1.39
4	7/28/2011	14:06:00	02:06:00 PM	7/28/2011	19:00:00	07:00:00 PM	1.38	4.90	1.39	1.38
5	7/28/2011	16:11:00	04:11:00 PM	7/29/2011	08:48:00	08:48:00 AM	1.41	16.62	1.43	1.43
6	7/28/2011	18:07:00	06:07:00 PM	7/29/2011	09:48:00	09:48:00 AM	1.45	15.68	1.47	1.47
7	7/29/2011	08:06:00	08:06:00 AM	7/29/2011	13:10:00	01:10:00 PM	1.22	5.07	1.22	1.22
8	7/29/2011	13:10:00	01:10:00 PM	7/29/2011	18:15:00	06:15:00 PM	1.43	5.08	1.44	1.43
9	7/29/2011	16:07:00	04:07:00 PM	7/29/2011	18:19:00	06:19:00 PM	1.56	2.20	1.56	1.56
10	7/29/2011	18:00:00	06:00:00 PM	7/29/2011	19:20:00	07:20:00 PM	1.59	1.33	1.59	1.59

Site 4 Sample Number	Sample Collection			Sample Testing				Time Elapsed from Collection until Testing (hr)	Adjusted Chlorine Concentration (mg/L)	
	Sample Collection Date (mm/dd/yr)	Sample Collection Time (24 Hours)	Sample Collection Time (AM/PM)	Sample Testing Date (mm/dd/yr)	Sample Testing Time (24 Hours)	Sample Testing Time (AM/PM)	Chlorine Concentration (mg/L)		First Order Model	Second Order Model
1	7/28/2011	08:07:00	08:07:00 AM	7/28/2011	11:00:00	11:00:00 AM	1.18	2.88	1.18	1.18
2	7/28/2011	10:20:00	10:20:00 AM	7/28/2011	15:28:00	03:28:00 PM	1.18	5.13	1.18	1.18
3	7/28/2011	12:08:00	12:08:00 PM	7/28/2011	15:55:00	03:55:00 PM	1.36	3.78	1.36	1.36
4	7/28/2011	14:08:00	02:08:00 PM	7/29/2011	00:40:00	12:40:00 AM	1.27	10.53	1.28	1.28
5	7/28/2011	16:08:00	04:08:00 PM	7/29/2011	09:05:00	09:05:00 AM	1.35	16.95	1.37	1.36
6	7/28/2011	18:12:00	06:12:00 PM	7/29/2011	12:45:00	12:45:00 PM	1.34	18.55	1.36	1.36
7	7/29/2011	08:05:00	08:05:00 AM	7/29/2011	19:40:00	07:40:00 PM	1.09	11.58	1.10	1.10
8	7/29/2011	10:07:00	10:07:00 AM	7/29/2011	19:47:00	07:47:00 PM	1.14	9.67	1.15	1.15
9	7/29/2011	12:08:00	12:08:00 PM	7/29/2011	19:50:00	07:50:00 PM	1.34	7.70	1.35	1.35
10	7/29/2011	14:07:00	02:07:00 PM	7/29/2011	19:55:00	07:55:00 PM	1.39	5.80	1.40	1.40
11	7/29/2011	16:08:00	04:08:00 PM	7/29/2011	20:05:00	08:05:00 PM	1.45	3.95	1.45	1.45
12	7/29/2011	18:07:00	06:07:00 PM	7/29/2011	20:15:00	08:15:00 PM	1.48	2.13	1.48	1.48

Site 5 Sample Number	Sample Collection			Sample Testing				Time Elapsed from Collection until Testing (hr)	Adjusted Chlorine Concentration (mg/L)	
	Sample Collection Date (mm/dd/yr)	Sample Collection Time (24 Hours)	Sample Collection Time (AM/PM)	Sample Testing Date (mm/dd/yr)	Sample Testing Time (24 Hours)	Sample Testing Time (AM/PM)	Chlorine Concentration (mg/L)		First Order Model	Second Order Model
1	7/28/2011	08:06:00	08:06:00 AM	7/28/2011	10:45:00	10:45:00 AM	1.62	2.65	1.62	1.62
2	7/28/2011	10:03:00	10:03:00 AM	7/28/2011	14:30:00	02:30:00 PM	1.60	4.45	1.61	1.61
3	7/28/2011	12:05:00	12:05:00 PM	7/28/2011	17:25:00	05:25:00 PM	1.62	5.33	1.63	1.63
4	7/28/2011	14:05:00	02:05:00 PM	7/28/2011	22:30:00	10:30:00 PM	1.57	8.42	1.58	1.58
5	7/28/2011	16:05:00	04:05:00 PM	7/29/2011	08:57:00	08:57:00 AM	1.61	16.87	1.63	1.63
6	7/28/2011	18:05:00	06:05:00 PM	7/29/2011	12:55:00	12:55:00 PM	1.54	18.83	1.56	1.56

Site 6 Sample Number	Sample Collection			Sample Testing				Time Elapsed from Collection until Testing (hr)	Adjusted Chlorine Concentration (mg/L)	
	Sample Collection Date (mm/dd/yr)	Sample Collection Time (24 Hours)	Sample Collection Time (AM/PM)	Sample Testing Date (mm/dd/yr)	Sample Testing Time (24 Hours)	Sample Testing Time (AM/PM)	Chlorine Concentration (mg/L)		First Order Model	Second Order Model
1	7/28/2011	08:04:00	08:04:00 AM	7/28/2011	10:10:00	10:10:00 AM	1.51	2.10	1.51	1.51
2	7/28/2011	10:00:00	10:00:00 AM	7/28/2011	15:46:00	03:46:00 PM	1.46	5.77	1.47	1.47
3	7/28/2011	12:00:00	12:00:00 PM	7/28/2011	17:40:00	05:40:00 PM	1.56	5.67	1.57	1.57

Site 7 Sample Number	Sample Collection			Sample Testing				Time Elapsed from Collection until Testing (hr)	Adjusted Chlorine Concentration (mg/L)	
	Sample Collection Date (mm/dd/yr)	Sample Collection Time (24 Hours)	Sample Collection Time (AM/PM)	Sample Testing Date (mm/dd/yr)	Sample Testing Time (24 Hours)	Sample Testing Time (AM/PM)	Chlorine Concentration (mg/L)		First Order Model	Second Order Model
1	7/29/2011	07:30:00	07:30:00 AM	7/29/2011	14:23:00	02:23:00 PM	1.50	6.88	1.51	1.51
2	7/29/2011	09:30:00	09:30:00 AM	7/29/2011	14:33:00	02:33:00 PM	1.58	5.05	1.59	1.59
3	7/29/2011	11:30:00	11:30:00 AM	7/29/2011	19:00:00	07:00:00 PM	1.56	7.50	1.57	1.57

Site 8 Sample Number	Sample Collection			Sample Testing				Time Elapsed from Collection until Testing (hr)	Adjusted Chlorine Concentration (mg/L)	
	Sample Collection Date (mm/dd/yr)	Sample Collection Time (24 Hours)	Sample Collection Time (AM/PM)	Sample Testing Date (mm/dd/yr)	Sample Testing Time (24 Hours)	Sample Testing Time (AM/PM)	Chlorine Concentration (mg/L)		First Order Model	Second Order Model
1	7/28/2011	08:06:00	08:06:00 AM	7/28/2011	12:30:00	12:30:00 PM	1.32	4.40	1.32	1.32
2	7/28/2011	10:07:00	10:07:00 AM	7/28/2011	14:00:00	02:00:00 PM	1.47	3.88	1.47	1.47
3	7/28/2011	12:07:00	12:07:00 PM	7/28/2011	18:05:00	06:05:00 PM	1.45	5.97	1.46	1.46
4	7/28/2011	14:06:00	02:06:00 PM	7/28/2011	22:20:00	10:20:00 PM	1.51	8.23	1.52	1.52
5	7/28/2011	16:07:00	04:07:00 PM	7/29/2011	09:18:00	09:18:00 AM	1.31	17.18	1.33	1.32
6	7/28/2011	18:06:00	06:06:00 PM	7/29/2011	12:37:00	12:37:00 PM	1.39	18.52	1.41	1.41
7	7/29/2011	08:06:00	08:06:00 AM	7/29/2011	13:19:00	01:19:00 PM	1.49	5.22	1.50	1.50
8	7/29/2011	10:09:00	10:09:00 AM	7/29/2011	13:34:00	01:34:00 PM	1.55	3.42	1.55	1.55
9	7/29/2011	12:07:00	12:07:00 PM	7/29/2011	18:27:00	06:27:00 PM	1.46	6.33	1.47	1.47
10	7/29/2011	14:07:00	02:07:00 PM	7/29/2011	18:40:00	06:40:00 PM	1.50	4.55	1.51	1.50
11	7/29/2011	16:07:00	04:07:00 PM	7/29/2011	18:50:00	06:50:00 PM	1.53	2.72	1.53	1.53
12	7/29/2011	18:08:00	06:08:00 PM	7/29/2011	19:11:00	07:11:00 PM	1.64	1.05	1.64	1.64

Site 9 Sample Number	Sample Collection			Sample Testing				Time Elapsed from Collection until Testing (hr)	Adjusted Chlorine Concentration (mg/L)	
	Sample Collection Date (mm/dd/yr)	Sample Collection Time (24 Hours)	Sample Collection Time (AM/PM)	Sample Testing Date (mm/dd/yr)	Sample Testing Time (24 Hours)	Sample Testing Time (AM/PM)	Chlorine Concentration (mg/L)		First Order Model	Second Order Model
1	7/28/11	07:59:00	07:59:00 AM	7/28/11	12:40:00	12:40:00 PM	1.18	4.68	1.18	1.18
2	7/28/11	10:00:00	10:00:00 AM	7/28/11	15:20:00	03:20:00 PM	1.32	5.33	1.33	1.32
3	7/28/11	12:01:00	12:01:00 PM	7/28/11	17:35:00	05:35:00 PM	1.36	5.57	1.37	1.36
4	7/28/11	14:00:00	02:00:00 PM	7/28/11	19:05:00	07:05:00 PM	1.36	5.08	1.37	1.36
5	7/28/11	16:02:00	04:02:00 PM	7/28/11	23:50:00	11:50:00 PM	1.43	7.80	1.44	1.44
6	7/28/11	18:01:00	06:01:00 PM	7/29/11	11:00:00	11:00:00 AM	1.34	16.98	1.36	1.35

Site 10 Sample Number	Sample Collection			Sample Testing				Time Elapsed from Collection until Testing (hr)	Adjusted Chlorine Concentration (mg/L)	
	Sample Collection Date (mm/dd/yr)	Sample Collection Time (24 Hours)	Sample Collection Time (AM/PM)	Sample Testing Date (mm/dd/yr)	Sample Testing Time (24 Hours)	Sample Testing Time (AM/PM)	Chlorine Concentration (mg/L)		First Order Model	Second Order Model
1	7/28/11	08:00:00	08:00:00 AM	7/28/11	11:40:00	11:40:00 AM	1.20	3.67	1.20	1.20
2	7/28/11	10:00:00	10:00:00 AM	7/28/11	14:22:00	02:22:00 PM	1.12	4.37	1.12	1.12
3	7/28/11	11:50:00	11:50:00 AM	7/28/11	17:45:00	05:45:00 PM	1.13	5.92	1.14	1.13
4	7/28/11	14:00:00	02:00:00 PM	7/28/11	18:53:00	06:53:00 PM	1.27	4.88	1.27	1.27
5	7/28/11	16:00:00	04:00:00 PM	7/29/11	09:10:00	09:10:00 AM	1.18	17.17	1.20	1.19
6	7/28/11	18:00:00	06:00:00 PM	7/29/11	10:43:00	10:43:00 AM	1.24	16.72	1.26	1.25

Site 11 Sample Number	Sample Collection			Sample Testing				Time Elapsed from Collection until Testing (hr)	Adjusted Chlorine Concentration (mg/L)	
	Sample Collection Date (mm/dd/yr)	Sample Collection Time (24 Hours)	Sample Collection Time (AM/PM)	Sample Testing Date (mm/dd/yr)	Sample Testing Time (24 Hours)	Sample Testing Time (AM/PM)	Chlorine Concentration (mg/L)		First Order Model	Second Order Model
1	7/28/11	08:01:00	08:01:00 AM	7/28/11	11:50:00	11:50:00 AM	1.16	3.82	1.16	1.16
2	7/28/11	09:59:00	09:59:00 AM	7/28/11	14:45:00	02:45:00 PM	0.90	4.77	0.90	0.90
3	7/28/11	12:02:00	12:02:00 PM	7/28/11	17:55:00	05:55:00 PM	1.06	5.88	1.06	1.06
4	7/28/11	14:02:00	02:02:00 PM	7/28/11	19:15:00	07:15:00 PM	1.12	5.22	1.12	1.12

Site 12 Sample Number	Sample Collection			Sample Testing				Time Elapsed from Collection until Testing (hr)	Adjusted Chlorine Concentration (mg/L)	
	Sample Collection Date (mm/dd/yr)	Sample Collection Time (24 Hours)	Sample Collection Time (AM/PM)	Sample Testing Date (mm/dd/yr)	Sample Testing Time (24 Hours)	Sample Testing Time (AM/PM)	Chlorine Concentration (mg/L)		First Order Model	Second Order Model
1	7/28/11	08:02:00	08:02:00 AM	7/28/11	10:25:00	10:25:00 AM	1.25	2.38	1.25	1.25
2	7/28/11	10:06:00	10:06:00 AM	7/28/11	13:10:00	01:10:00 PM	1.14	3.07	1.14	1.14
3	7/28/11	11:54:00	11:54:00 AM	7/28/11	16:11:00	04:11:00 PM	1.16	4.28	1.16	1.16

Site 13 Sample Number	Sample Collection			Sample Testing				Time Elapsed from Collection until Testing (hr)	Adjusted Chlorine Concentration (mg/L)	
	Sample Collection Date (mm/dd/yr)	Sample Collection Time (24 Hours)	Sample Collection Time (AM/PM)	Sample Testing Date (mm/dd/yr)	Sample Testing Time (24 Hours)	Sample Testing Time (AM/PM)	Chlorine Concentration (mg/L)		First Order Model	Second Order Model
1	7/28/2011	07:56:00	07:56:00 AM	7/28/2011	12:55:00	12:55:00 PM	0.91	4.98	0.91	0.91
2	7/28/2011	09:46:00	09:46:00 AM	7/28/2011	13:35:00	01:35:00 PM	0.92	3.82	0.92	0.92
3	7/28/2011	11:53:00	11:53:00 AM	7/28/2011	16:30:00	04:30:00 PM	0.87	4.62	0.87	0.87

Site 14 Sample Number	Sample Collection			Sample Testing				Time Elapsed from Collection until Testing (hr)	Adjusted Chlorine Concentration (mg/L)	
	Sample Collection Date (mm/dd/yr)	Sample Collection Time (24 Hours)	Sample Collection Time (AM/PM)	Sample Testing Date (mm/dd/yr)	Sample Testing Time (24 Hours)	Sample Testing Time (AM/PM)	Chlorine Concentration (mg/L)		First Order Model	Second Order Model
1	7/28/2011	08:03:00	08:03:00 AM	7/28/2011	13:03:00	01:03:00 PM	0.98	5.00	0.98	0.98
2	7/28/2011	10:50:00	10:50:00 AM	7/28/2011	13:25:00	01:25:00 PM	1.06	2.58	1.06	1.06
3	7/28/2011	12:43:00	12:43:00 PM	7/28/2011	17:10:00	05:10:00 PM	0.96	4.45	0.96	0.96
4	7/28/2011	14:43:00	02:43:00 PM	7/29/2011	10:00:00	10:00:00 AM	0.94	19.28	0.95	0.95
5	7/28/2011	16:47:00	04:47:00 PM	7/29/2011	10:07:00	10:07:00 AM	0.95	17.33	0.96	0.96
6	7/28/2011	18:43:00	06:43:00 PM	7/29/2011	10:15:00	10:15:00 AM	0.99	15.53	1.00	1.00

Site 15 Sample Number	Sample Collection			Sample Testing				Time Elapsed from Collection until Testing (hr)	Adjusted Chlorine Concentration (mg/L)	
	Sample Collection Date (mm/dd/yr)	Sample Collection Time (24 Hours)	Sample Collection Time (AM/PM)	Sample Testing Date (mm/dd/yr)	Sample Testing Time (24 Hours)	Sample Testing Time (AM/PM)	Chlorine Concentration (mg/L)		First Order Model	Second Order Model
1	7/28/2011	08:00:00	08:00:00 AM	7/28/2011	11:25:00	11:25:00 AM	0.94	3.42	0.94	0.94
2	7/28/2011	10:00:00	10:00:00 AM	7/28/2011	14:40:00	02:40:00 PM	0.95	4.67	0.95	0.95
3	7/28/2011	12:00:00	12:00:00 PM	7/28/2011	16:05:00	04:05:00 PM	0.98	4.08	0.98	0.98
4	7/28/2011	14:00:00	02:00:00 PM	7/28/2011	22:40:00	10:40:00 PM	0.90	8.67	0.91	0.90
5	7/28/2011	16:00:00	04:00:00 PM	7/29/2011	00:55:00	12:55:00 AM	0.95	8.92	0.96	0.95
6	7/28/2011	18:00:00	06:00:00 PM	7/29/2011	10:28:00	10:28:00 AM	0.87	16.47	0.88	0.88

Site 16 Sample Number	Sample Collection			Sample Testing				Time Elapsed from Collection until Testing (hr)	Adjusted Chlorine Concentration (mg/L)	
	Sample Collection Date (mm/dd/yr)	Sample Collection Time (24 Hours)	Sample Collection Time (AM/PM)	Sample Testing Date (mm/dd/yr)	Sample Testing Time (24 Hours)	Sample Testing Time (AM/PM)	Chlorine Concentration (mg/L)		First Order Model	Second Order Model
1	7/29/2011	07:56:00	07:56:00 AM	7/29/2011	14:44:00	02:44:00 PM	0.91	6.80	0.92	0.92
2	7/29/2011	10:01:00	10:01:00 AM	7/29/2011	15:21:00	03:21:00 PM	0.88	5.33	0.89	0.89
3	7/29/2011	12:20:00	12:20:00 PM	7/29/2011	15:41:00	03:41:00 PM	0.88	3.35	0.88	0.88
4	7/29/2011	13:50:00	01:50:00 PM	7/29/2011	16:10:00	04:10:00 PM	0.89	2.33	0.89	0.89
5	7/29/2011	16:08:00	04:08:00 PM	7/30/2011	05:55:00	05:55:00 AM	0.85	13.78	0.86	0.85
6	7/29/2011	18:10:00	06:10:00 PM	7/30/2011	06:20:00	06:20:00 AM	0.84	12.17	0.85	0.85

Site 17 Sample Number	Sample Collection			Sample Testing				Time Elapsed from Collection until Testing (hr)	Adjusted Chlorine Concentration (mg/L)	
	Sample Collection Date (mm/dd/yr)	Sample Collection Time (24 Hours)	Sample Collection Time (AM/PM)	Sample Testing Date (mm/dd/yr)	Sample Testing Time (24 Hours)	Sample Testing Time (AM/PM)	Chlorine Concentration (mg/L)		First Order Model	Second Order Model
1	7/29/2011	07:58:00	07:58:00 AM	7/29/2011	16:30:00	04:30:00 PM	1.44	8.53	1.45	1.45
2	7/29/2011	10:05:00	10:05:00 AM	7/29/2011	16:40:00	04:40:00 PM	1.49	6.58	1.50	1.50
3	7/29/2011	11:50:00	11:50:00 AM	7/29/2011	16:49:00	04:49:00 PM	1.57	4.98	1.58	1.58
4	7/29/2011	14:20:00	02:20:00 PM	7/29/2011	17:10:00	05:10:00 PM	1.61	2.83	1.61	1.61
5	7/29/2011	16:03:00	04:03:00 PM	7/29/2011	17:12:00	05:12:00 PM	1.60	1.15	1.60	1.60
6	7/29/2011	18:00:00	06:00:00 PM	7/29/2011	19:30:00	07:30:00 PM	1.59	1.50	1.59	1.59

Site 18 Sample Number	Sample Collection			Sample Testing				Time Elapsed from Collection until Testing (hr)	Adjusted Chlorine Concentration (mg/L)	
	Sample Collection Date (mm/dd/yr)	Sample Collection Time (24 Hours)	Sample Collection Time (AM/PM)	Sample Testing Date (mm/dd/yr)	Sample Testing Time (24 Hours)	Sample Testing Time (AM/PM)	Chlorine Concentration (mg/L)		First Order Model	Second Order Model
1	7/29/2011	08:07:00	08:07:00 AM	7/30/2011	00:00:00	12:00:00 AM	1.67	15.88	1.69	1.69
2	7/29/2011	10:08:00	10:08:00 AM	7/30/2011	00:10:00	12:10:00 AM	1.77	14.03	1.79	1.79
3	7/29/2011	12:08:00	12:08:00 PM	7/30/2011	00:20:00	12:20:00 AM	1.71	12.20	1.73	1.73
4	7/29/2011	14:10:00	02:10:00 PM	7/30/2011	00:30:00	12:30:00 AM	1.73	10.33	1.74	1.74
5	7/29/2011	16:09:00	04:09:00 PM	7/30/2011	00:40:00	12:40:00 AM	1.71	8.52	1.72	1.72
6	7/29/2011	18:10:00	06:10:00 PM	7/30/2011	01:00:00	01:00:00 AM	1.71	6.83	1.72	1.72

Site 19 Sample Number	Sample Collection			Sample Testing				Time Elapsed from Collection until Testing (hr)	Adjusted Chlorine Concentration (mg/L)	
	Sample Collection Date (mm/dd/yr)	Sample Collection Time (24 Hours)	Sample Collection Time (AM/PM)	Sample Testing Date (mm/dd/yr)	Sample Testing Time (24 Hours)	Sample Testing Time (AM/PM)	Chlorine Concentration (mg/L)		First Order Model	Second Order Model
1	7/28/11	08:00:00	08:00:00 AM	7/28/11	09:45:00	09:45:00 AM	1.49	1.75	1.49	1.49
2	7/28/11	10:00:00	10:00:00 AM	7/28/11	15:10:00	03:10:00 PM	1.38	5.17	1.39	1.38
3	7/28/11	12:00:00	12:00:00 PM	7/28/11	16:50:00	04:50:00 PM	1.48	4.83	1.49	1.49
4	7/28/11	14:00:00	02:00:00 PM	7/28/11	19:20:00	07:20:00 PM	1.25	5.33	1.26	1.25
5	7/28/11	16:00:00	04:00:00 PM	7/28/11	23:30:00	11:30:00 PM	1.49	7.50	1.50	1.50
6	7/28/11	18:00:00	06:00:00 PM	7/28/11	23:45:00	11:45:00 PM	1.54	5.75	1.55	1.55

Site 20 Sample Number	Sample Collection			Sample Testing				Time Elapsed from Collection until Testing (hr)	Adjusted Chlorine Concentration (mg/L)	
	Sample Collection Date (mm/dd/yr)	Sample Collection Time (24 Hours)	Sample Collection Time (AM/PM)	Sample Testing Date (mm/dd/yr)	Sample Testing Time (24 Hours)	Sample Testing Time (AM/PM)	Chlorine Concentration (mg/L)		First Order Model	Second Order Model
1	7/28/2011	08:05:00	08:05:00 AM	7/28/2011	11:07:00	11:07:00 AM	1.26	3.03	1.26	1.26
2	7/28/2011	10:05:00	10:05:00 AM	7/28/2011	14:55:00	02:55:00 PM	1.26	4.83	1.26	1.26
3	7/28/2011	12:00:00	12:00:00 PM	7/28/2011	17:15:00	05:15:00 PM	1.25	5.25	1.26	1.25
4	7/28/2011	14:00:00	02:00:00 PM	7/28/2011	22:10:00	10:10:00 PM	1.29	8.17	1.30	1.30
5	7/28/2011	16:00:00	04:00:00 PM	7/29/2011	12:22:00	12:22:00 PM	1.27	20.37	1.29	1.29
6	7/28/2011	18:00:00	06:00:00 PM	7/29/2011	12:29:00	12:29:00 PM	1.25	18.48	1.27	1.26
7	7/29/2011	08:00:00	08:00:00 AM	7/30/2011	04:40:00	04:40:00 AM	1.29	20.67	1.31	1.31
8	7/29/2011	10:00:00	10:00:00 AM	7/30/2011	04:46:00	04:46:00 AM	1.28	18.77	1.30	1.29
9	7/29/2011	12:00:00	12:00:00 PM	7/30/2011	04:55:00	04:55:00 AM	1.35	16.92	1.37	1.36
10	7/29/2011	14:00:00	02:00:00 PM	7/30/2011	05:05:00	05:05:00 AM	1.19	15.08	1.20	1.20
11	7/29/2011	16:00:00	04:00:00 PM	7/30/2011	05:20:00	05:20:00 AM	1.33	13.33	1.34	1.34
12	7/29/2011	18:00:00	06:00:00 PM	7/30/2011	05:30:00	05:30:00 AM	1.37	11.50	1.38	1.38

Site 21 Sample Number	Sample Collection			Sample Testing				Time Elapsed from Collection until Testing (hr)	Adjusted Chlorine Concentration (mg/L)	
	Sample Collection Date (mm/dd/yr)	Sample Collection Time (24 Hours)	Sample Collection Time (AM/PM)	Sample Testing Date (mm/dd/yr)	Sample Testing Time (24 Hours)	Sample Testing Time (AM/PM)	Chlorine Concentration (mg/L)		First Order Model	Second Order Model
1	7/28/2011	08:10:00	08:10:00 AM	7/28/2011	09:30:00	09:30:00 AM	1.57	1.33	1.57	1.57
2	7/28/2011	10:07:00	10:07:00 AM	7/28/2011	15:00:00	03:00:00 PM	1.30	4.88	1.31	1.30
3	7/28/2011	12:07:00	12:07:00 PM	7/28/2011	18:00:00	06:00:00 PM	1.43	5.88	1.44	1.44
4	7/28/2011	14:00:00	02:00:00 PM	7/28/2011	18:40:00	06:40:00 PM	1.06	4.67	1.06	1.06
5	7/28/2011	16:00:00	04:00:00 PM	7/29/2011	09:26:00	09:26:00 AM	1.08	17.43	1.10	1.09
6	7/28/2011	18:00:00	06:00:00 PM	7/29/2011	09:35:00	09:35:00 AM	1.30	15.58	1.32	1.31

Site 22 Sample Number	Sample Collection			Sample Testing				Time Elapsed from Collection until Testing (hr)	Adjusted Chlorine Concentration (mg/L)	
	Sample Collection Date (mm/dd/yr)	Sample Collection Time (24 Hours)	Sample Collection Time (AM/PM)	Sample Testing Date (mm/dd/yr)	Sample Testing Time (24 Hours)	Sample Testing Time (AM/PM)	Chlorine Concentration (mg/L)		First Order Model	Second Order Model
1	7/28/2011	08:00:00	08:00:00 AM	7/28/2011	13:43:00	01:43:00 PM	1.40	5.72	1.41	1.41
2	7/28/2011	10:01:00	10:01:00 AM	7/28/2011	13:50:00	01:50:00 PM	1.43	3.82	1.43	1.43
3	7/28/2011	12:00:00	12:00:00 PM	7/28/2011	17:20:00	05:20:00 PM	1.40	5.33	1.41	1.41
4	7/28/2011	14:01:00	02:01:00 PM	7/29/2011	11:07:00	11:07:00 AM	1.43	21.10	1.45	1.45
5	7/28/2011	16:00:00	04:00:00 PM	7/29/2011	11:15:00	11:15:00 AM	1.43	19.25	1.45	1.45
6	7/28/2011	18:02:00	06:02:00 PM	7/29/2011	11:38:00	11:38:00 AM	1.39	17.60	1.41	1.41

Site 23 Sample Number	Sample Collection			Sample Testing				Time Elapsed from Collection until Testing (hr)	Adjusted Chlorine Concentration (mg/L)	
	Sample Collection Date (mm/dd/yr)	Sample Collection Time (24 Hours)	Sample Collection Time (AM/PM)	Sample Testing Date (mm/dd/yr)	Sample Testing Time (24 Hours)	Sample Testing Time (AM/PM)	Chlorine Concentration (mg/L)		First Order Model	Second Order Model
1	7/29/2011	08:05:00	08:05:00 AM	7/30/2011	02:50:00	02:50:00 AM	1.39	18.75	1.41	1.41
2	7/29/2011	10:01:00	10:01:00 AM	7/30/2011	03:00:00	03:00:00 AM	1.37	16.98	1.39	1.39
3	7/29/2011	12:05:00	12:05:00 PM	7/30/2011	03:10:00	03:10:00 AM	1.39	15.08	1.41	1.40
4	7/29/2011	14:04:00	02:04:00 PM	7/30/2011	03:25:00	03:25:00 AM	1.40	13.35	1.42	1.41
5	7/29/2011	16:03:00	04:03:00 PM	7/30/2011	03:35:00	03:35:00 AM	1.41	11.53	1.42	1.42
6	7/29/2011	18:05:00	06:05:00 PM	7/30/2011	03:45:00	03:45:00 AM	1.44	9.67	1.45	1.45

Site 24 Sample Number	Sample Collection			Sample Testing				Time Elapsed from Collection until Testing (hr)	Adjusted Chlorine Concentration (mg/L)	
	Sample Collection Date (mm/dd/yr)	Sample Collection Time (24 Hours)	Sample Collection Time (AM/PM)	Sample Testing Date (mm/dd/yr)	Sample Testing Time (24 Hours)	Sample Testing Time (AM/PM)	Chlorine Concentration (mg/L)		First Order Model	Second Order Model
1	7/28/2011	08:04:00	08:04:00 AM	7/28/2011	11:15:00	11:15:00 AM	1.41	3.18	1.41	1.41
2	7/28/2011	10:03:00	10:03:00 AM	7/28/2011	14:05:00	02:05:00 PM	1.46	4.03	1.46	1.46
3	7/28/2011	14:03:00	02:03:00 PM	7/28/2011	22:55:00	10:55:00 PM	1.44	8.87	1.45	1.45
4	7/28/2011	16:03:00	04:03:00 PM	7/29/2011	11:50:00	11:50:00 AM	1.46	19.78	1.48	1.48
5	7/28/2011	18:02:00	06:02:00 PM	7/29/2011	11:57:00	11:57:00 AM	1.45	17.92	1.47	1.47
6	7/29/2011	08:46:00	08:46:00 AM	7/30/2011	01:20:00	01:20:00 AM	1.48	16.57	1.50	1.50
7	7/29/2011	10:11:00	10:11:00 AM	7/30/2011	02:30:00	02:30:00 AM	1.50	16.32	1.52	1.52
8	7/29/2011	14:01:00	02:01:00 PM	7/30/2011	01:30:00	01:30:00 AM	1.63	11.48	1.65	1.64
9	7/29/2011	16:01:00	04:01:00 PM	7/30/2011	01:40:00	01:40:00 AM	1.55	9.65	1.56	1.56
10	7/29/2011	18:06:00	06:06:00 PM	7/30/2011	01:52:00	01:52:00 AM	1.61	7.77	1.62	1.62

APPENDIX E

Raw and Processed Data for Second Field Sampling (October 2011)

The data are sorted by sampling sites.

Site 1 Sample Number	Sample Collection			Sample Testing				Time Elapsed from Collection until Testing (hr)	Adjusted Chlorine Concentration (mg/L)	
	Sample Collection Date (mm/dd/yr)	Sample Collection Time (24 Hours)	Sample Collection Time (AM/PM)	Sample Testing Date (mm/dd/yr)	Sample Testing Time (24 Hours)	Sample Testing Time (AM/PM)	Chlorine Concentration (mg/L)		First Order Model	Second Order Model
1	10/05/11	10:20:00	10:20:00 AM	10/05/11	17:45:00	05:45:00 PM	1.86	7.42	1.87	1.87
2	10/05/11	12:00:00	12:00:00 PM	10/05/11	18:00:00	06:00:00 PM	1.96	6.00	1.97	1.97
3	10/06/11	10:20:00	10:20:00 AM	10/06/11	21:35:00	09:35:00 PM	1.87	11.25	1.89	1.89
4	10/06/11	12:00:00	12:00:00 PM	10/06/11	21:50:00	09:50:00 PM	1.90	9.83	1.91	1.92

Site 2 Sample Number	Sample Collection			Sample Testing				Time Elapsed from Collection until Testing (hr)	Adjusted Chlorine Concentration (mg/L)	
	Sample Collection Date (mm/dd/yr)	Sample Collection Time (24 Hours)	Sample Collection Time (AM/PM)	Sample Testing Date (mm/dd/yr)	Sample Testing Time (24 Hours)	Sample Testing Time (AM/PM)	Chlorine Concentration (mg/L)		First Order Model	Second Order Model
1	10/05/11	09:00:00	09:00:00 AM	10/05/11	20:30:00	08:30:00 PM	1.76	11.50	1.78	1.78
2	10/05/11	13:00:00	01:00:00 PM	10/05/11	20:40:00	08:40:00 PM	1.73	7.67	1.74	1.74
3	10/06/11	09:45:00	09:45:00 AM	10/06/11	22:30:00	10:30:00 PM	1.74	12.75	1.76	1.76
4	10/06/11	11:36:00	11:36:00 AM	10/06/11	22:40:00	10:40:00 PM	1.75	11.07	1.77	1.77

Site 3 Sample Number	Sample Collection			Sample Testing				Time Elapsed from Collection until Testing (hr)	Adjusted Chlorine Concentration (mg/L)	
	Sample Collection Date (mm/dd/yr)	Sample Collection Time (24 Hours)	Sample Collection Time (AM/PM)	Sample Testing Date (mm/dd/yr)	Sample Testing Time (24 Hours)	Sample Testing Time (AM/PM)	Chlorine Concentration (mg/L)		First Order Model	Second Order Model
1	10/05/11	10:40:00	10:40:00 AM	10/05/11	18:15:00	06:15:00 PM	1.87	7.58	1.88	1.88
2	10/05/11	12:25:00	12:25:00 PM	10/05/11	18:25:00	06:25:00 PM	1.92	6.00	1.93	1.93
3	10/06/11	10:40:00	10:40:00 AM	10/06/11	22:05:00	10:05:00 PM	1.85	11.42	1.87	1.87
4	10/06/11	12:20:00	12:20:00 PM	10/06/11	22:15:00	10:15:00 PM	1.94	9.92	1.96	1.96

Site 4 Sample Number	Sample Collection			Sample Testing				Time Elapsed from Collection until Testing (hr)	Adjusted Chlorine Concentration (mg/L)	
	Sample Collection Date (mm/dd/yr)	Sample Collection Time (24 Hours)	Sample Collection Time (AM/PM)	Sample Testing Date (mm/dd/yr)	Sample Testing Time (24 Hours)	Sample Testing Time (AM/PM)	Chlorine Concentration (mg/L)		First Order Model	Second Order Model
1	10/05/11	10:00:00	10:00:00 AM	10/06/11	07:15:00	07:15:00 AM	1.80	21.25	1.83	1.83
2	10/05/11	12:00:00	12:00:00 PM	10/06/11	07:25:00	07:25:00 AM	1.87	19.42	1.90	1.90
3	10/06/11	10:00:00	10:00:00 AM	10/07/11	13:35:00	01:35:00 PM	1.83	27.58	1.87	1.88
4	10/06/11	12:00:00	12:00:00 PM	10/07/11	13:45:00	01:45:00 PM	1.88	25.75	1.92	1.92

Site 5 Sample Number	Sample Collection			Sample Testing				Time Elapsed from Collection until Testing (hr)	Adjusted Chlorine Concentration (mg/L)	
	Sample Collection Date (mm/dd/yr)	Sample Collection Time (24 Hours)	Sample Collection Time (AM/PM)	Sample Testing Date (mm/dd/yr)	Sample Testing Time (24 Hours)	Sample Testing Time (AM/PM)	Chlorine Concentration (mg/L)		First Order Model	Second Order Model
1	10/05/11	10:08:00	10:08:00 AM	10/06/11	05:20:00	05:20:00 AM	1.84	19.20	1.87	1.87
2	10/05/11	11:59:00	11:59:00 AM	10/06/11	05:30:00	05:30:00 AM	1.94	17.52	1.97	1.97
3	10/06/11	09:52:00	09:52:00 AM	10/07/11	04:55:00	04:55:00 AM	1.84	19.05	1.87	1.87
4	10/06/11	11:53:00	11:53:00 AM	10/07/11	05:00:00	05:00:00 AM	1.87	17.12	1.90	1.90

Site 6 Sample Number	Sample Collection			Sample Testing				Time Elapsed from Collection until Testing (hr)	Adjusted Chlorine Concentration (mg/L)	
	Sample Collection Date (mm/dd/yr)	Sample Collection Time (24 Hours)	Sample Collection Time (AM/PM)	Sample Testing Date (mm/dd/yr)	Sample Testing Time (24 Hours)	Sample Testing Time (AM/PM)	Chlorine Concentration (mg/L)		First Order Model	Second Order Model
1	10/05/11	10:07:00	10:07:00 AM	10/05/11	20:50:00	08:50:00 PM	1.85	10.72	1.87	1.87
2	10/05/11	12:06:00	12:06:00 PM	10/05/11	21:00:00	09:00:00 PM	1.91	8.90	1.92	1.93

Site 7 Sample Number	Sample Collection			Sample Testing				Time Elapsed from Collection until Testing (hr)	Adjusted Chlorine Concentration (mg/L)	
	Sample Collection Date (mm/dd/yr)	Sample Collection Time (24 Hours)	Sample Collection Time (AM/PM)	Sample Testing Date (mm/dd/yr)	Sample Testing Time (24 Hours)	Sample Testing Time (AM/PM)	Chlorine Concentration (mg/L)		First Order Model	Second Order Model
1	10/05/11	10:01:00	10:01:00 AM	10/05/11	23:20:00	11:20:00 PM	1.84	13.32	1.86	1.86
2	10/05/11	12:02:00	12:02:00 PM	10/05/11	23:30:00	11:30:00 PM	1.83	11.47	1.85	1.85
3	10/06/11	10:01:00	10:01:00 AM	10/07/11	00:20:00	12:20:00 AM	1.79	14.32	1.81	1.81
4	10/06/11	12:02:00	12:02:00 PM	10/07/11	00:30:00	12:30:00 AM	1.57	12.47	1.59	1.58

Site 8 Sample Number	Sample Collection			Sample Testing				Time Elapsed from Collection until Testing (hr)	Adjusted Chlorine Concentration (mg/L)	
	Sample Collection Date (mm/dd/yr)	Sample Collection Time (24 Hours)	Sample Collection Time (AM/PM)	Sample Testing Date (mm/dd/yr)	Sample Testing Time (24 Hours)	Sample Testing Time (AM/PM)	Chlorine Concentration (mg/L)		First Order Model	Second Order Model
1	10/05/11	10:05:00	10:05:00 AM	10/06/11	01:00:00	01:00:00 AM	1.76	14.92	1.78	1.78
2	10/05/11	12:06:00	12:06:00 PM	10/06/11	01:10:00	01:10:00 AM	1.74	13.07	1.76	1.76

Site 9 Sample Number	Sample Collection			Sample Testing				Time Elapsed from Collection until Testing (hr)	Adjusted Chlorine Concentration (mg/L)	
	Sample Collection Date (mm/dd/yr)	Sample Collection Time (24 Hours)	Sample Collection Time (AM/PM)	Sample Testing Date (mm/dd/yr)	Sample Testing Time (24 Hours)	Sample Testing Time (AM/PM)	Chlorine Concentration (mg/L)		First Order Model	Second Order Model
1	10/05/11	10:00:00	10:00:00 AM	10/07/11	21:15:00	09:15:00 PM	1.70	59.25	1.78	1.79
2	10/05/11	12:00:00	12:00:00 PM	10/07/11	21:25:00	09:25:00 PM	1.74	57.42	1.82	1.83
3	10/06/11	10:00:00	10:00:00 AM	10/07/11	00:50:00	12:50:00 AM	1.75	14.83	1.77	1.77
4	10/06/11	12:00:00	12:00:00 PM	10/07/11	01:05:00	01:05:00 AM	1.76	13.08	1.78	1.78

Site 10 Sample Number	Sample Collection			Sample Testing				Time Elapsed from Collection until Testing (hr)	Adjusted Chlorine Concentration (mg/L)	
	Sample Collection Date (mm/dd/yr)	Sample Collection Time (24 Hours)	Sample Collection Time (AM/PM)	Sample Testing Date (mm/dd/yr)	Sample Testing Time (24 Hours)	Sample Testing Time (AM/PM)	Chlorine Concentration (mg/L)		First Order Model	Second Order Model
1	10/06/11	10:00:00	10:00:00 AM	10/07/11	23:20:00	11:20:00 PM	1.76	37.33	1.81	1.82
2	10/06/11	12:00:00	12:00:00 PM	10/07/11	23:30:00	11:30:00 PM	1.77	35.50	1.82	1.82

Site 11 Sample Number	Sample Collection			Sample Testing				Time Elapsed from Collection until Testing (hr)	Adjusted Chlorine Concentration (mg/L)	
	Sample Collection Date (mm/dd/yr)	Sample Collection Time (24 Hours)	Sample Collection Time (AM/PM)	Sample Testing Date (mm/dd/yr)	Sample Testing Time (24 Hours)	Sample Testing Time (AM/PM)	Chlorine Concentration (mg/L)		First Order Model	Second Order Model
1	10/05/11	10:07:00	10:07:00 AM	10/06/11	06:05:00	06:05:00 AM	1.69	19.97	1.72	1.72
2	10/05/11	12:07:00	12:07:00 PM	10/06/11	06:10:00	06:10:00 AM	1.73	18.05	1.76	1.76

Site 12 Sample Number	Sample Collection			Sample Testing				Time Elapsed from Collection until Testing (hr)	Adjusted Chlorine Concentration (mg/L)	
	Sample Collection Date (mm/dd/yr)	Sample Collection Time (24 Hours)	Sample Collection Time (AM/PM)	Sample Testing Date (mm/dd/yr)	Sample Testing Time (24 Hours)	Sample Testing Time (AM/PM)	Chlorine Concentration (mg/L)		First Order Model	Second Order Model
1	10/05/11	10:00:00	10:00:00 AM	10/06/11	00:15:00	12:15:00 AM	1.37	14.25	1.39	1.38
2	10/05/11	12:00:00	12:00:00 PM	10/06/11	00:25:00	12:25:00 AM	1.33	12.42	1.34	1.34
3	10/06/11	10:00:00	10:00:00 AM	10/07/11	05:15:00	05:15:00 AM	1.57	19.25	1.59	1.59
4	10/06/11	12:00:00	12:00:00 PM	10/07/11	05:20:00	05:20:00 AM	1.52	17.33	1.54	1.54

Site 13 Sample Number	Sample Collection			Sample Testing				Time Elapsed from Collection until Testing (hr)	Adjusted Chlorine Concentration (mg/L)	
	Sample Collection Date (mm/dd/yr)	Sample Collection Time (24 Hours)	Sample Collection Time (AM/PM)	Sample Testing Date (mm/dd/yr)	Sample Testing Time (24 Hours)	Sample Testing Time (AM/PM)	Chlorine Concentration (mg/L)		First Order Model	Second Order Model
1	10/05/11	10:00:00	10:00:00 AM	10/05/11	21:35:00	09:35:00 PM	1.71	11.58	1.73	1.73
2	10/05/11	12:00:00	12:00:00 PM	10/05/11	21:45:00	09:45:00 PM	1.54	9.75	1.55	1.55
3	10/06/11	10:04:00	10:04:00 AM	10/06/11	23:55:00	11:55:00 PM	1.69	13.85	1.71	1.71
4	10/06/11	12:00:00	12:00:00 PM	10/07/11	00:05:00	12:05:00 AM	1.58	12.08	1.60	1.59

Site 14 Sample Number	Sample Collection			Sample Testing				Time Elapsed from Collection until Testing (hr)	Adjusted Chlorine Concentration (mg/L)	
	Sample Collection Date (mm/dd/yr)	Sample Collection Time (24 Hours)	Sample Collection Time (AM/PM)	Sample Testing Date (mm/dd/yr)	Sample Testing Time (24 Hours)	Sample Testing Time (AM/PM)	Chlorine Concentration (mg/L)		First Order Model	Second Order Model
1	10/06/11	10:00:00	10:00:00 AM	10/07/11	22:50:00	10:50:00 PM	1.64	36.83	1.69	1.69
2	10/06/11	12:00:00	12:00:00 PM	10/07/11	23:00:00	11:00:00 PM	1.70	35.00	1.75	1.75

Site 15 Sample Number	Sample Collection			Sample Testing				Time Elapsed from Collection until Testing (hr)	Adjusted Chlorine Concentration (mg/L)	
	Sample Collection Date (mm/dd/yr)	Sample Collection Time (24 Hours)	Sample Collection Time (AM/PM)	Sample Testing Date (mm/dd/yr)	Sample Testing Time (24 Hours)	Sample Testing Time (AM/PM)	Chlorine Concentration (mg/L)		First Order Model	Second Order Model
1	10/05/11	10:00:00	10:00:00 AM	10/06/11	04:15:00	04:15:00 AM	1.64	18.25	1.66	1.66
2	10/05/11	11:59:00	11:59:00 AM	10/06/11	04:25:00	04:25:00 AM	1.67	16.43	1.69	1.69
3	10/06/11	10:02:00	10:02:00 AM	10/07/11	03:55:00	03:55:00 AM	1.64	17.88	1.66	1.66
4	10/06/11	12:02:00	12:02:00 PM	10/07/11	04:00:00	04:00:00 AM	1.68	15.97	1.70	1.70

Site 16 Sample Number	Sample Collection			Sample Testing				Time Elapsed from Collection until Testing (hr)	Adjusted Chlorine Concentration (mg/L)	
	Sample Collection Date (mm/dd/yr)	Sample Collection Time (24 Hours)	Sample Collection Time (AM/PM)	Sample Testing Date (mm/dd/yr)	Sample Testing Time (24 Hours)	Sample Testing Time (AM/PM)	Chlorine Concentration (mg/L)		First Order Model	Second Order Model
1	10/05/11	10:00:00	10:00:00 AM	10/05/11	22:25:00	10:25:00 PM	1.56	12.42	1.58	1.57
2	10/05/11	12:03:00	12:03:00 PM	10/05/11	22:40:00	10:40:00 PM	1.64	10.62	1.65	1.65

Site 17 Sample Number	Sample Collection			Sample Testing				Time Elapsed from Collection until Testing (hr)	Adjusted Chlorine Concentration (mg/L)	
	Sample Collection Date (mm/dd/yr)	Sample Collection Time (24 Hours)	Sample Collection Time (AM/PM)	Sample Testing Date (mm/dd/yr)	Sample Testing Time (24 Hours)	Sample Testing Time (AM/PM)	Chlorine Concentration (mg/L)		First Order Model	Second Order Model
1	10/06/11	10:02:00	10:02:00 AM	10/06/11	23:20:00	11:20:00 PM	1.59	13.30	1.61	1.61
2	10/06/11	12:01:00	12:01:00 PM	10/06/11	23:30:00	11:30:00 PM	1.62	11.48	1.63	1.63

Site 18 Sample Number	Sample Collection			Sample Testing				Time Elapsed from Collection until Testing (hr)	Adjusted Chlorine Concentration (mg/L)	
	Sample Collection Date (mm/dd/yr)	Sample Collection Time (24 Hours)	Sample Collection Time (AM/PM)	Sample Testing Date (mm/dd/yr)	Sample Testing Time (24 Hours)	Sample Testing Time (AM/PM)	Chlorine Concentration (mg/L)		First Order Model	Second Order Model
1	10/05/11	10:01:00	10:01:00 AM	10/06/11	05:00:00	05:00:00 AM	1.44	18.98	1.46	1.46
2	10/05/11	12:01:00	12:01:00 PM	10/06/11	05:10:00	05:10:00 AM	1.49	17.15	1.51	1.51
3	10/06/11	10:00:00	10:00:00 AM	10/07/11	03:25:00	03:25:00 AM	1.51	17.42	1.53	1.53
4	10/06/11	12:01:00	12:01:00 PM	10/07/11	03:35:00	03:35:00 AM	1.54	15.57	1.56	1.56

Site 19 Sample Number	Sample Collection			Sample Testing				Time Elapsed from Collection until Testing (hr)	Adjusted Chlorine Concentration (mg/L)	
	Sample Collection Date (mm/dd/yr)	Sample Collection Time (24 Hours)	Sample Collection Time (AM/PM)	Sample Testing Date (mm/dd/yr)	Sample Testing Time (24 Hours)	Sample Testing Time (AM/PM)	Chlorine Concentration (mg/L)		First Order Model	Second Order Model
1	10/05/11	10:12:00	10:12:00 AM	10/05/11	23:45:00	11:45:00 PM	1.40	13.55	1.42	1.41
2	10/05/11	12:12:00	12:12:00 PM	10/06/11	00:00:00	12:00:00 AM	1.46	11.80	1.47	1.47

Site 20 Sample Number	Sample Collection			Sample Testing				Time Elapsed from Collection until Testing (hr)	Adjusted Chlorine Concentration (mg/L)	
	Sample Collection Date (mm/dd/yr)	Sample Collection Time (24 Hours)	Sample Collection Time (AM/PM)	Sample Testing Date (mm/dd/yr)	Sample Testing Time (24 Hours)	Sample Testing Time (AM/PM)	Chlorine Concentration (mg/L)		First Order Model	Second Order Model
1	10/06/11	10:06:00	10:06:00 AM	10/07/11	12:10:00	12:10:00 PM	1.46	26.07	1.49	1.49
2	10/06/11	12:06:00	12:06:00 PM	10/07/11	12:30:00	12:30:00 PM	1.49	24.40	1.52	1.52

Site 21 Sample Number	Sample Collection			Sample Testing				Time Elapsed from Collection until Testing (hr)	Adjusted Chlorine Concentration (mg/L)	
	Sample Collection Date (mm/dd/yr)	Sample Collection Time (24 Hours)	Sample Collection Time (AM/PM)	Sample Testing Date (mm/dd/yr)	Sample Testing Time (24 Hours)	Sample Testing Time (AM/PM)	Chlorine Concentration (mg/L)		First Order Model	Second Order Model
1	10/05/11	10:09:00	10:09:00 AM	10/05/11	22:00:00	10:00:00 PM	1.28	11.85	1.29	1.29
2	10/05/11	12:07:00	12:07:00 PM	10/05/11	22:10:00	10:10:00 PM	1.32	10.05	1.33	1.33
3	10/06/11	10:07:00	10:07:00 AM	10/07/11	03:05:00	03:05:00 AM	1.41	16.97	1.43	1.43
4	10/06/11	12:07:00	12:07:00 PM	10/07/11	03:15:00	03:15:00 AM	1.44	15.13	1.46	1.46

Site 22 Sample Number	Sample Collection			Sample Testing				Time Elapsed from Collection until Testing (hr)	Adjusted Chlorine Concentration (mg/L)	
	Sample Collection Date (mm/dd/yr)	Sample Collection Time (24 Hours)	Sample Collection Time (AM/PM)	Sample Testing Date (mm/dd/yr)	Sample Testing Time (24 Hours)	Sample Testing Time (AM/PM)	Chlorine Concentration (mg/L)		First Order Model	Second Order Model
1	10/05/11	10:00:00	10:00:00 AM	10/06/11	04:40:00	04:40:00 AM	1.22	18.67	1.24	1.23
2	10/05/11	12:00:00	12:00:00 PM	10/06/11	04:50:00	04:50:00 AM	1.21	16.83	1.23	1.22
3	10/06/11	10:00:00	10:00:00 AM	10/07/11	02:45:00	02:45:00 AM	1.33	16.75	1.35	1.34
4	10/06/11	12:00:00	12:00:00 PM	10/07/11	02:55:00	02:55:00 AM	1.35	14.92	1.37	1.36

Site 23 Sample Number	Sample Collection			Sample Testing				Time Elapsed from Collection until Testing (hr)	Adjusted Chlorine Concentration (mg/L)	
	Sample Collection Date (mm/dd/yr)	Sample Collection Time (24 Hours)	Sample Collection Time (AM/PM)	Sample Testing Date (mm/dd/yr)	Sample Testing Time (24 Hours)	Sample Testing Time (AM/PM)	Chlorine Concentration (mg/L)		First Order Model	Second Order Model
1	10/05/11	10:00:00	10:00:00 AM	10/05/11	21:15:00	09:15:00 PM	1.19	11.25	1.20	1.20
2	10/05/11	12:02:00	12:02:00 PM	10/05/11	21:25:00	09:25:00 PM	1.21	9.38	1.22	1.22

Site 24 Sample Number	Sample Collection			Sample Testing				Time Elapsed from Collection until Testing (hr)	Adjusted Chlorine Concentration (mg/L)	
	Sample Collection Date (mm/dd/yr)	Sample Collection Time (24 Hours)	Sample Collection Time (AM/PM)	Sample Testing Date (mm/dd/yr)	Sample Testing Time (24 Hours)	Sample Testing Time (AM/PM)	Chlorine Concentration (mg/L)		First Order Model	Second Order Model
1	10/05/11	10:00:00	10:00:00 AM	10/06/11	01:25:00	01:25:00 AM	1.17	15.42	1.18	1.18
2	10/05/11	12:00:00	12:00:00 PM	10/06/11	01:55:00	01:55:00 AM	1.15	13.92	1.16	1.16
3	10/06/11	10:03:00	10:03:00 AM	10/07/11	12:40:00	12:40:00 PM	1.31	26.62	1.34	1.33
4	10/06/11	12:00:00	12:00:00 PM	10/07/11	12:50:00	12:50:00 PM	1.34	24.83	1.37	1.36

Site 25 Sample Number	Sample Collection			Sample Testing				Time Elapsed from Collection until Testing (hr)	Adjusted Chlorine Concentration (mg/L)	
	Sample Collection Date (mm/dd/yr)	Sample Collection Time (24 Hours)	Sample Collection Time (AM/PM)	Sample Testing Date (mm/dd/yr)	Sample Testing Time (24 Hours)	Sample Testing Time (AM/PM)	Chlorine Concentration (mg/L)		First Order Model	Second Order Model
1	10/05/11	10:00:00	10:00:00 AM	10/06/11	05:45:00	05:45:00 AM	1.10	19.75	1.12	1.11
2	10/05/11	12:15:00	12:15:00 PM	10/06/11	05:55:00	05:55:00 AM	1.14	17.67	1.16	1.15
3	10/06/11	10:00:00	10:00:00 AM	10/07/11	13:05:00	01:05:00 PM	1.30	27.08	1.33	1.32
4	10/06/11	12:00:00	12:00:00 PM	10/07/11	13:20:00	01:20:00 PM	1.28	25.33	1.31	1.30

Site 26 Sample Number	Sample Collection			Sample Testing				Time Elapsed from Collection until Testing (hr)	Adjusted Chlorine Concentration (mg/L)	
	Sample Collection Date (mm/dd/yr)	Sample Collection Time (24 Hours)	Sample Collection Time (AM/PM)	Sample Testing Date (mm/dd/yr)	Sample Testing Time (24 Hours)	Sample Testing Time (AM/PM)	Chlorine Concentration (mg/L)		First Order Model	Second Order Model
1	10/05/11	10:05:00	10:05:00 AM	10/06/11	06:55:00	06:55:00 AM	1.11	20.83	1.13	1.12
2	10/05/11	12:04:00	12:04:00 PM	10/06/11	07:00:00	07:00:00 AM	1.11	18.93	1.13	1.12

Site 27 Sample Number	Sample Collection			Sample Testing				Time Elapsed from Collection until Testing (hr)	Adjusted Chlorine Concentration (mg/L)	
	Sample Collection Date (mm/dd/yr)	Sample Collection Time (24 Hours)	Sample Collection Time (AM/PM)	Sample Testing Date (mm/dd/yr)	Sample Testing Time (24 Hours)	Sample Testing Time (AM/PM)	Chlorine Concentration (mg/L)		First Order Model	Second Order Model
1	10/05/11	10:00:00	10:00:00 AM	10/05/11	22:55:00	10:55:00 PM	1.10	12.92	1.11	1.11
2	10/05/11	12:00:00	12:00:00 PM	10/05/11	23:05:00	11:05:00 PM	1.11	11.08	1.12	1.12
3	10/06/11	10:00:00	10:00:00 AM	10/07/11	01:20:00	01:20:00 AM	1.14	15.33	1.15	1.15
4	10/06/11	12:00:00	12:00:00 PM	10/07/11	01:30:00	01:30:00 AM	1.20	13.50	1.21	1.21

Site 28 Sample Number	Sample Collection			Sample Testing				Time Elapsed from Collection until Testing (hr)	Adjusted Chlorine Concentration (mg/L)	
	Sample Collection Date (mm/dd/yr)	Sample Collection Time (24 Hours)	Sample Collection Time (AM/PM)	Sample Testing Date (mm/dd/yr)	Sample Testing Time (24 Hours)	Sample Testing Time (AM/PM)	Chlorine Concentration (mg/L)		First Order Model	Second Order Model
1	10/06/11	10:07:00	10:07:00 AM	10/07/11	14:25:00	02:25:00 PM	1.86	28.30	1.90	1.91
2	10/06/11	12:08:00	12:08:00 PM	10/07/11	14:45:00	02:45:00 PM	1.89	26.62	1.93	1.94

Site 29 Sample Number	Sample Collection			Sample Testing				Time Elapsed from Collection until Testing (hr)	Adjusted Chlorine Concentration (mg/L)	
	Sample Collection Date (mm/dd/yr)	Sample Collection Time (24 Hours)	Sample Collection Time (AM/PM)	Sample Testing Date (mm/dd/yr)	Sample Testing Time (24 Hours)	Sample Testing Time (AM/PM)	Chlorine Concentration (mg/L)		First Order Model	Second Order Model
1	10/06/11	10:00:00	10:00:00 AM	10/07/11	15:00:00	03:00:00 PM	1.83	29.00	1.87	1.88
2	10/06/11	12:00:00	12:00:00 PM	10/07/11	15:10:00	03:10:00 PM	1.88	27.17	1.92	1.93

Site 30 Sample Number	Sample Collection			Sample Testing				Time Elapsed from Collection until Testing (hr)	Adjusted Chlorine Concentration (mg/L)	
	Sample Collection Date (mm/dd/yr)	Sample Collection Time (24 Hours)	Sample Collection Time (AM/PM)	Sample Testing Date (mm/dd/yr)	Sample Testing Time (24 Hours)	Sample Testing Time (AM/PM)	Chlorine Concentration (mg/L)		First Order Model	Second Order Model
1	10/05/11	10:00:00	10:00:00 AM	10/06/11	02:05:00	02:05:00 AM	1.79	16.08	1.81	1.82
2	10/05/11	12:00:00	12:00:00 PM	10/06/11	02:15:00	02:15:00 AM	1.82	14.25	1.84	1.84

Site 31 Sample Number	Sample Collection			Sample Testing				Time Elapsed from Collection until Testing (hr)	Adjusted Chlorine Concentration (mg/L)	
	Sample Collection Date (mm/dd/yr)	Sample Collection Time (24 Hours)	Sample Collection Time (AM/PM)	Sample Testing Date (mm/dd/yr)	Sample Testing Time (24 Hours)	Sample Testing Time (AM/PM)	Chlorine Concentration (mg/L)		First Order Model	Second Order Model
1	10/05/11	10:00:00	10:00:00 AM	10/06/11	02:25:00	02:25:00 AM	1.69	16.42	1.71	1.71
2	10/05/11	12:00:00	12:00:00 PM	10/06/11	02:35:00	02:35:00 AM	1.74	14.58	1.76	1.76

Site 32 Sample Number	Sample Collection			Sample Testing				Time Elapsed from Collection until Testing (hr)	Adjusted Chlorine Concentration (mg/L)	
	Sample Collection Date (mm/dd/yr)	Sample Collection Time (24 Hours)	Sample Collection Time (AM/PM)	Sample Testing Date (mm/dd/yr)	Sample Testing Time (24 Hours)	Sample Testing Time (AM/PM)	Chlorine Concentration (mg/L)		First Order Model	Second Order Model
1	10/05/11	10:00:00	10:00:00 AM	10/06/11	03:15:00	03:15:00 AM	1.72	17.25	1.74	1.74
2	10/05/11	12:00:00	12:00:00 PM	10/06/11	03:20:00	03:20:00 AM	1.74	15.33	1.76	1.76
3	10/06/11	10:00:00	10:00:00 AM	10/06/11	23:00:00	11:00:00 PM	1.76	13.00	1.78	1.78
4	10/06/11	12:00:00	12:00:00 PM	10/06/11	23:05:00	11:05:00 PM	1.79	11.08	1.81	1.81

Site 33 Sample Number	Sample Collection			Sample Testing				Time Elapsed from Collection until Testing (hr)	Adjusted Chlorine Concentration (mg/L)	
	Sample Collection Date (mm/dd/yr)	Sample Collection Time (24 Hours)	Sample Collection Time (AM/PM)	Sample Testing Date (mm/dd/yr)	Sample Testing Time (24 Hours)	Sample Testing Time (AM/PM)	Chlorine Concentration (mg/L)		First Order Model	Second Order Model
1	10/05/11	10:00:00	10:00:00 AM	10/06/11	03:35:00	03:35:00 AM	1.51	17.58	1.53	1.53
2	10/05/11	12:20:00	12:20:00 PM	10/06/11	03:45:00	03:45:00 AM	1.54	15.42	1.56	1.56
3	10/06/11	10:27:00	10:27:00 AM	10/07/11	05:35:00	05:35:00 AM	1.49	19.13	1.51	1.51
4	10/06/11	12:20:00	12:20:00 PM	10/07/11	05:45:00	05:45:00 AM	1.53	17.42	1.55	1.55

Site 34 Sample Number	Sample Collection			Sample Testing				Time Elapsed from Collection until Testing (hr)	Adjusted Chlorine Concentration (mg/L)	
	Sample Collection Date (mm/dd/yr)	Sample Collection Time (24 Hours)	Sample Collection Time (AM/PM)	Sample Testing Date (mm/dd/yr)	Sample Testing Time (24 Hours)	Sample Testing Time (AM/PM)	Chlorine Concentration (mg/L)		First Order Model	Second Order Model
1	10/05/11	10:00:00	10:00:00 AM	10/06/11	02:50:00	02:50:00 AM	1.36	16.83	1.38	1.38
2	10/05/11	12:12:00	12:12:00 PM	10/06/11	03:00:00	03:00:00 AM	1.35	14.80	1.37	1.36

Site 35 Sample Number	Sample Collection			Sample Testing				Time Elapsed from Collection until Testing (hr)	Adjusted Chlorine Concentration (mg/L)	
	Sample Collection Date (mm/dd/yr)	Sample Collection Time (24 Hours)	Sample Collection Time (AM/PM)	Sample Testing Date (mm/dd/yr)	Sample Testing Time (24 Hours)	Sample Testing Time (AM/PM)	Chlorine Concentration (mg/L)		First Order Model	Second Order Model
1	10/05/11	10:00:00	10:00:00 AM	10/06/11	07:55:00	07:55:00 AM	1.50	21.92	1.53	1.52
2	10/05/11	12:01:00	12:01:00 PM	10/06/11	08:00:00	08:00:00 AM	1.57	19.98	1.60	1.59
3	10/06/11	10:07:00	10:07:00 AM	10/07/11	16:35:00	04:35:00 PM	1.52	30.47	1.56	1.55
4	10/06/11	12:02:00	12:02:00 PM	10/07/11	16:45:00	04:45:00 PM	1.57	28.72	1.61	1.60

Site 36 Sample Number	Sample Collection			Sample Testing				Time Elapsed from Collection until Testing (hr)	Adjusted Chlorine Concentration (mg/L)	
	Sample Collection Date (mm/dd/yr)	Sample Collection Time (24 Hours)	Sample Collection Time (AM/PM)	Sample Testing Date (mm/dd/yr)	Sample Testing Time (24 Hours)	Sample Testing Time (AM/PM)	Chlorine Concentration (mg/L)		First Order Model	Second Order Model
1	10/05/11	10:00:00	10:00:00 AM	10/06/11	06:25:00	06:25:00 AM	1.68	20.42	1.71	1.71
2	10/05/11	12:00:00	12:00:00 PM	10/06/11	06:35:00	06:35:00 AM	1.61	18.58	1.63	1.63

APPENDIX F

Raw and Processed Data for Bulk Decay Coefficient Determination (Site 1)

Table 1 Temperature measurements of the bulk chloramine decay experiment.

<table>
<tr><th>Date</th><th>Time</th><th>Thermometer Used to Measure Temperature Inside Fridge</th><th>Temperature Inside Fridge (°C)</th><th>Thermometer Used to Measure Temperature Inside Cabinet</th><th>Temperature Inside Cabinet (°C)</th></tr>
<tr><td rowspan="3">Nov/2/2011</td><td>3:10 PM</td><td>Total-Range</td><td>3.9</td><td rowspan="17">Total-Range</td><td>21.2</td></tr>
<tr><td>5:10 PM</td><td>Total-Range</td><td>4.4</td><td>18.5</td></tr>
<tr><td>7:40 PM</td><td>Total-Range</td><td>1.0</td><td>18.3</td></tr>
<tr><td rowspan="2">Nov/3/2011</td><td rowspan="2">3:35 PM</td><td>Total-Range</td><td>3.3</td><td rowspan="2">19.5</td></tr>
<tr><td>Alcohol</td><td>4.2</td></tr>
<tr><td rowspan="2">Nov/4/2011</td><td rowspan="2">2:55 PM</td><td>Total-Range</td><td>2.0</td><td rowspan="2">19.4</td></tr>
<tr><td>Alcohol</td><td>3.8</td></tr>
<tr><td rowspan="2">Nov/5/2011</td><td rowspan="2">4:45 PM</td><td>Total-Range</td><td>3.7</td><td rowspan="2">19.5</td></tr>
<tr><td>Alcohol</td><td>4.0</td></tr>
<tr><td rowspan="2">Nov/7/2011</td><td rowspan="2">3:45 PM</td><td>Total-Range</td><td>4.2</td><td rowspan="2">19.1</td></tr>
<tr><td>Alcohol</td><td>3.3</td></tr>
<tr><td rowspan="2">Nov/8/2011</td><td rowspan="2">3:55 PM</td><td>Total-Range</td><td>1.0</td><td rowspan="2">19.2</td></tr>
<tr><td>Alcohol</td><td>2.1</td></tr>
<tr><td rowspan="2">Nov/9/2011</td><td rowspan="2">3:40 PM</td><td>Total-Range</td><td>1.0</td><td rowspan="2">18.9</td></tr>
<tr><td>Alcohol</td><td>3.1</td></tr>
<tr><td colspan="2">Average Temperature over 8 Days (°C)</td><td>Inside Fridge:</td><td>3.0</td><td>Inside Cabinet:</td><td>19.3</td></tr>
</table>

Note: The alcohol thermometer in a beaker of water apparatus was placed on the bottom layer of the fridge starting at 4:15 pm on Nov/2/2011.

Table 2(a) Raw results of the bottle tests conducted for the water samples of site 1 that were stored at the test temperature of 19.3°C.

Test Temperature		19.3 °C															
Bottle Type and Number (G - Glass; P - Plastic)		G1		G2		G3		G4		G5		G6		P1		P2	
Date	Testing Round Number	Sample Testing Time (HH:MM)	Chlorine Concentration (mg/L)	Sample Testing Time (HH:MM)	Chlorine Concentration (mg/L)	Sample Testing Time (HH:MM)	Chlorine Concentration (mg/L)	Sample Testing Time (HH:MM)	Chlorine Concentration (mg/L)	Sample Testing Time (HH:MM)	Chlorine Concentration (mg/L)	Sample Testing Time (HH:MM)	Chlorine Concentration (mg/L)	Sample Testing Time (HH:MM)	Chlorine Concentration (mg/L)	Sample Testing Time (HH:MM)	Chlorine Concentration (mg/L)
Nov 2/2011	Testing Round 1	15:20	1.99	15:30	2.00	15:40	1.97							16:20	1.96		
	Testing Round 2							21:45	1.92	21:55	1.94	22:05	1.95			22:10	1.92
Nov 3/2011	Testing Round 3							20:15	1.73	20:25	1.75	20:30	1.75			20:40	1.74
Nov 4/2011	Testing Round 4							18:30	1.65	18:35	1.64	18:45	1.64			18:50	1.63
Nov 5/2011	Testing Round 5	21:20	1.57	21:35	1.57	21:55	1.57							22:45	1.56	22:20	1.57
		21:25	1.55	21:45	1.57	22:00	1.56							22:50	1.57	22:30	1.56
		21:30	1.55	21:50	1.58	22:10	1.58							22:55	1.57	22:35	1.56
Nov 7/2011	Testing Round 6							17:15	1.49	17:25	1.52	17:35	1.53				

Table 2(b) Raw results of the bottle tests conducted for the water samples of site 1 that were stored at the test temperature of 3.0°C.

Test Temperature		3.0 °C															
Bottle Type and Number (G - Glass; P - Plastic)		G1		G2		G3		G4		G5		G6		P1		P2	
Date	Testing Round Number	Sample Testing Time (HH:MM)	Chlorine Concentration (mg/L)	Sample Testing Time (HH:MM)	Chlorine Concentration (mg/L)	Sample Testing Time (HH:MM)	Chlorine Concentration (mg/L)	Sample Testing Time (HH:MM)	Chlorine Concentration (mg/L)	Sample Testing Time (HH:MM)	Chlorine Concentration (mg/L)	Sample Testing Time (HH:MM)	Chlorine Concentration (mg/L)	Sample Testing Time (HH:MM)	Chlorine Concentration (mg/L)	Sample Testing Time (HH:MM)	Chlorine Concentration (mg/L)
Nov 2/2011	Testing Round 1	18:05	1.97	18:10	2.01	18:15	1.97							18:35	1.97		
	Testing Round 2							20:35	1.97	20:45	1.95	20:50	1.97			20:55	1.97
Nov 3/2011	Testing Round 3							17:05	1.90	17:15	1.88	17:20	1.91			17:35	1.91
Nov 4/2011	Testing Round 4							16:30	1.84	16:40	1.87	16:50	1.85			17:00	1.87
Nov 5/2011	Testing Round 5	17:05	1.74	17:30	1.83	17:55	1.82							19:00	1.85	18:30	1.85
		17:10	1.74	17:40	1.81	18:05	1.83							19:05	1.82	18:40	1.84
		17:20	1.81	17:45	1.84	18:15	1.83							19:15	1.83	18:45	1.82
Nov 7/2011	Testing Round 6							16:00	1.69	16:10	1.70	16:20	1.69				

Table 3(a) Calculating the average chloramine concentrations for the bottle tests conducted for the glass bottles of water samples of site 1 that were stored at the test temperature of 19.3°C.

Test Temperature		19.3 °C																			
Bottle Type and Number (G - Glass; P - Plastic)		G1			G2			G3			Average Chlorine Concentration (mg/L)	G4			G5			G6			Average Chlorine Concentration (mg/L)
Date	Testing Round Number	Sample Testing Time (HH:MM)	Time Elapsed (hr)	Chlorine Concentration (mg/L)	Sample Testing Time (HH:MM)	Time Elapsed (hr)	Chlorine Concentration (mg/L)	Sample Testing Time (HH:MM)	Time Elapsed (hr)	Chlorine Concentration (mg/L)		Sample Testing Time (HH:MM)	Time Elapsed (hr)	Chlorine Concentration (mg/L)	Sample Testing Time (HH:MM)	Time Elapsed (hr)	Chlorine Concentration (mg/L)	Sample Testing Time (HH:MM)	Time Elapsed (hr)	Chlorine Concentration (mg/L)	
Nov 2/2011	Testing Round 1	15:20	0.00	1.99	15:30	0.00	2.00	15:40	0.00	1.97	1.99										
	Testing Round 2											21:45	7.25	1.92	21:55	7.42	1.94	22:05	7.58	1.95	1.94
Nov 3/2011	Testing Round 3											20:15	29.75	1.73	20:25	29.92	1.75	20:30	30.00	1.75	1.74
Nov 4/2011	Testing Round 4											18:30	52.00	1.65	18:35	52.08	1.64	18:45	52.25	1.64	1.64
Nov 5/2011	Testing Round 5	21:20	78.83	1.57	21:35	79.08	1.57	21:55	79.42	1.57											
		21:25	78.92	1.55	21:45	79.25	1.57	22:00	79.50	1.56											
		21:30	79.00	1.55	21:50	79.33	1.58	22:10	79.67	1.58											
Nov 7/2011	Testing Round 6											17:15	123.75	1.49	17:25	123.92	1.52	17:35	124.08	1.53	1.51
Average Chlorine Concentration (mg/L)				1.56			1.57			1.57	1.57										

Table 3(b) Calculating the average chloramine concentrations for the bottle tests conducted for the glass bottles of water samples of site 1 that were stored at the test temperature of 3.0°C.

Test Temperature		3.0 °C																			
Bottle Type and Number (G - Glass; P - Plastic)		G1			G2			G3			Average Chlorine Concentration (mg/L)	G4			G5			G6			Average Chlorine Concentration (mg/L)
Date	Testing Round Number	Sample Testing Time (HH:MM)	Time Elapsed (hr)	Chlorine Concentration (mg/L)	Sample Testing Time (HH:MM)	Time Elapsed (hr)	Chlorine Concentration (mg/L)	Sample Testing Time (HH:MM)	Time Elapsed (hr)	Chlorine Concentration (mg/L)		Sample Testing Time (HH:MM)	Time Elapsed (hr)	Chlorine Concentration (mg/L)	Sample Testing Time (HH:MM)	Time Elapsed (hr)	Chlorine Concentration (mg/L)	Sample Testing Time (HH:MM)	Time Elapsed (hr)	Chlorine Concentration (mg/L)	
Nov 2/2011	Testing Round 1	18:05	0.00	1.97	18:10	0.00	2.01	18:15	0.00	1.97	1.98										
	Testing Round 2											20:35	6.08	1.97	20:45	6.25	1.95	20:50	6.33	1.97	1.96
Nov 3/2011	Testing Round 3											17:05	26.58	1.90	17:15	26.75	1.88	17:20	26.83	1.91	1.90
Nov 4/2011	Testing Round 4											16:30	50.00	1.84	16:40	50.17	1.87	16:50	50.33	1.85	1.85
Nov 5/2011	Testing Round 5	17:05	74.58	1.74	17:30	75.00	1.83	17:55	75.42	1.82											
		17:10	74.67	1.74	17:40	75.17	1.81	18:05	75.58	1.83											
		17:20	74.83	1.81	17:45	75.25	1.84	18:15	75.75	1.83											
Nov 7/2011	Testing Round 6											16:00	122.50	1.69	16:10	122.67	1.70	16:20	122.83	1.69	1.69
Average Chlorine Concentration (mg/L)				1.76			1.83			1.83	1.83										

Table 3(c) Calculating the average chloramine concentrations for the bottle tests conducted for the plastic (HDPE) bottles of water samples of site 1.

Test Temperature		19.3 °C							3.0 °C						
Bottle Type and Number (G - Glass; P - Plastic)		P1			P2			Average Chlorine Concentration (mg/L)	P1			P2			Average Chlorine Concentration (mg/L)
Date	Testing Round Number	Sample Testing Time (HH:MM)	Time Elapsed (hr)	Chlorine Concentration (mg/L)	Sample Testing Time (HH:MM)	Time Elapsed (hr)	Chlorine Concentration (mg/L)		Sample Testing Time (HH:MM)	Time Elapsed (hr)	Chlorine Concentration (mg/L)	Sample Testing Time (HH:MM)	Time Elapsed (hr)	Chlorine Concentration (mg/L)	
Nov 2/2011	Testing Round 1	16:20	0.00	1.96					18:35	0.00	1.97				
	Testing Round 2				22:10	7.67	1.92					20:55	6.42	1.97	
Nov 3/2011	Testing Round 3				20:40	30.17	1.74					17:35	27.08	1.91	
Nov 4/2011	Testing Round 4				18:50	52.33	1.63					17:00	50.50	1.87	
Nov 5/2011	Testing Round 5	22:45	80.25	1.56	22:20	79.83	1.57		19:00	76.50	1.85	18:30	76.00	1.85	
		22:50	80.33	1.57	22:30	80.00	1.56		19:05	76.58	1.82	18:40	76.17	1.84	
		22:55	80.42	1.57	22:35	80.08	1.56		19:15	76.75	1.83	18:45	76.25	1.82	
Average Chlorine Concentration (mg/L)				1.57			1.56	1.57			1.83			1.84	1.84

Table 4 Finalized results of the bottle tests conducted for the water samples of site 1.

Test Temperature		19.3 °C						3.0 °C					
Bottle Type		Glass			Plastic			Glass			Plastic		
Date	Testing Round Number	Sample Testing Time (HH:MM)	Time Elapsed (hr)	Chlorine Concentration (mg/L)	Sample Testing Time (HH:MM)	Time Elapsed (hr)	Chlorine Concentration (mg/L)	Sample Testing Time (HH:MM)	Time Elapsed (hr)	Chlorine Concentration (mg/L)	Sample Testing Time (HH:MM)	Time Elapsed (hr)	Chlorine Concentration (mg/L)
Nov 2/2011	Testing Round 1	15:20	0.00	1.99	16:20	0.00	1.96	18:10	0.00	1.99	18:35	0.00	1.97
	Testing Round 2	21:45	7.25	1.94	22:10	7.67	1.92	20:35	6.08	1.96	20:55	6.42	1.97
Nov 3/2011	Testing Round 3	20:15	29.75	1.74	20:40	30.17	1.74	17:05	26.58	1.90	17:35	27.08	1.91
Nov 4/2011	Testing Round 4	18:30	52.00	1.64	18:50	52.33	1.63	16:30	50.00	1.85	17:00	50.50	1.87
Nov 5/2011	Testing Round 5	21:20	78.83	1.57	22:20	79.83	1.57	17:30	75.00	1.83	18:30	76.00	1.84
Nov 7/2011	Testing Round 6	17:15	123.75	1.51				16:00	122.50	1.69			

Table 5(a) Site 1, first order decay model linearization.

Test Temperature		19.3 °C								3.0 °C							
Bottle Type		Glass				Plastic				Glass				Plastic			
Date	Testing Round Number	Sample Testing Time (HH:MM)	Time Elapsed (hr)	Chlorine Concentration, C (mg/L)	ln C	Sample Testing Time (HH:MM)	Time Elapsed (hr)	Chlorine Concentration, C (mg/L)	ln C	Sample Testing Time (HH:MM)	Time Elapsed (hr)	Chlorine Concentration, C (mg/L)	ln C	Sample Testing Time (HH:MM)	Time Elapsed (hr)	Chlorine Concentration, C (mg/L)	ln C
Nov 2/2011	Testing Round 1	15:20	0.00	1.99	0.69	16:20	0.00	1.96	0.67	18:10	0.00	1.99	0.69	18:35	0.00	1.97	0.68
	Testing Round 2	21:45	7.25	1.94	0.66	22:10	7.67	1.92	0.65	20:35	6.08	1.96	0.67	20:55	6.42	1.97	0.68
Nov 3/2011	Testing Round 3	20:15	29.75	1.74	0.55	20:40	30.17	1.74	0.55	17:05	26.58	1.90	0.64	17:35	27.08	1.91	0.65
Nov 4/2011	Testing Round 4	18:30	52.00	1.64	0.49	18:50	52.33	1.63	0.49	16:30	50.00	1.85	0.62	17:00	50.50	1.87	0.63
Nov 5/2011	Testing Round 5	21:20	78.83	1.57	0.45	22:20	79.83	1.57	0.45	17:30	75.00	1.83	0.60	18:30	76.00	1.84	0.61
Nov 7/2011	Testing Round 6	17:15	123.75	1.51	0.41					16:00	122.50	1.69	0.52				

Table 5(b) Site 1, second order decay model linearization.

Test Temperature		19.3 °C								3.0 °C							
Bottle Type		Glass				Plastic				Glass				Plastic			
Date	Testing Round Number	Sample Testing Time (HH:MM)	Time Elapsed (hr)	Chlorine Concentration, C (mg/L)	1/C	Sample Testing Time (HH:MM)	Time Elapsed (hr)	Chlorine Concentration, C (mg/L)	1/C	Sample Testing Time (HH:MM)	Time Elapsed (hr)	Chlorine Concentration, C (mg/L)	1/C	Sample Testing Time (HH:MM)	Time Elapsed (hr)	Chlorine Concentration, C (mg/L)	1/C
Nov 2/2011	Testing Round 1	15:20	0.00	1.99	0.50	16:20	0.00	1.96	0.51	18:10	0.00	1.99	0.50	18:35	0.00	1.97	0.51
	Testing Round 2	21:45	7.25	1.94	0.52	22:10	7.67	1.92	0.52	20:35	6.08	1.96	0.51	20:55	6.42	1.97	0.51
Nov 3/2011	Testing Round 3	20:15	29.75	1.74	0.57	20:40	30.17	1.74	0.57	17:05	26.58	1.90	0.53	17:35	27.08	1.91	0.52
Nov 4/2011	Testing Round 4	18:30	52.00	1.64	0.61	18:50	52.33	1.63	0.61	16:30	50.00	1.85	0.54	17:00	50.50	1.87	0.53
Nov 5/2011	Testing Round 5	21:20	78.83	1.57	0.64	22:20	79.83	1.57	0.64	17:30	75.00	1.83	0.55	18:30	76.00	1.84	0.54
Nov 7/2011	Testing Round 6	17:15	123.75	1.51	0.66					16:00	122.50	1.69	0.59				

Table 6 Site 1, chloramine concentrations in first and second order decay models.

Test Temperature		19.3 °C										3.0 °C									
Bottle Type		Glass					Plastic					Glass					Plastic				
Date	Testing Round Number	Sample Testing Time (HH:MM)	Time Elapsed (hr)	Chlorine Concentration (mg/L)	First Order Model (mg/L)	Second Order Model (mg/L)	Sample Testing Time (HH:MM)	Time Elapsed (hr)	Chlorine Concentration (mg/L)	First Order Model (mg/L)	Second Order Model (mg/L)	Sample Testing Time (HH:MM)	Time Elapsed (hr)	Chlorine Concentration (mg/L)	First Order Model (mg/L)	Second Order Model (mg/L)	Sample Testing Time (HH:MM)	Time Elapsed (hr)	Chlorine Concentration (mg/L)	First Order Model (mg/L)	Second Order Model (mg/L)
Nov 2/2011	Testing Round 1	15:20	0.00	1.99	1.92	1.93	16:20	0.00	1.96	1.94	1.94	18:10	0.00	1.99	1.98	1.98	18:35	0.00	1.97	1.97	1.97
	Testing Round 2	21:45	7.25	1.94	1.89	1.89	22:10	7.67	1.92	1.90	1.90	20:35	6.08	1.96	1.96	1.97	20:55	6.42	1.97	1.96	1.96
Nov 3/2011	Testing Round 3	20:15	29.75	1.74	1.80	1.79	20:40	30.17	1.74	1.78	1.77	17:05	26.58	1.90	1.91	1.91	17:35	27.08	1.91	1.92	1.92
Nov 4/2011	Testing Round 4	18:30	52.00	1.64	1.71	1.70	18:50	52.33	1.63	1.67	1.66	16:30	50.00	1.85	1.86	1.86	17:00	50.50	1.87	1.88	1.88
Nov 5/2011	Testing Round 5	21:20	78.83	1.57	1.61	1.60	22:20	79.83	1.57	1.54	1.54	17:30	75.00	1.83	1.80	1.80	18:30	76.00	1.84	1.83	1.83
Nov 7/2011	Testing Round 6	17:15	123.75	1.51	1.45	1.46						16:00	122.50	1.69	1.70	1.70					

Table 7(a) Calculation of the variance and the standard deviation.

Test Temperature		19.3°C															
Bottle Type and Number (G - Glass; P - Plastic)		G1		G2		G3		G4		G5		G6		P1		P2	
Date	Testing Round Number	Sample Testing Time (HH:MM)	Chlorine Concentration (mg/L)	Sample Testing Time (HH:MM)	Chlorine Concentration (mg/L)	Sample Testing Time (HH:MM)	Chlorine Concentration (mg/L)	Sample Testing Time (HH:MM)	Chlorine Concentration (mg/L)	Sample Testing Time (HH:MM)	Chlorine Concentration (mg/L)	Sample Testing Time (HH:MM)	Chlorine Concentration (mg/L)	Sample Testing Time (HH:MM)	Chlorine Concentration (mg/L)	Sample Testing Time (HH:MM)	Chlorine Concentration (mg/L)
Nov 2/2011	Testing Round 1	15:20	1.99	15:30	2.00	15:40	1.97							16:20	1.96		
	Testing Round 2							21:45	1.92	21:55	1.94	22:05	1.95			22:10	1.92
Nov 3/2011	Testing Round 3							20:15	1.73	20:25	1.75	20:30	1.75			20:40	1.74
Nov 4/2011	Testing Round 4							18:30	1.65	18:35	1.64	18:45	1.64			18:50	1.63
Nov 5/2011	Testing Round 5	21:20	1.57	21:35	1.57	21:55	1.57							22:45	1.56	22:20	1.57
		21:25	1.55	21:45	1.57	22:00	1.56							22:50	1.57	22:30	1.56
		21:30	1.55	21:50	1.58	22:10	1.58							22:55	1.57	22:35	1.56
Nov 7/2011	Testing Round 6							17:15	1.49	17:25	1.52	17:35	1.53				
	Variance		0.00013		0.00003		0.00010								0.00003		0.00003
	Standard Deviation		0.0115		0.0058		0.0100								0.0058		0.0058

Table 7(b) Calculation of the variance and the standard deviation.

Test Temperature		3.0°C															
Bottle Type and Number (G - Glass; P - Plastic)		G1		G2		G3		G4		G5		G6		P1		P2	
Date	Testing Round Number	Sample Testing Time (HH:MM)	Chlorine Concentration (mg/L)	Sample Testing Time (HH:MM)	Chlorine Concentration (mg/L)	Sample Testing Time (HH:MM)	Chlorine Concentration (mg/L)	Sample Testing Time (HH:MM)	Chlorine Concentration (mg/L)	Sample Testing Time (HH:MM)	Chlorine Concentration (mg/L)	Sample Testing Time (HH:MM)	Chlorine Concentration (mg/L)	Sample Testing Time (HH:MM)	Chlorine Concentration (mg/L)	Sample Testing Time (HH:MM)	Chlorine Concentration (mg/L)
Nov 2/2011	Testing Round 1	18:05	1.97	18:10	2.01	18:15	1.97							18:35	1.97		
	Testing Round 2							20:35	1.97	20:45	1.95	20:50	1.97			20:55	1.97
Nov 3/2011	Testing Round 3							17:05	1.90	17:15	1.88	17:20	1.91			17:35	1.91
Nov 4/2011	Testing Round 4							16:30	1.84	16:40	1.87	16:50	1.85			17:00	1.87
Nov 5/2011	Testing Round 5	17:05	1.74	17:30	1.83	17:55	1.82							19:00	1.85	18:30	1.85
		17:10	1.74	17:40	1.81	18:05	1.83							19:05	1.82	18:40	1.84
		17:20	1.81	17:45	1.84	18:15	1.83							19:15	1.83	18:45	1.82
Nov 7/2011	Testing Round 6							16:00	1.69	16:10	1.70	16:20	1.69				
	Variance		0.00163		0.00023		0.00003								0.00023		0.00023
	Standard Deviation		0.0404		0.0153		0.0058								0.0153		0.0153

APPENDIX G

Raw and Processed Data for Bulk Decay Coefficient Determination (Site 2)

Table 1 Site 2, raw data.

Test Temperature		19.3 °C								3.0 °C							
Bottle Type and Number (G - Glass; P - Plastic)		G1		G2		P1		P2		G1		G2		P1		P2	
Date	Testing Round Number	Sample Testing Time (HH:MM)	Chlorine Concentration (mg/L)	Sample Testing Time (HH:MM)	Chlorine Concentration (mg/L)	Sample Testing Time (HH:MM)	Chlorine Concentration (mg/L)	Sample Testing Time (HH:MM)	Chlorine Concentration (mg/L)	Sample Testing Time (HH:MM)	Chlorine Concentration (mg/L)	Sample Testing Time (HH:MM)	Chlorine Concentration (mg/L)	Sample Testing Time (HH:MM)	Chlorine Concentration (mg/L)	Sample Testing Time (HH:MM)	Chlorine Concentration (mg/L)
Nov 2/2011	Testing Round 1	16:30	1.88			16:45	1.88			16:55	1.86			17:15	1.87		
	Testing Round 2			21:10	1.85			21:20	1.84			19:55	1.88			20:05	1.87
Nov 3/2011	Testing Round 3			19:35	1.67			19:45	1.65			16:25	1.84			16:35	1.83
Nov 4/2011	Testing Round 4			17:55	1.59			18:00	1.57			15:10	1.80			15:50	1.78
Nov 5/2011	Testing Round 5	20:45	1.52			20:55	1.52			19:30	1.74			19:40	1.74		
Nov 7/2011	Testing Round 6	17:40	1.44			17:50	1.43			16:30	1.68			16:40	1.67		
Nov 8/2011	Testing Round 7	17:00	1.41			17:10	1.39			16:15	1.66			16:20	1.68		
Nov 9/2011	Testing Round 8			16:55	1.41			17:05	1.38			16:00	1.65				

Table 2 Site 2, finalized raw data.

Test Temperature		19.3 °C						3.0 °C					
Bottle Type		Glass			Plastic			Glass			Plastic		
Date	Testing Round Number	Sample Testing Time (HH:MM)	Time Elapsed (hr)	Chlorine Concentration (mg/L)	Sample Testing Time (HH:MM)	Time Elapsed (hr)	Chlorine Concentration (mg/L)	Sample Testing Time (HH:MM)	Time Elapsed (hr)	Chlorine Concentration (mg/L)	Sample Testing Time (HH:MM)	Time Elapsed (hr)	Chlorine Concentration (mg/L)
Nov 2/2011	Testing Round 1	16:30	0.00	1.88	16:45	0.00	1.88	16:55	0.00	1.86	17:15	0.00	1.87
	Testing Round 2	21:10	6.67	1.85	21:20	6.83	1.84	19:55	5.42	1.88	20:05	5.58	1.87
Nov 3/2011	Testing Round 3	19:35	29.08	1.67	19:45	29.25	1.65	16:25	25.92	1.84	16:35	26.08	1.83
Nov 4/2011	Testing Round 4	17:55	51.42	1.59	18:00	51.50	1.57	15:10	48.67	1.80	15:50	49.33	1.78
Nov 5/2011	Testing Round 5	20:45	78.25	1.52	20:55	78.42	1.52	19:30	77.00	1.74	19:40	77.17	1.74
Nov 7/2011	Testing Round 6	17:40	124.17	1.44	17:50	124.33	1.43	16:30	123.00	1.68	16:40	123.17	1.67
Nov 8/2011	Testing Round 7	17:00	147.50	1.41	17:10	147.67	1.39	16:15	146.75	1.66	16:20	146.83	1.68
Nov 9/2011	Testing Round 8	16:55	171.42	1.41	17:05	171.58	1.38	16:00	170.50	1.65			

Table 3(a) Site 2, linearization of the first order decay model.

Test Temperature		19.3 °C								3.0 °C							
Bottle Type		Glass				Plastic				Glass				Plastic			
Date	Testing Round Number	Sample Testing Time (HH:MM)	Time Elapsed (hr)	Chlorine Concentration, C (mg/L)	ln C	Sample Testing Time (HH:MM)	Time Elapsed (hr)	Chlorine Concentration, C (mg/L)	ln C	Sample Testing Time (HH:MM)	Time Elapsed (hr)	Chlorine Concentration, C (mg/L)	ln C	Sample Testing Time (HH:MM)	Time Elapsed (hr)	Chlorine Concentration, C (mg/L)	ln C
Nov 2/2011	Testing Round 1	16:30	0.00	1.88	0.63	16:45	0.00	1.88	0.63	16:55	0.00	1.86	0.62	17:15	0.00	1.87	0.63
	Testing Round 2	21:10	6.67	1.85	0.62	21:20	6.83	1.84	0.61	19:55	5.42	1.88	0.63	20:05	5.58	1.87	0.63
Nov 3/2011	Testing Round 3	19:35	29.08	1.67	0.51	19:45	29.25	1.65	0.50	16:25	25.92	1.84	0.61	16:35	26.08	1.83	0.60
Nov 4/2011	Testing Round 4	17:55	51.42	1.59	0.46	18:00	51.50	1.57	0.45	15:10	48.67	1.80	0.59	15:50	49.33	1.78	0.58
Nov 5/2011	Testing Round 5	20:45	78.25	1.52	0.42	20:55	78.42	1.52	0.42	19:30	77.00	1.74	0.55	19:40	77.17	1.74	0.55
Nov 7/2011	Testing Round 6	17:40	124.17	1.44	0.36	17:50	124.33	1.43	0.36	16:30	123.00	1.68	0.52	16:40	123.17	1.67	0.51
Nov 8/2011	Testing Round 7	17:00	147.50	1.41	0.34	17:10	147.67	1.39	0.33	16:15	146.75	1.66	0.51	16:20	146.83	1.68	0.52
Nov 9/2011	Testing Round 8	16:55	171.42	1.41	0.34	17:05	171.58	1.38	0.32	16:00	170.50	1.65	0.50				

Table 3(b) Site 2, linearization of the second order decay model.

Test Temperature		19.3 °C								3.0 °C							
Bottle Type		Glass				Plastic				Glass				Plastic			
Date	Testing Round Number	Sample Testing Time (HH:MM)	Time Elapsed (hr)	Chlorine Concentration, C (mg/L)	1/C	Sample Testing Time (HH:MM)	Time Elapsed (hr)	Chlorine Concentration, C (mg/L)	1/C	Sample Testing Time (HH:MM)	Time Elapsed (hr)	Chlorine Concentration, C (mg/L)	1/C	Sample Testing Time (HH:MM)	Time Elapsed (hr)	Chlorine Concentration, C (mg/L)	1/C
Nov 2/2011	Testing Round 1	16:30	0.00	1.88	0.53	16:45	0.00	1.88	0.53	16:55	0.00	1.86	0.54	17:15	0.00	1.87	0.53
	Testing Round 2	21:10	6.67	1.85	0.54	21:20	6.83	1.84	0.54	19:55	5.42	1.88	0.53	20:05	5.58	1.87	0.53
Nov 3/2011	Testing Round 3	19:35	29.08	1.67	0.60	19:45	29.25	1.65	0.61	16:25	25.92	1.84	0.54	16:35	26.08	1.83	0.55
Nov 4/2011	Testing Round 4	17:55	51.42	1.59	0.63	18:00	51.50	1.57	0.64	15:10	48.67	1.80	0.56	15:50	49.33	1.78	0.56
Nov 5/2011	Testing Round 5	20:45	78.25	1.52	0.66	20:55	78.42	1.52	0.66	19:30	77.00	1.74	0.57	19:40	77.17	1.74	0.57
Nov 7/2011	Testing Round 6	17:40	124.17	1.44	0.69	17:50	124.33	1.43	0.70	16:30	123.00	1.68	0.60	16:40	123.17	1.67	0.60
Nov 8/2011	Testing Round 7	17:00	147.50	1.41	0.71	17:10	147.67	1.39	0.72	16:15	146.75	1.66	0.60	16:20	146.83	1.68	0.60
Nov 9/2011	Testing Round 8	16:55	171.42	1.41	0.71	17:05	171.58	1.38	0.72	16:00	170.50	1.65	0.61				

Table 4 Site 2, chloramine concentrations in first and second order decay models.

Test Temperature		19.3°C										3.0°C									
Bottle Type		Glass					Plastic					Glass					Plastic				
Date	Testing Round Number	Sample Testing Time (HH:MM)	Time Elapsed (hr)	Chlorine Concentration (mg/L)	First Order Model (mg/L)	Second Order Model (mg/L)	Sample Testing Time (HH:MM)	Time Elapsed (hr)	Chlorine Concentration (mg/L)	First Order Model (mg/L)	Second Order Model (mg/L)	Sample Testing Time (HH:MM)	Time Elapsed (hr)	Chlorine Concentration (mg/L)	First Order Model (mg/L)	Second Order Model (mg/L)	Sample Testing Time (HH:MM)	Time Elapsed (hr)	Chlorine Concentration (mg/L)	First Order Model (mg/L)	Second Order Model (mg/L)
Nov 2/2011	Testing Round 1	16:30	0.00	1.88	1.80	1.81	16:45	0.00	1.88	1.80	1.80	16:55	0.00	1.86	1.87	1.87	17:15	0.00	1.87	1.87	1.87
	Testing Round 2	21:10	6.67	1.85	1.78	1.78	21:20	6.83	1.84	1.78	1.78	19:55	5.42	1.88	1.86	1.86	20:05	5.58	1.87	1.86	1.86
Nov 3/2011	Testing Round 3	19:35	29.08	1.67	1.72	1.71	19:45	29.25	1.65	1.71	1.70	16:25	25.92	1.84	1.83	1.83	16:35	26.08	1.83	1.83	1.83
Nov 4/2011	Testing Round 4	17:55	51.42	1.59	1.65	1.64	18:00	51.50	1.57	1.64	1.63	15:10	48.67	1.80	1.80	1.80	15:50	49.33	1.78	1.79	1.79
Nov 5/2011	Testing Round 5	20:45	78.25	1.52	1.58	1.57	20:55	78.42	1.52	1.57	1.56	19:30	77.00	1.74	1.76	1.76	19:40	77.17	1.74	1.75	1.75
Nov 7/2011	Testing Round 6	17:40	124.17	1.44	1.46	1.46	17:50	124.33	1.43	1.44	1.44	16:30	123.00	1.68	1.69	1.69	16:40	123.17	1.67	1.69	1.69
Nov 8/2011	Testing Round 7	17:00	147.50	1.41	1.41	1.41	17:10	147.67	1.39	1.39	1.39	16:15	146.75	1.66	1.66	1.66	16:20	146.83	1.68	1.66	1.66
Nov 9/2011	Testing Round 8	16:55	171.42	1.41	1.35	1.36	17:05	171.58	1.38	1.33	1.34	16:00	170.50	1.65	1.63	1.63					

APPENDIX H

Raw and Processed Data for Bulk Decay Coefficient Determination (Site 3)

Table 1 Site 3, raw data.

Test Temperature		19.3 °C								3.0 °C							
Bottle Type and Number (G - Glass; P - Plastic)		G1		G2		P1		P2		G1		G2		P1		P2	
Date	Testing Round Number	Sample Testing Time (HH:MM)	Chlorine Concentration (mg/L)	Sample Testing Time (HH:MM)	Chlorine Concentration (mg/L)	Sample Testing Time (HH:MM)	Chlorine Concentration (mg/L)	Sample Testing Time (HH:MM)	Chlorine Concentration (mg/L)	Sample Testing Time (HH:MM)	Chlorine Concentration (mg/L)	Sample Testing Time (HH:MM)	Chlorine Concentration (mg/L)	Sample Testing Time (HH:MM)	Chlorine Concentration (mg/L)	Sample Testing Time (HH:MM)	Chlorine Concentration (mg/L)
Nov 2/2011	Testing Round 1	17:25	1.38			17:35	1.38			17:45	1.37			17:55	1.38		
	Testing Round 2			21:30	1.35			21:40	1.35			20:15	1.39			20:25	1.39
Nov 3/2011	Testing Round 3			19:55	1.26			20:05	1.25			16:45	1.37			16:55	1.37
Nov 4/2011	Testing Round 4			18:10	1.19			18:20	1.20			16:00	1.30			16:10	1.34
Nov 5/2011	Testing Round 5	21:00	1.15			21:10	1.15			19:50	1.29			20:00	1.31		
Nov 7/2011	Testing Round 6	18:05	1.07			18:10	1.10			16:50	1.24			17:00	1.27		
Nov 8/2011	Testing Round 7	17:20	1.05			17:30	1.06			16:30	1.20			16:40	1.26		
Nov 9/2011	Testing Round 8			17:15	1.05			17:25	1.04							16:30	1.26

Table 2 Site 3, finalized raw data.

Test Temperature		19.3 °C						3.0 °C					
Bottle Type		Glass			Plastic			Glass			Plastic		
Date	Testing Round Number	Sample Testing Time (HH:MM)	Time Elapsed (hr)	Chlorine Concentration (mg/L)	Sample Testing Time (HH:MM)	Time Elapsed (hr)	Chlorine Concentration (mg/L)	Sample Testing Time (HH:MM)	Time Elapsed (hr)	Chlorine Concentration (mg/L)	Sample Testing Time (HH:MM)	Time Elapsed (hr)	Chlorine Concentration (mg/L)
Nov 2/2011	Testing Round 1	17:25	0.00	1.38	17:35	0.00	1.38	17:45	0.00	1.37	17:55	0.00	1.38
	Testing Round 2	21:30	7.00	1.35	21:40	7.17	1.35	20:15	5.75	1.39	20:25	5.92	1.39
Nov 3/2011	Testing Round 3	19:55	29.42	1.26	20:05	29.58	1.25	16:45	26.25	1.37	16:55	26.42	1.37
Nov 4/2011	Testing Round 4	18:10	51.67	1.19	18:20	51.83	1.20	16:00	49.50	1.30	16:10	49.67	1.34
Nov 5/2011	Testing Round 5	21:00	78.50	1.15	21:10	78.67	1.15	19:50	77.33	1.29	20:00	77.50	1.31
Nov 7/2011	Testing Round 6	18:05	124.58	1.07	18:10	124.67	1.10	16:50	123.33	1.24	17:00	123.50	1.27
Nov 8/2011	Testing Round 7	17:20	147.83	1.05	17:30	148.00	1.06	16:30	147.00	1.20	16:40	147.17	1.26
Nov 9/2011	Testing Round 8	17:15	171.75	1.05	17:25	171.92	1.04				16:30	171.00	1.26

Table 3(a) Site 3, linearization of the first order decay model.

Test Temperature		19.3 °C								3.0 °C							
Bottle Type		Glass				Plastic				Glass				Plastic			
Date	Testing Round Number	Sample Testing Time (HH:MM)	Time Elapsed (hr)	Chlorine Concentration, C (mg/L)	ln C	Sample Testing Time (HH:MM)	Time Elapsed (hr)	Chlorine Concentration, C (mg/L)	ln C	Sample Testing Time (HH:MM)	Time Elapsed (hr)	Chlorine Concentration, C (mg/L)	ln C	Sample Testing Time (HH:MM)	Time Elapsed (hr)	Chlorine Concentration, C (mg/L)	ln C
Nov 2/2011	Testing Round 1	17:25	0.00	1.38	0.32	17:35	0.00	1.38	0.32	17:45	0.00	1.37	0.31	17:55	0.00	1.38	0.32
	Testing Round 2	21:30	7.00	1.35	0.30	21:40	7.17	1.35	0.30	20:15	5.75	1.39	0.33	20:25	5.92	1.39	0.33
Nov 3/2011	Testing Round 3	19:55	29.42	1.26	0.23	20:05	29.58	1.25	0.22	16:45	26.25	1.37	0.31	16:55	26.42	1.37	0.31
Nov 4/2011	Testing Round 4	18:10	51.67	1.19	0.17	18:20	51.83	1.20	0.18	16:00	49.50	1.30	0.26	16:10	49.67	1.34	0.29
Nov 5/2011	Testing Round 5	21:00	78.50	1.15	0.14	21:10	78.67	1.15	0.14	19:50	77.33	1.29	0.25	20:00	77.50	1.31	0.27
Nov 7/2011	Testing Round 6	18:05	124.58	1.07	0.07	18:10	124.67	1.10	0.10	16:50	123.33	1.24	0.22	17:00	123.50	1.27	0.24
Nov 8/2011	Testing Round 7	17:20	147.83	1.05	0.05	17:30	148.00	1.06	0.06	16:30	147.00	1.20	0.18	16:40	147.17	1.26	0.23
Nov 9/2011	Testing Round 8	17:15	171.75	1.05	0.05	17:25	171.92	1.04	0.04					16:30	171.00	1.26	0.23

Table 3(b) Site 3, linearization of the second order decay model.

Test Temperature		19.3 °C								3.0 °C							
Bottle Type		Glass				Plastic				Glass				Plastic			
Date	Testing Round Number	Sample Testing Time (HH:MM)	Time Elapsed (hr)	Chlorine Concentration, C (mg/L)	1/C	Sample Testing Time (HH:MM)	Time Elapsed (hr)	Chlorine Concentration, C (mg/L)	1/C	Sample Testing Time (HH:MM)	Time Elapsed (hr)	Chlorine Concentration, C (mg/L)	1/C	Sample Testing Time (HH:MM)	Time Elapsed (hr)	Chlorine Concentration, C (mg/L)	1/C
Nov 2/2011	Testing Round 1	17:25	0.00	1.38	0.72	17:35	0.00	1.38	0.72	17:45	0.00	1.37	0.73	17:55	0.00	1.38	0.72
	Testing Round 2	21:30	7.00	1.35	0.74	21:40	7.17	1.35	0.74	20:15	5.75	1.39	0.72	20:25	5.92	1.39	0.72
Nov 3/2011	Testing Round 3	19:55	29.42	1.26	0.79	20:05	29.58	1.25	0.80	16:45	26.25	1.37	0.73	16:55	26.42	1.37	0.73
Nov 4/2011	Testing Round 4	18:10	51.67	1.19	0.84	18:20	51.83	1.20	0.83	16:00	49.50	1.30	0.77	16:10	49.67	1.34	0.75
Nov 5/2011	Testing Round 5	21:00	78.50	1.15	0.87	21:10	78.67	1.15	0.87	19:50	77.33	1.29	0.78	20:00	77.50	1.31	0.76
Nov 7/2011	Testing Round 6	18:05	124.58	1.07	0.93	18:10	124.67	1.10	0.91	16:50	123.33	1.24	0.81	17:00	123.50	1.27	0.79
Nov 8/2011	Testing Round 7	17:20	147.83	1.05	0.95	17:30	148.00	1.06	0.94	16:30	147.00	1.20	0.83	16:40	147.17	1.26	0.79
Nov 9/2011	Testing Round 8	17:15	171.75	1.05	0.95	17:25	171.92	1.04	0.96					16:30	171.00	1.26	0.79

Table 4 Site 3, chloramine concentrations in first and second order decay models.

Test Temperature		19.3 °C										3.0 °C									
Bottle Type		Glass					Plastic					Glass					Plastic				
Date	Testing Round Number	Sample Testing Time (HH:MM)	Time Elapsed (hr)	Chlorine Concentration (mg/L)	First Order Model (mg/L)	Second Order Model (mg/L)	Sample Testing Time (HH:MM)	Time Elapsed (hr)	Chlorine Concentration (mg/L)	First Order Model (mg/L)	Second Order Model (mg/L)	Sample Testing Time (HH:MM)	Time Elapsed (hr)	Chlorine Concentration (mg/L)	First Order Model (mg/L)	Second Order Model (mg/L)	Sample Testing Time (HH:MM)	Time Elapsed (hr)	Chlorine Concentration (mg/L)	First Order Model (mg/L)	Second Order Model (mg/L)
Nov 2/2011	Testing Round 1	17:25	0.00	1.38	1.34	1.34	17:35	0.00	1.38	1.34	1.34	17:45	0.00	1.37	1.39	1.39	17:55	0.00	1.38	1.38	1.39
	Testing Round 2	21:30	7.00	1.35	1.32	1.32	21:40	7.17	1.35	1.32	1.32	20:15	5.75	1.39	1.38	1.38	20:25	5.92	1.39	1.38	1.38
Nov 3/2011	Testing Round 3	19:55	29.42	1.26	1.27	1.27	20:05	29.58	1.25	1.28	1.27	16:45	26.25	1.37	1.35	1.35	16:55	26.42	1.37	1.36	1.36
Nov 4/2011	Testing Round 4	18:10	51.67	1.19	1.23	1.22	18:20	51.83	1.20	1.23	1.23	16:00	49.50	1.30	1.32	1.32	16:10	49.67	1.34	1.34	1.34
Nov 5/2011	Testing Round 5	21:00	78.50	1.15	1.18	1.17	21:10	78.67	1.15	1.18	1.18	19:50	77.33	1.29	1.29	1.29	20:00	77.50	1.31	1.32	1.32
Nov 7/2011	Testing Round 6	18:05	124.58	1.07	1.09	1.09	18:10	124.67	1.10	1.10	1.10	16:50	123.33	1.24	1.23	1.23	17:00	123.50	1.27	1.28	1.28
Nov 8/2011	Testing Round 7	17:20	147.83	1.05	1.05	1.05	17:30	148.00	1.06	1.06	1.06	16:30	147.00	1.20	1.20	1.21	16:40	147.17	1.26	1.26	1.26
Nov 9/2011	Testing Round 8	17:15	171.75	1.05	1.01	1.02	17:25	171.92	1.04	1.02	1.03						16:30	171.00	1.26	1.24	1.25

APPENDIX I

Model Simulation Results and Output

Table 1 July 2011 model simulation, comparing no decay to first and second order bulk decay, nodes

Node Number	Chlorine Concentration (mg/L)			Node Number	Chlorine Concentration (mg/L)			Node Number	Chlorine Concentration (mg/L)			Node Number	Chlorine Concentration (mg/L)		
	No Decay, Sources Mixing Only	First Order Bulk Decay Only	Second Order Bulk Decay Only		No Decay, Sources Mixing Only	First Order Bulk Decay Only	Second Order Bulk Decay Only		No Decay, Sources Mixing Only	First Order Bulk Decay Only	Second Order Bulk Decay Only		No Decay, Sources Mixing Only	First Order Bulk Decay Only	Second Order Bulk Decay Only
1	1.36	1.36	1.36	69	1.62	1.59	1.59	137	1.61	1.58	1.58	205	1.62	1.59	1.59
2	1.62	1.58	1.58	70	1.62	1.60	1.60	138	1.57	1.53	1.53	206	1.62	1.59	1.59
3	1.37	1.37	1.37	71	1.62	1.60	1.60	139	1.62	1.59	1.59	207	1.62	1.59	1.59
4	1.41	1.41	1.41	72	1.62	1.60	1.60	140	1.62	1.59	1.60	208	1.62	1.59	1.59
5	1.62	1.61	1.61	73	1.62	1.60	1.61	141	1.59	1.55	1.55	209	1.62	1.59	1.59
6	1.62	1.60	1.60	74	1.62	1.57	1.58	142	1.62	1.57	1.58	210	1.48	1.47	1.47
7	1.62	1.61	1.61	75	1.62	1.59	1.59	143	1.62	1.58	1.59	211	1.62	1.57	1.58
8	1.62	1.61	1.61	76	1.62	1.54	1.55	144	1.62	1.59	1.59	212	1.62	1.61	1.61
9	1.62	1.61	1.61	77	1.62	1.55	1.56	145	1.62	1.58	1.58	213	1.62	1.59	1.59
10	1.62	1.61	1.61	78	1.62	1.53	1.54	146	1.62	1.59	1.59	214	1.62	1.61	1.61
11	1.41	1.41	1.41	79	1.62	1.56	1.57	147	1.62	1.58	1.58	215	1.62	1.59	1.60
12	1.38	1.37	1.37	80	1.62	1.59	1.59	148	1.62	1.58	1.58	216	1.62	1.60	1.60
13	1.38	1.37	1.37	81	1.62	1.58	1.59	149	1.62	1.58	1.58	217	1.62	1.60	1.60
14	1.41	1.41	1.41	82	1.62	1.60	1.60	150	1.62	1.57	1.58	218	1.62	1.60	1.60
15	1.49	1.48	1.48	83	1.62	1.60	1.60	151	1.62	1.57	1.57	219	1.62	1.59	1.59
16	1.59	1.58	1.58	84	1.62	1.60	1.61	152	1.59	1.55	1.55	220	1.62	1.60	1.60
17	1.62	1.61	1.61	85	1.62	1.60	1.60	153	1.62	1.62	1.62	221	1.62	1.58	1.58
18	1.41	1.40	1.40	86	1.62	1.60	1.60	154	1.62	1.62	1.62	222	1.62	1.59	1.59
19	1.43	1.41	1.41	87	1.62	1.59	1.59	155	1.62	1.62	1.62	223	1.62	1.59	1.59
20	1.48	1.43	1.43	88	1.62	1.59	1.59	156	1.62	1.62	1.62	224	1.62	1.60	1.60
21	1.41	1.39	1.39	89	1.62	1.59	1.59	157	1.62	1.62	1.62	225	1.62	1.59	1.60
22	1.41	1.40	1.40	90	1.62	1.59	1.59	158	1.62	1.62	1.62	226	1.62	1.59	1.59
23	1.47	1.45	1.45	91	1.62	1.60	1.60	159	1.62	1.62	1.62	227	1.62	1.59	1.60
24	1.47	1.45	1.45	92	1.62	1.59	1.59	160	1.62	1.62	1.62	228	1.62	1.58	1.58
25	1.48	1.46	1.47	93	1.62	1.59	1.59	161	1.62	1.62	1.62	229	1.62	1.59	1.59
26	1.48	1.47	1.47	94	1.62	1.58	1.58	162	1.62	1.62	1.62	230	1.62	1.59	1.59
27	1.51	1.49	1.49	95	1.62	1.58	1.58	163	1.38	1.37	1.37	231	1.62	1.58	1.59
28	1.51	1.49	1.49	96	1.62	1.59	1.59	164	1.38	1.37	1.37	232	1.48	1.42	1.43
29	1.48	1.47	1.47	97	1.62	1.58	1.59	165	1.62	1.60	1.60	233	1.48	1.43	1.43
30	1.62	1.58	1.59	98	1.62	1.58	1.59	166	1.42	1.40	1.41	234	1.62	1.59	1.59
31	1.61	1.59	1.59	99	1.62	1.59	1.59	167	1.42	1.41	1.41	235	1.62	1.59	1.60
32	1.62	1.60	1.60	100	1.62	1.59	1.59	168	1.41	1.41	1.41	236	1.62	1.57	1.58
33	1.62	1.60	1.60	101	1.62	1.58	1.58	169	1.62	1.61	1.61	237	1.62	1.58	1.58
34	0.00	0.00	0.00	102	1.43	1.40	1.40	170	1.62	1.61	1.61	238	1.62	1.58	1.58
35	1.43	1.41	1.41	103	1.47	1.45	1.45	171	1.62	1.62	1.62	239	1.62	1.58	1.58
36	1.48	1.47	1.47	104	1.47	1.44	1.45	172	1.62	1.62	1.62	240	1.62	1.58	1.58
37	1.48	1.47	1.47	105	1.49	1.46	1.46	173	1.62	1.62	1.62	241	1.62	1.58	1.58
38	1.48	1.47	1.47	106	1.52	1.49	1.50	174	1.62	1.62	1.62	242	1.62	1.58	1.59
39	1.51	1.49	1.49	107	1.51	1.48	1.49	175	1.62	1.61	1.61	243	1.62	1.58	1.59
40	1.51	1.49	1.49	108	1.54	1.51	1.51	176	1.62	1.62	1.62	244	1.41	1.39	1.39
41	1.51	1.49	1.49	109	1.61	1.58	1.58	177	1.62	1.62	1.62	245	1.37	1.37	1.37
42	1.62	1.61	1.61	110	1.61	1.59	1.59	178	1.62	1.61	1.61	246	1.62	1.62	1.62
43	1.62	1.61	1.61	111	1.61	1.59	1.59	179	1.62	1.61	1.61	247	1.62	1.61	1.61
44	1.62	1.61	1.61	112	1.46	1.43	1.44	180	1.62	1.61	1.61	248	1.62	1.61	1.61
45	1.62	1.60	1.61	113	1.45	1.41	1.41	181	1.62	1.60	1.60	249	1.62	1.61	1.61
46	1.62	1.61	1.61	114	1.47	1.43	1.43	182	1.62	1.61	1.61	250	1.48	1.47	1.47
47	1.62	1.61	1.61	115	1.47	1.44	1.44	183	1.62	1.59	1.59	251	1.48	1.46	1.46
48	1.62	1.61	1.61	116	1.47	1.44	1.44	184	1.62	1.60	1.60	252	1.51	1.49	1.49
49	1.62	1.60	1.60	117	1.48	1.45	1.45	185	1.62	1.58	1.58	253	1.51	1.49	1.49
50	1.62	1.60	1.60	118	1.50	1.46	1.46	186	1.62	1.58	1.58	254	1.51	1.49	1.49
51	1.62	1.60	1.61	119	1.53	1.50	1.50	187	1.62	1.59	1.60	255	1.43	1.40	1.41
52	1.62	1.61	1.61	120	1.55	1.49	1.50	188	1.61	1.59	1.59	256	1.45	1.41	1.41
53	1.62	1.61	1.61	121	1.54	1.51	1.51	189	1.61	1.59	1.59	257	1.48	1.43	1.44
54	1.62	1.61	1.61	122	1.61	1.59	1.59	190	1.57	1.53	1.53	258	1.62	1.60	1.60
55	1.62	1.60	1.60	123	1.61	1.58	1.58	191	1.59	1.55	1.55	259	1.62	1.61	1.61
56	1.62	1.60	1.60	124	1.62	1.60	1.60	192	1.62	1.49	1.50	260	1.62	1.58	1.59
57	1.62	1.61	1.61	125	1.43	1.40	1.41	193	0.00	0.00	0.00	261	1.62	1.56	1.57
58	1.62	1.61	1.61	126	1.43	1.40	1.41	194	1.62	1.26	1.31	262	1.62	1.58	1.59
59	1.62	1.61	1.62	127	1.45	1.41	1.41	195	0.00	0.00	0.00	263	1.62	1.59	1.59
60	1.62	1.60	1.60	128	1.48	1.43	1.44	196	1.59	1.32	1.36	264	1.62	1.57	1.58
61	1.62	1.60	1.60	129	1.48	1.43	1.44	197	1.62	1.61	1.61	265	1.62	1.59	1.59
62	1.62	1.61	1.61	130	1.48	1.43	1.43	198	0.00	0.00	0.00				
63	1.62	1.59	1.60	131	1.48	1.43	1.44	199	1.62	1.59	1.59				
64	1.62	1.60	1.60	132	1.48	1.43	1.43	200	1.62	1.59	1.59				
65	1.62	1.60	1.60	133	1.62	1.58	1.58	201	0.00	0.00	0.00				
66	1.62	1.61	1.61	134	1.62	1.59	1.59	202	1.62	1.59	1.59				
67	1.62	1.61	1.61	135	1.62	1.58	1.58	203	1.62	1.59	1.59				
68	1.62	1.59	1.60	136	1.62	1.59	1.59	204	1.62	1.59	1.59				

Table 2 July 2011 model simulation, comparing no decay to first and second order bulk decay, pipes

Pipe Number	Chlorine Concentration (mg/L)			Pipe Number	Chlorine Concentration (mg/L)			Pipe Number	Chlorine Concentration (mg/L)			Pipe Number	Chlorine Concentration (mg/L)		
	No Decay, Sources Mixing Only	First Order Bulk Decay Only	Second Order Bulk Decay Only		No Decay, Sources Mixing Only	First Order Bulk Decay Only	Second Order Bulk Decay Only		No Decay, Sources Mixing Only	First Order Bulk Decay Only	Second Order Bulk Decay Only		No Decay, Sources Mixing Only	First Order Bulk Decay Only	Second Order Bulk Decay Only
1	1.43	1.41	1.41	89	1.62	1.57	1.58	177	1.62	1.62	1.62	265	1.62	1.59	1.59
2	1.43	1.41	1.41	90	1.62	1.57	1.58	178	1.62	1.62	1.62	266	0.00	0.00	0.00
3	1.41	1.39	1.39	91	1.62	1.57	1.58	179	1.62	1.62	1.62	267	1.62	1.59	1.60
4	1.41	1.40	1.40	92	1.62	1.58	1.59	180	1.36	1.36	1.36	268	1.62	1.59	1.59
5	1.41	1.39	1.39	93	1.62	1.58	1.58	181	1.62	1.60	1.60	269	1.62	1.59	1.59
6	1.41	1.39	1.40	94	1.62	1.59	1.59	182	1.37	1.37	1.37	270	1.62	1.59	1.59
7	1.47	1.45	1.45	95	1.62	1.59	1.59	183	1.37	1.37	1.37	271	1.62	1.59	1.59
8	1.47	1.45	1.45	96	1.62	1.59	1.60	184	1.62	1.57	1.57	272	1.62	1.59	1.59
9	1.47	1.45	1.45	97	1.62	1.59	1.59	185	1.62	1.60	1.61	273	1.62	1.59	1.59
10	1.47	1.45	1.45	98	1.62	1.58	1.58	186	1.62	1.61	1.61	274	1.62	1.59	1.59
11	1.48	1.46	1.46	99	1.62	1.58	1.58	187	1.62	1.61	1.61	275	1.62	1.59	1.59
12	1.51	1.49	1.49	100	1.62	1.58	1.58	188	1.62	1.61	1.61	276	1.62	1.59	1.59
13	1.51	1.49	1.49	101	1.62	1.59	1.59	189	1.38	1.37	1.37	277	1.62	1.59	1.59
14	1.51	1.49	1.49	102	1.62	1.58	1.59	190	1.38	1.37	1.37	278	1.48	1.45	1.45
15	1.62	1.55	1.56	103	1.59	1.55	1.55	191	1.38	1.37	1.37	279	1.48	1.47	1.47
16	1.62	1.59	1.59	104	1.62	1.57	1.58	192	1.38	1.37	1.37	280	1.62	1.60	1.60
17	1.51	1.49	1.49	105	1.62	1.59	1.59	193	1.62	1.59	1.59	281	1.62	1.60	1.60
18	1.61	1.59	1.59	106	1.62	1.58	1.59	194	1.42	1.41	1.41	282	1.62	1.61	1.61
19	1.62	1.60	1.60	107	1.62	1.57	1.57	195	1.41	1.40	1.40	283	1.62	1.61	1.61
20	1.62	1.58	1.58	108	1.62	1.58	1.58	196	1.41	1.40	1.40	284	1.62	1.58	1.58
21	1.62	1.60	1.60	109	1.62	1.58	1.58	197	1.41	1.41	1.41	285	1.62	1.62	1.62
22	1.48	1.45	1.46	110	1.62	1.58	1.58	198	1.41	1.40	1.40	286	1.62	1.61	1.61
23	1.51	1.49	1.49	111	1.62	1.57	1.58	199	1.41	1.38	1.38	287	1.62	1.61	1.61
24	1.51	1.49	1.49	112	1.62	1.59	1.60	200	1.48	1.47	1.47	288	1.62	1.58	1.58
25	1.51	1.49	1.49	113	1.41	1.41	1.41	201	1.51	1.49	1.49	289	1.62	1.58	1.58
26	1.62	1.61	1.61	114	1.62	1.60	1.61	202	0.00	0.00	0.00	290	1.62	1.62	1.62
27	1.62	1.60	1.60	115	1.41	1.41	1.41	203	1.62	1.60	1.60	291	1.62	1.60	1.60
28	1.62	1.60	1.60	116	1.62	1.61	1.61	204	1.62	1.61	1.61	292	1.62	1.60	1.60
29	1.62	1.60	1.60	117	1.62	1.61	1.61	205	1.62	1.61	1.61	293	1.62	1.60	1.60
30	1.62	1.60	1.60	118	1.41	1.40	1.40	206	1.62	1.61	1.61	294	1.62	1.61	1.61
31	1.62	1.60	1.60	119	1.41	1.41	1.41	207	1.62	1.61	1.61	295	1.62	1.59	1.59
32	1.62	1.60	1.60	120	1.41	1.40	1.41	208	1.62	1.60	1.60	296	1.62	1.62	1.62
33	1.62	1.61	1.61	121	1.49	1.48	1.48	209	1.62	1.61	1.61	297	1.62	1.57	1.57
34	1.43	1.40	1.40	122	1.59	1.58	1.58	210	1.62	1.60	1.61	298	1.62	1.61	1.61
35	1.43	1.40	1.40	123	1.48	1.47	1.47	211	1.62	1.62	1.62	299	1.62	1.59	1.59
36	1.47	1.44	1.45	124	1.48	1.47	1.47	212	1.62	1.62	1.62	300	1.62	1.61	1.61
37	1.47	1.44	1.44	125	1.48	1.47	1.47	213	1.62	1.61	1.62	301	1.62	1.59	1.60
38	1.52	1.49	1.50	126	1.48	1.47	1.47	214	1.62	1.62	1.62	302	1.62	1.59	1.60
39	1.49	1.46	1.46	127	1.48	1.47	1.47	215	1.62	1.62	1.62	303	1.62	1.60	1.60
40	1.49	1.46	1.46	128	1.62	1.61	1.61	216	1.62	1.62	1.62	304	1.62	1.60	1.60
41	1.54	1.51	1.51	129	1.62	1.61	1.61	217	1.62	1.62	1.62	305	1.62	1.60	1.60
42	1.52	1.49	1.50	130	1.62	1.61	1.61	218	1.62	1.62	1.62	306	1.62	1.59	1.59
43	1.51	1.48	1.48	131	1.62	1.61	1.61	219	1.62	1.61	1.61	307	1.62	1.60	1.60
44	1.51	1.48	1.48	132	1.62	1.60	1.60	220	1.62	1.61	1.61	308	1.62	1.58	1.58
45	1.53	1.50	1.50	133	1.62	1.61	1.61	221	1.62	1.62	1.62	309	1.62	1.59	1.59
46	1.61	1.58	1.58	134	1.62	1.61	1.61	222	1.62	1.62	1.62	310	1.62	1.59	1.59
47	1.54	1.51	1.51	135	1.62	1.61	1.61	223	1.62	1.60	1.60	311	1.62	1.60	1.60
48	1.61	1.58	1.58	136	1.62	1.60	1.60	224	1.62	1.61	1.61	312	1.62	1.59	1.60
49	1.61	1.58	1.59	137	1.62	1.59	1.60	225	1.62	1.60	1.61	313	1.62	1.59	1.59
50	1.62	1.60	1.60	138	1.62	1.60	1.60	226	1.62	1.61	1.61	314	1.62	1.59	1.60
51	1.61	1.58	1.58	139	1.62	1.59	1.59	227	1.62	1.62	1.62	315	1.62	1.58	1.58
52	1.61	1.59	1.59	140	1.62	1.60	1.60	228	1.62	1.61	1.61	316	1.62	1.59	1.59
53	1.61	1.55	1.56	141	1.62	1.59	1.59	229	1.62	1.61	1.61	317	1.62	1.59	1.59
54	1.61	1.58	1.59	142	1.62	1.60	1.60	230	1.62	1.61	1.61	318	1.62	1.58	1.59
55	1.47	1.44	1.45	143	1.62	1.60	1.60	231	1.62	1.61	1.61	319	1.48	1.42	1.43
56	1.43	1.39	1.39	144	1.62	1.60	1.60	232	1.62	1.61	1.61	320	1.48	1.43	1.43
57	1.46	1.43	1.43	145	1.62	1.60	1.60	233	1.62	1.59	1.59	321	1.62	1.59	1.59
58	1.45	1.41	1.41	146	1.62	1.61	1.61	234	1.62	1.59	1.59	322	1.62	1.59	1.59
59	1.47	1.43	1.43	147	1.62	1.60	1.60	235	1.62	1.60	1.60	323	1.62	1.58	1.58
60	1.47	1.44	1.44	148	1.62	1.61	1.61	236	1.62	1.60	1.60	324	1.62	1.58	1.59
61	1.47	1.44	1.44	149	1.62	1.61	1.61	237	1.62	1.58	1.59	325	1.62	1.58	1.58
62	1.47	1.44	1.44	150	1.62	1.61	1.61	238	1.62	1.60	1.60	326	1.62	1.58	1.58
63	1.48	1.45	1.45	151	1.62	1.59	1.59	239	1.62	1.59	1.59	327	1.62	1.58	1.58
64	1.55	1.49	1.50	152	1.62	1.60	1.60	240	1.62	1.60	1.60	328	1.62	1.58	1.58
65	1.54	1.51	1.51	153	1.62	1.59	1.59	241	1.62	1.59	1.59	329	1.62	1.58	1.58
66	1.54	1.50	1.51	154	1.62	1.60	1.60	242	1.62	1.59	1.59	330	1.62	1.58	1.59
67	1.43	1.40	1.41	155	1.62	1.61	1.61	243	1.62	1.60	1.60	331	1.41	1.39	1.39
68	1.45	1.40	1.41	156	1.62	1.60	1.60	244	1.61	1.59	1.59	332	1.37	1.37	1.37
69	1.48	1.43	1.44	157	1.62	1.55	1.56	245	1.61	1.59	1.59	333	1.62	1.62	1.62
70	1.48	1.43	1.44	158	1.62	1.60	1.60	246	1.61	1.59	1.59	334	1.62	1.61	1.61
71	1.48	1.43	1.44	159	1.62	1.59	1.59	247	1.57	1.53	1.53	335	1.62	1.61	1.61
72	1.48	1.40	1.41	160	1.62	1.57	1.57	248	1.57	1.53	1.53	336	1.48	1.47	1.47
73	1.48	1.43	1.43	161	1.62	1.59	1.59	249	1.62	1.59	1.60	337	1.51	1.49	1.49
74	1.48	1.43	1.43	162	1.62	1.55	1.55	250	1.62	1.58	1.59	338	1.51	1.49	1.49
75	1.48	1.43	1.43	163	1.62	1.56	1.56	251	1.59	1.55	1.55	339	1.51	1.49	1.49
76	1.61	1.58	1.58	164	1.62	1.54	1.55	252	1.62	1.53	1.54	340	1.43	1.40	1.41
77	1.62	1.59	1.59	165	1.62	1.51	1.52	253	0.00	0.00	0.00	341	1.45	1.41	1.41
78	1.62	1.59	1.59	166	1.62	1.58	1.59	254	1.62	1.37	1.41	342	1.48	1.43	1.44
79	1.62	1.60	1.60	167	1.62	1.59	1.59	255	1.62	1.62	1.62	343	1.62	1.59	1.60
80	1.62	1.60	1.60	168	1.62	1.60	1.60	256	1.62	1.60	1.60	344	1.62	1.61	1.61
81	1.62	1.59	1.59	169	1.62	1.59	1.59	257	0.00	0.00	0.00	345	1.62	1.57	1.58
82	1.62	1.59	1.59	170	1.62	1.62	1.62	258	1.62	1.60	1.60	346	1.62	1.56	1.56
83	1.62	1.59	1.59	171	1.62	1.62	1.62	259	1.51	1.49	1.49	347	1.62	1.58	1.58
84	1.62	1.58	1.58	172	1.62	1.62	1.62	260	1.59	1.43	1.45	348	1.62	1.59	1.59
85	1.62	1.58	1.58	173	1.62	1.62	1.62	261	1.50	1.45	1.46	349	1.62	1.57	1.58
86	1.62	1.58	1.59	174	1.62	1.62	1.62	262	0.00	0.00	0.00	350	1.62	1.59	1.59
87	1.62	1.58	1.59	175	1.62	1.62	1.62	263	1.62	1.59	1.59				
88	1.62	1.58	1.59	176	1.62	1.61	1.61	264	1.62	1.59	1.59				

Table 3 October 2011 model simulation, comparing no decay to first and second order bulk decay, nodes

Node Number	Chlorine Concentration (mg/L)			Node Number	Chlorine Concentration (mg/L)			Node Number	Chlorine Concentration (mg/L)			Node Number	Chlorine Concentration (mg/L)		
	No Decay, Sources Mixing Only	First Order Bulk Decay Only	Second Order Bulk Decay Only		No Decay, Sources Mixing Only	First Order Bulk Decay Only	Second Order Bulk Decay Only		No Decay, Sources Mixing Only	First Order Bulk Decay Only	Second Order Bulk Decay Only		No Decay, Sources Mixing Only	First Order Bulk Decay Only	Second Order Bulk Decay Only
1	1.76	1.76	1.76	71	1.91	1.88	1.88	141	1.92	1.88	1.88	211	1.91	1.88	1.88
2	1.92	1.84	1.84	72	1.91	1.89	1.89	142	1.92	1.88	1.88	212	1.92	1.88	1.88
3	1.76	1.76	1.76	73	1.91	1.89	1.89	143	1.89	1.84	1.84	213	1.92	1.88	1.88
4	1.79	1.78	1.78	74	1.91	1.89	1.89	144	1.92	1.88	1.88	214	1.92	1.88	1.88
5	1.92	1.90	1.90	75	1.91	1.89	1.89	145	1.92	1.89	1.89	215	1.92	1.88	1.88
6	1.92	1.90	1.89	76	1.91	1.90	1.89	146	1.90	1.85	1.85	216	1.92	1.88	1.88
7	1.92	1.91	1.91	77	1.91	1.86	1.85	147	1.92	1.86	1.85	217	1.92	1.88	1.88
8	1.92	1.91	1.91	78	1.91	1.88	1.87	148	1.92	1.87	1.87	218	1.83	1.81	1.81
9	1.92	1.91	1.91	79	1.91	1.82	1.82	149	1.92	1.88	1.88	219	1.91	1.86	1.86
10	1.92	1.91	1.90	80	1.91	1.84	1.83	150	1.92	1.86	1.85	220	1.91	1.90	1.90
11	1.79	1.78	1.78	81	1.91	1.81	1.81	151	1.92	1.88	1.87	221	1.91	1.88	1.87
12	1.76	1.76	1.76	82	1.91	1.85	1.84	152	1.92	1.86	1.86	222	1.92	1.91	1.91
13	1.76	1.76	1.76	83	1.92	1.88	1.88	153	1.92	1.86	1.86	223	1.91	1.89	1.88
14	1.79	1.78	1.78	84	1.92	1.87	1.87	154	1.92	1.87	1.87	224	1.92	1.89	1.89
15	1.83	1.82	1.82	85	1.92	1.90	1.90	155	1.92	1.85	1.85	225	1.92	1.89	1.89
16	1.90	1.88	1.88	86	1.92	1.90	1.90	156	1.92	1.85	1.85	226	1.92	1.89	1.89
17	1.92	1.91	1.91	87	1.92	1.90	1.90	157	1.90	1.85	1.85	227	1.92	1.88	1.88
18	1.79	1.77	1.77	88	1.92	1.89	1.89	158	1.91	1.91	1.91	228	1.92	1.89	1.89
19	1.80	1.77	1.77	89	1.92	1.89	1.89	159	1.92	1.92	1.92	229	1.91	1.87	1.86
20	1.83	1.77	1.77	90	1.92	1.88	1.88	160	1.92	1.92	1.92	230	1.92	1.88	1.88
21	1.79	1.76	1.76	91	1.92	1.88	1.88	161	1.92	1.92	1.92	231	1.92	1.88	1.88
22	1.79	1.77	1.77	92	1.92	1.88	1.88	162	1.92	1.92	1.92	232	1.92	1.89	1.89
23	1.82	1.80	1.80	93	1.92	1.88	1.88	163	1.92	1.92	1.92	233	1.92	1.89	1.89
24	1.82	1.80	1.80	94	1.92	1.89	1.89	164	1.92	1.91	1.91	234	1.92	1.89	1.88
25	1.83	1.81	1.81	95	1.92	1.88	1.88	165	1.91	1.91	1.91	235	1.92	1.89	1.89
26	1.83	1.81	1.81	96	1.92	1.88	1.88	166	1.91	1.91	1.91	236	1.92	1.87	1.87
27	1.85	1.82	1.82	97	1.91	1.87	1.86	167	1.92	1.92	1.92	237	1.92	1.88	1.88
28	1.85	1.83	1.82	98	1.92	1.87	1.87	168	1.76	1.76	1.76	238	1.92	1.88	1.88
29	1.83	1.81	1.81	99	1.92	1.88	1.87	169	1.76	1.76	1.76	239	1.92	1.87	1.87
30	1.92	1.88	1.88	100	1.91	1.88	1.87	170	1.92	1.89	1.89	240	1.83	1.76	1.76
31	1.92	1.89	1.89	101	1.92	1.87	1.87	171	1.81	1.79	1.79	241	1.83	1.77	1.77
32	1.92	1.90	1.90	102	1.92	1.88	1.87	172	1.81	1.79	1.79	242	1.92	1.89	1.89
33	1.92	1.90	1.90	103	1.91	1.88	1.87	173	1.79	1.78	1.78	243	1.92	1.89	1.89
34	0.00	0.00	0.00	104	1.92	1.86	1.86	174	1.92	1.91	1.91	244	1.92	1.86	1.85
35	1.80	1.77	1.77	105	1.80	1.76	1.76	175	1.92	1.91	1.91	245	1.92	1.86	1.86
36	1.83	1.80	1.80	106	1.82	1.80	1.79	176	1.92	1.91	1.91	246	1.92	1.86	1.86
37	1.83	1.82	1.81	107	1.82	1.79	1.79	177	1.92	1.92	1.92	247	1.92	1.86	1.86
38	1.83	1.82	1.81	108	1.84	1.80	1.80	178	1.92	1.92	1.92	248	1.92	1.86	1.86
39	1.83	1.81	1.81	109	1.86	1.83	1.83	179	1.92	1.92	1.92	249	1.92	1.87	1.86
40	1.85	1.82	1.82	110	1.85	1.82	1.82	180	1.92	1.92	1.92	250	1.92	1.87	1.87
41	1.85	1.82	1.82	111	1.87	1.84	1.84	181	1.92	1.91	1.91	251	1.92	1.87	1.87
42	1.85	1.83	1.83	112	1.92	1.88	1.88	182	1.92	1.91	1.91	252	1.79	1.76	1.76
43	1.92	1.90	1.90	113	1.92	1.89	1.88	183	1.91	1.91	1.91	253	1.92	1.92	1.92
44	1.92	1.90	1.90	114	1.92	1.89	1.88	184	1.92	1.91	1.91	254	1.92	1.92	1.92
45	1.92	1.91	1.91	115	1.82	1.78	1.78	185	1.91	1.90	1.90	255	1.92	1.91	1.91
46	1.92	1.90	1.90	116	1.81	1.76	1.76	186	1.91	1.90	1.90	256	1.92	1.90	1.90
47	1.92	1.90	1.90	117	1.82	1.78	1.77	187	1.91	1.89	1.88	257	1.92	1.90	1.90
48	1.92	1.91	1.91	118	1.82	1.79	1.79	188	1.91	1.90	1.90	258	1.92	1.90	1.89
49	1.92	1.91	1.91	119	1.82	1.79	1.78	189	1.91	1.88	1.87	259	1.92	1.90	1.89
50	1.92	1.90	1.90	120	1.83	1.79	1.79	190	1.92	1.89	1.89	260	1.92	1.87	1.86
51	1.91	1.89	1.89	121	1.85	1.80	1.80	191	1.91	1.87	1.87	261	1.92	1.88	1.87
52	1.91	1.90	1.90	122	1.86	1.83	1.83	192	1.91	1.87	1.87	262	1.76	1.76	1.76
53	1.91	1.90	1.90	123	1.88	1.83	1.82	193	1.92	1.84	1.83	263	1.79	1.78	1.78
54	1.92	1.91	1.90	124	1.87	1.84	1.83	194	1.92	1.89	1.89	264	1.79	1.78	1.78
55	1.92	1.91	1.91	125	1.92	1.89	1.88	195	1.92	1.89	1.89	265	1.79	1.78	1.78
56	1.92	1.90	1.89	126	1.92	1.88	1.88	196	1.89	1.84	1.84	266	1.79	1.77	1.77
57	1.92	1.90	1.90	127	1.92	1.90	1.90	197	1.90	1.85	1.85	267	1.79	1.77	1.77
58	1.92	1.90	1.90	128	1.80	1.77	1.77	198	1.92	1.73	1.73	268	1.79	1.77	1.77
59	1.92	1.91	1.91	129	1.80	1.76	1.76	199	0.00	0.00	0.00	269	1.79	1.77	1.76
60	1.92	1.91	1.91	130	1.81	1.76	1.76	200	1.92	1.42	1.45	270	1.79	1.76	1.76
61	1.92	1.89	1.89	131	1.83	1.78	1.77	201	0.00	0.00	0.00	271	1.80	1.77	1.77
62	1.92	1.89	1.89	132	1.83	1.78	1.78	202	1.90	1.72	1.71	272	1.80	1.76	1.76
63	1.92	1.91	1.91	133	1.83	1.77	1.77	203	1.91	1.90	1.90	273	1.80	1.76	1.76
64	1.91	1.88	1.88	134	1.83	1.78	1.78	204	0.00	0.00	0.00	274	1.80	1.76	1.75
65	1.91	1.89	1.89	135	1.83	1.77	1.77	205	1.92	1.88	1.87	275	1.81	1.76	1.76
66	1.91	1.89	1.89	136	1.92	1.87	1.87	206	1.92	1.88	1.87	276	1.92	1.92	1.92
67	1.91	1.90	1.90	137	1.92	1.88	1.88	207	0.00	0.00	0.00	277	1.92	1.92	1.92
68	1.91	1.90	1.90	138	1.92	1.87	1.87	208	1.91	1.88	1.88	278	1.92	1.91	1.91
69	1.92	1.91	1.91	139	1.91	1.88	1.88	209	1.91	1.85	1.84				
70	1.91	1.88	1.88	140	1.91	1.88	1.88	210	1.91	1.87	1.87				

Table 4 October 2011 model simulation, comparing no decay to first and second order bulk decay, pipes

Pipe Number	Chlorine Concentration			Pipe Number	Chlorine Concentration			Pipe Number	Chlorine Concentration			Pipe Number	Chlorine Concentration			Pipe Number	Chlorine Concentration		
	No Decay, Sources Mixing Only	First Order Bulk Decay Only	Second Order Bulk Decay Only		No Decay, Sources Mixing Only	First Order Bulk Decay Only	Second Order Bulk Decay Only		No Decay, Sources Mixing Only	First Order Bulk Decay Only	Second Order Bulk Decay Only		No Decay, Sources Mixing Only	First Order Bulk Decay Only	Second Order Bulk Decay Only		No Decay, Sources Mixing Only	First Order Bulk Decay Only	Second Order Bulk Decay Only
1	1.80	1.77	1.77	74	1.92	1.86	1.85	147	1.92	1.92	1.92	220	1.92	1.88	1.87	293	1.83	1.77	1.77
2	1.80	1.77	1.77	75	1.92	1.85	1.85	148	1.92	1.92	1.92	221	0.00	0.00	0.00	294	1.83	1.77	1.77
3	1.79	1.76	1.76	76	1.92	1.86	1.85	149	1.91	1.91	1.91	222	1.91	1.88	1.88	295	1.83	1.77	1.77
4	1.79	1.76	1.76	77	1.92	1.87	1.87	150	1.76	1.76	1.76	223	1.91	1.88	1.88	296	1.92	1.88	1.88
5	1.79	1.76	1.76	78	1.92	1.87	1.87	151	1.92	1.85	1.85	224	1.91	1.88	1.88	297	1.92	1.88	1.88
6	1.79	1.77	1.76	79	1.92	1.88	1.88	152	1.76	1.76	1.76	225	1.92	1.88	1.88	298	1.92	1.88	1.88
7	1.82	1.80	1.80	80	1.92	1.88	1.88	153	1.76	1.76	1.76	226	1.92	1.88	1.88	299	1.92	1.89	1.89
8	1.82	1.80	1.80	81	1.92	1.89	1.89	154	0.00	0.00	0.00	227	1.92	1.88	1.88	300	1.92	1.89	1.89
9	1.82	1.80	1.79	82	1.92	1.88	1.87	155	1.92	1.90	1.90	228	1.92	1.88	1.88	301	1.92	1.88	1.88
10	1.82	1.80	1.79	83	1.92	1.87	1.87	156	1.92	1.91	1.91	229	1.92	1.88	1.88	302	1.92	1.88	1.88
11	1.83	1.81	1.81	84	1.92	1.87	1.87	157	1.92	1.91	1.91	230	1.92	1.88	1.88	303	1.92	1.88	1.88
12	1.85	1.82	1.82	85	1.92	1.86	1.86	158	1.92	1.91	1.91	231	1.92	1.88	1.88	304	1.92	1.86	1.86
13	1.85	1.82	1.82	86	1.92	1.88	1.88	159	1.76	1.76	1.76	232	1.92	1.88	1.88	305	1.92	1.87	1.86
14	1.85	1.82	1.82	87	1.92	1.88	1.87	160	1.76	1.76	1.76	233	1.83	1.79	1.79	306	1.92	1.87	1.87
15	1.92	1.87	1.86	88	1.90	1.85	1.85	161	1.76	1.76	1.76	234	1.83	1.81	1.81	307	1.92	1.87	1.87
16	1.92	1.89	1.89	89	1.92	1.86	1.85	162	1.76	1.75	1.75	235	1.91	1.90	1.90	308	1.92	1.87	1.87
17	1.85	1.82	1.82	90	1.92	1.88	1.88	163	1.92	1.89	1.89	236	1.91	1.89	1.89	309	1.80	1.75	1.75
18	1.92	1.89	1.88	91	1.92	1.87	1.87	164	1.81	1.79	1.79	237	1.91	1.90	1.90	310	1.81	1.76	1.76
19	1.92	1.90	1.89	92	1.92	1.85	1.84	165	1.79	1.78	1.78	238	1.91	1.90	1.90	311	1.92	1.92	1.92
20	1.92	1.89	1.89	93	1.92	1.86	1.86	166	1.79	1.77	1.77	239	1.91	1.87	1.86	312	1.91	1.87	1.87
21	1.92	1.90	1.90	94	1.92	1.86	1.86	167	1.79	1.78	1.78	240	1.91	1.91	1.91	313	1.91	1.83	1.83
22	1.83	1.80	1.80	95	1.92	1.87	1.86	168	1.79	1.77	1.77	241	1.91	1.90	1.90	314	1.91	1.84	1.84
23	1.85	1.83	1.82	96	1.92	1.85	1.85	169	1.79	1.72	1.71	242	1.91	1.90	1.90	315	1.91	1.82	1.82
24	1.85	1.82	1.82	97	1.92	1.87	1.87	170	1.83	1.81	1.81	243	1.91	1.87	1.87	316	1.91	1.79	1.78
25	1.85	1.82	1.82	98	1.79	1.78	1.78	171	1.85	1.83	1.82	244	1.91	1.87	1.87	317	1.92	1.87	1.87
26	1.92	1.90	1.90	99	1.92	1.91	1.90	172	0.00	0.00	0.00	245	1.91	1.90	1.90	318	1.92	1.88	1.88
27	1.92	1.90	1.90	100	1.79	1.78	1.78	173	1.92	1.90	1.89	246	1.91	1.88	1.88	319	1.92	1.89	1.89
28	1.92	1.90	1.90	101	1.92	1.90	1.90	174	1.92	1.90	1.90	247	1.91	1.89	1.89	320	1.91	1.88	1.87
29	1.92	1.90	1.90	102	1.92	1.91	1.91	175	1.92	1.91	1.91	248	1.91	1.89	1.89	321	1.91	1.91	1.91
30	1.92	1.90	1.90	103	1.79	1.78	1.78	176	1.92	1.91	1.91	249	1.91	1.90	1.90	322	1.92	1.92	1.92
31	1.92	1.90	1.90	104	1.79	1.78	1.78	177	1.92	1.91	1.91	250	1.91	1.88	1.87	323	1.92	1.92	1.92
32	1.92	1.89	1.89	105	1.79	1.78	1.78	178	1.92	1.78	1.78	251	1.91	1.91	1.91	324	1.92	1.92	1.92
33	1.92	1.90	1.90	106	1.83	1.82	1.82	179	1.92	1.91	1.91	252	1.91	1.86	1.85	325	1.92	1.92	1.92
34	1.80	1.76	1.76	107	1.90	1.88	1.88	180	1.92	1.90	1.90	253	1.91	1.90	1.90	326	1.92	1.92	1.92
35	1.80	1.76	1.76	108	1.83	1.81	1.81	181	1.92	1.92	1.91	254	1.91	1.87	1.87	327	1.92	1.91	1.91
36	1.82	1.79	1.79	109	1.83	1.81	1.81	182	1.92	1.92	1.92	255	1.92	1.91	1.91	328	1.92	1.92	1.92
37	1.82	1.79	1.79	110	1.83	1.81	1.81	183	1.92	1.91	1.91	256	1.91	1.88	1.88	329	1.92	1.91	1.91
38	1.86	1.83	1.82	111	1.83	1.82	1.81	184	1.92	1.92	1.92	257	1.92	1.89	1.88	330	1.92	1.91	1.91
39	1.84	1.80	1.80	112	1.83	1.81	1.81	185	1.92	1.92	1.91	258	1.92	1.89	1.89	331	1.92	1.89	1.89
40	1.84	1.80	1.80	113	1.92	1.91	1.91	186	1.92	1.91	1.91	259	1.92	1.89	1.89	332	1.92	1.88	1.88
41	1.87	1.84	1.83	114	1.92	1.90	1.90	187	1.92	1.92	1.92	260	1.92	1.89	1.89	333	1.90	1.85	1.85
42	1.86	1.83	1.83	115	1.92	1.91	1.91	188	1.92	1.92	1.92	261	1.92	1.88	1.88	334	1.92	1.79	1.79
43	1.85	1.82	1.81	116	1.92	1.91	1.91	189	1.92	1.91	1.91	262	1.92	1.89	1.89	335	0.00	0.00	0.00
44	1.85	1.82	1.81	117	1.92	1.90	1.89	190	1.92	1.91	1.91	263	1.91	1.87	1.86	336	1.92	1.58	1.59
45	1.86	1.83	1.83	118	1.92	1.91	1.91	191	1.92	1.91	1.91	264	1.92	1.88	1.88	337	1.92	1.92	1.91
46	1.92	1.88	1.88	119	1.92	1.91	1.91	192	1.92	1.91	1.91	265	1.92	1.88	1.88	338	1.92	1.90	1.90
47	1.87	1.84	1.83	120	1.92	1.90	1.90	193	1.91	1.89	1.89	266	1.92	1.89	1.89	339	0.00	0.00	0.00
48	1.92	1.88	1.88	121	1.92	1.90	1.90	194	1.91	1.90	1.90	267	1.92	1.89	1.89	340	1.92	1.90	1.90
49	1.92	1.89	1.88	122	1.91	1.89	1.88	195	1.91	1.90	1.90	268	1.92	1.89	1.88	341	1.85	1.82	1.82
50	1.92	1.89	1.89	123	1.91	1.89	1.89	196	1.91	1.91	1.91	269	1.92	1.89	1.89	342	1.90	1.78	1.78
51	1.92	1.88	1.88	124	1.91	1.87	1.87	197	1.92	1.91	1.91	270	1.92	1.87	1.87	343	1.85	1.80	1.79
52	1.92	1.89	1.88	125	1.91	1.89	1.89	198	1.92	1.91	1.91	271	1.92	1.88	1.88	344	0.00	0.00	0.00
53	1.92	1.88	1.87	126	1.91	1.88	1.88	199	1.92	1.90	1.90	272	1.92	1.88	1.87	345	1.92	1.88	1.87
54	1.92	1.88	1.88	127	1.92	1.89	1.89	200	1.91	1.90	1.90	273	1.92	1.87	1.87	346	1.92	1.88	1.87
55	1.82	1.79	1.79	128	1.92	1.90	1.90	201	1.92	1.91	1.91	274	1.83	1.76	1.76	347	1.91	1.89	1.89
56	1.80	1.75	1.75	129	1.92	1.89	1.89	202	1.92	1.91	1.91	275	1.83	1.77	1.77	348	1.91	1.80	1.80
57	1.82	1.77	1.77	130	1.92	1.90	1.89	203	1.91	1.86	1.86	276	1.92	1.89	1.88	349	1.91	1.89	1.88
58	1.81	1.76	1.76	131	1.92	1.91	1.91	204	1.91	1.88	1.88	277	1.92	1.89	1.89	350	1.92	1.90	1.89
59	1.82	1.77	1.77	132	1.92	1.89	1.89	205	1.92	1.89	1.89	278	1.92	1.86	1.86	351	1.92	1.90	1.89
60	1.82	1.78	1.78	133	1.92	1.91	1.91	206	1.92	1.89	1.89	279	1.92	1.87	1.87	352	1.92	1.85	1.85
61	1.82	1.79	1.78	134	1.92	1.91	1.91	207	1.91	1.87	1.87	280	1.92	1.86	1.86	353	1.92	1.90	1.89
62	1.82	1.78	1.78	135	1.92	1.91	1.91	208	1.92	1.87	1.86	281	1.92	1.86	1.86	354	1.76	1.76	1.76
63	1.83	1.79	1.79	136	1.91	1.88	1.88	209	1.92	1.88	1.88	282	1.92	1.86	1.86	355	1.79	1.78	1.78
64	1.88	1.83	1.82	137	1.91	1.88	1.88	210	1.92	1.89	1.89	283	1.92	1.86	1.86	356	1.79	1.78	1.78
65	1.87	1.83	1.83	138	1.91	1.88	1.88	211	1.92	1.88	1.88	284	1.92	1.87	1.86	357	1.79	1.77	1.77
66	1.87	1.81	1.80	139	1.91	1.89	1.89	212	1.92	1.88	1.87	285	1.92	1.87	1.87	358	1.79	1.77	1.77
67	1.80	1.77	1.76	140	1.91	1.90	1.90	213	1.92	1.90	1.90	286	1.79	1.76	1.76	359	1.79	1.77	1.77
68	1.81	1.76	1.75	141	1.91	1.88	1.88	214	1.92	1.89	1.89	287	1.92	1.92	1.92	360	1.79	1.77	1.77
69	1.83	1.78	1.77	142	1.91	1.88	1.88	215	1.92	1.89	1.89	288	1.92	1.92	1.92	361	1.79	1.77	1.77
70	1.83	1.78	1.78	143	1.91	1.89	1.89	216	1.92	1.89	1.89	289	1.92	1.91	1.91	362	1.79	1.76	1.76
71	1.83	1.78	1.78	144	1.91	1.87	1.87	217	1.89	1.84	1.84	290	1.92	1.90	1.90	363	1.80	1.77	1.77
72	1.92	1.77	1.77	145	1.91	1.85	1.85	218	1.89	1.84	1.84	291	1.92	1.90	1.90				
73	1.80	1.76	1.75	146	1.91	1.84	1.83	219	1.91	1.86	1.86	292	1.80	1.76	1.76				

APPENDIX J

Model Calibration of K_w (October 2011 Conditions)

Table 1 (1 of 6) Calibration of global kw.

				Kw = 0		Kw = 0.0001 m/d		Kw = 0.0005 m/d		Kw = 0.001 m/d		Kw = 0.005 m/d		Kw = 0.01 m/d		Kw = 0.02 m/d	
Inflow/Route Number	Sample Site Number	Node Number in SynerGEE (Oct 2011 Model)	Average Chlorine Concentration (After Adjustment) on October 5, 2011 (mg/L)	Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual
Inflow 1	1	1	1.92	1.92	0.0000	1.92	0.0000	1.92	0.0000	1.92	0.0000	1.92	0.0000	1.92	0.0000	1.92	0.0000
Inflow 2	2	2	1.76	1.76	0.0000	1.76	0.0000	1.76	0.0000	1.76	0.0000	1.76	0.0000	1.76	0.0000	1.76	0.0000
Inflow 3	3	3	1.91	1.91	0.0000	1.91	0.0000	1.91	0.0000	1.91	0.0000	1.91	0.0000	1.91	0.0000	1.91	0.0000
Route 2 (West Side)	4	4	1.87	1.92	0.0028	1.92	0.0027	1.92	0.0027	1.92	0.0027	1.91	0.0024	1.91	0.0021	1.91	0.0016
	5	5	1.92	1.92	0.0000	1.92	0.0000	1.92	0.0000	1.92	0.0000	1.91	0.0000	1.91	0.0001	1.90	0.0003
	6	6	1.89	1.91	0.0004	1.91	0.0004	1.91	0.0003	1.91	0.0003	1.91	0.0001	1.90	0.0000	1.88	0.0002
	7	7	1.85	1.90	0.0026	1.90	0.0026	1.90	0.0024	1.90	0.0021	1.88	0.0007	1.86	0.0000	1.81	0.0016
	8	8	1.77	1.90	0.0165	1.90	0.0163	1.89	0.0155	1.89	0.0145	1.86	0.0083	1.83	0.0032	1.77	0.0000
	11	11	1.74	1.90	0.0252	1.89	0.0250	1.89	0.0238	1.89	0.0225	1.85	0.0135	1.81	0.0060	1.75	0.0001
	12	12	1.36	1.87	0.2524	1.86	0.2503	1.86	0.2420	1.85	0.2322	1.78	0.1706	1.71	0.1188	1.60	0.0571
Route 1 (West Side)	13	13	1.64	1.88	0.0565	1.87	0.0556	1.87	0.0522	1.86	0.0483	1.81	0.0282	1.77	0.0159	1.71	0.0055
	15	15	1.68	1.78	0.0103	1.78	0.0103	1.78	0.0100	1.78	0.0097	1.77	0.0076	1.75	0.0055	1.73	0.0026
	16	16	1.61	1.78	0.0261	1.78	0.0259	1.77	0.0253	1.77	0.0245	1.75	0.0189	1.73	0.0133	1.69	0.0057
	18	18	1.49	1.77	0.0816	1.77	0.0812	1.77	0.0794	1.76	0.0773	1.74	0.0619	1.70	0.0463	1.64	0.0241
	19	19	1.44	1.77	0.1064	1.77	0.1059	1.77	0.1037	1.76	0.1010	1.73	0.0817	1.69	0.0621	1.63	0.0338
	21	21	1.31	1.77	0.2059	1.76	0.2048	1.76	0.2006	1.75	0.1954	1.71	0.1580	1.66	0.1203	1.57	0.0667
	22	22	1.23	1.76	0.2816	1.76	0.2801	1.76	0.2741	1.75	0.2668	1.70	0.2153	1.64	0.1641	1.54	0.0923
	23	23	1.21	1.77	0.3119	1.77	0.3099	1.76	0.3022	1.75	0.2928	1.69	0.2270	1.61	0.1634	1.49	0.0793
	24	24	1.17	1.76	0.3465	1.76	0.3440	1.75	0.3342	1.74	0.3223	1.66	0.2404	1.58	0.1637	1.43	0.0680
	25	25	1.14	1.76	0.3851	1.76	0.3822	1.75	0.3705	1.73	0.3563	1.65	0.2597	1.55	0.1710	1.39	0.0647
	26	26	1.13	1.76	0.3947	1.75	0.3916	1.74	0.3794	1.73	0.3646	1.64	0.2638	1.54	0.1720	1.38	0.0632
	27	27	1.12	1.76	0.4161	1.76	0.4125	1.75	0.3985	1.73	0.3817	1.64	0.2708	1.53	0.1740	1.37	0.0632
Route 3 (East Side)	30	30	1.83	1.91	0.0074	1.91	0.0073	1.91	0.0073	1.91	0.0072	1.91	0.0064	1.90	0.0055	1.89	0.0041
	31	31	1.74	1.91	0.0294	1.91	0.0292	1.91	0.0286	1.90	0.0278	1.88	0.0220	1.86	0.0161	1.82	0.0075
	32	32	1.75	1.88	0.0171	1.88	0.0168	1.88	0.0154	1.87	0.0137	1.82	0.0045	1.77	0.0002	1.67	0.0061
	33	33	1.55	1.88	0.1127	1.88	0.1116	1.87	0.1072	1.86	0.1020	1.81	0.0682	1.74	0.0396	1.64	0.0093
	34	34	1.37	1.88	0.2596	1.88	0.2582	1.87	0.2525	1.87	0.2457	1.82	0.1983	1.76	0.1511	1.66	0.0845
	35	35	1.56	1.85	0.0817	1.84	0.0797	1.83	0.0723	1.81	0.0638	1.71	0.0208	1.60	0.0018	1.45	0.0112
	36	36	1.67	1.87	0.0398	1.87	0.0390	1.86	0.0361	1.85	0.0327	1.78	0.0127	1.71	0.0015	1.59	0.0072
			SSR (All Sites)		3.4704		3.4430		3.3361		3.2081		2.3618		1.6177		0.7599

Table 1 (2 of 6) Calibration of global kw.

Inflow/Route Number	Sample Site Number	Node Number in SynerGEE (Oct 2011 Model)	Average Chlorine Concentration (After Adjustment) on October 5, 2011 (mg/L)	Kw = 0.03 m/d		Kw = 0.035 m/d		Kw = 0.037 m/d		Kw = 0.0375 m/d		Kw = 0.0376 m/d		Kw = 0.0377 m/d		Kw = 0.0378 m/d	
				Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual
Inflow 1	1	1	1.92	1.92	0.0000	1.92	0.0000	1.92	0.0000	1.92	0.0000	1.92	0.0000	1.92	0.0000	1.92	0.0000
Inflow 2	2	2	1.76	1.76	0.0000	1.76	0.0000	1.76	0.0000	1.76	0.0000	1.76	0.0000	1.76	0.0000	1.76	0.0000
Inflow 3	3	3	1.91	1.91	0.0000	1.91	0.0000	1.91	0.0000	1.91	0.0000	1.91	0.0000	1.91	0.0000	1.91	0.0000
Route 2 (West Side)	4	4	1.87	1.90	0.0012	1.90	0.0010	1.90	0.0009	1.90	0.0009	1.90	0.0009	1.89	0.0009	1.89	0.0009
	5	5	1.92	1.89	0.0007	1.89	0.0009	1.89	0.0010	1.89	0.0010	1.89	0.0010	1.89	0.0010	1.89	0.0011
	6	6	1.89	1.87	0.0007	1.86	0.0011	1.86	0.0013	1.86	0.0014	1.86	0.0014	1.86	0.0014	1.86	0.0014
	7	7	1.85	1.78	0.0060	1.76	0.0090	1.75	0.0103	1.75	0.0106	1.75	0.0107	1.75	0.0107	1.75	0.0108
	8	8	1.77	1.71	0.0032	1.69	0.0064	1.68	0.0080	1.68	0.0084	1.68	0.0085	1.68	0.0085	1.68	0.0086
	11	11	1.74	1.69	0.0024	1.66	0.0058	1.65	0.0074	1.65	0.0079	1.65	0.0080	1.65	0.0081	1.65	0.0081
	12	12	1.36	1.52	0.0245	1.49	0.0147	1.47	0.0116	1.47	0.0109	1.47	0.0108	1.47	0.0107	1.47	0.0105
Route 1 (West Side)	13	13	1.64	1.68	0.0015	1.66	0.0006	1.66	0.0004	1.66	0.0003	1.66	0.0003	1.66	0.0003	1.66	0.0003
	15	15	1.68	1.71	0.0009	1.70	0.0004	1.70	0.0003	1.69	0.0003	1.69	0.0003	1.69	0.0002	1.69	0.0002
	16	16	1.61	1.66	0.0016	1.64	0.0006	1.63	0.0003	1.63	0.0003	1.63	0.0003	1.63	0.0002	1.63	0.0002
	18	18	1.49	1.59	0.0105	1.56	0.0062	1.56	0.0048	1.55	0.0045	1.55	0.0044	1.55	0.0044	1.55	0.0043
	19	19	1.44	1.57	0.0161	1.55	0.0102	1.54	0.0083	1.53	0.0079	1.53	0.0078	1.53	0.0077	1.53	0.0076
	21	21	1.31	1.49	0.0334	1.46	0.0223	1.45	0.0186	1.44	0.0178	1.44	0.0176	1.44	0.0174	1.44	0.0173
	22	22	1.23	1.45	0.0481	1.41	0.0331	1.40	0.0282	1.40	0.0270	1.40	0.0268	1.40	0.0266	1.39	0.0263
	23	23	1.21	1.39	0.0326	1.35	0.0186	1.33	0.0143	1.33	0.0134	1.32	0.0132	1.32	0.0130	1.32	0.0128
	24	24	1.17	1.32	0.0209	1.27	0.0089	1.25	0.0057	1.24	0.0050	1.24	0.0049	1.24	0.0048	1.24	0.0047
	25	25	1.14	1.26	0.0163	1.21	0.0054	1.19	0.0029	1.19	0.0024	1.18	0.0023	1.18	0.0022	1.18	0.0021
	26	26	1.13	1.25	0.0149	1.19	0.0045	1.17	0.0022	1.17	0.0017	1.17	0.0016	1.17	0.0016	1.17	0.0015
	27	27	1.12	1.24	0.0150	1.18	0.0046	1.16	0.0023	1.16	0.0018	1.16	0.0017	1.16	0.0017	1.16	0.0016
Route 3 (East Side)	30	30	1.83	1.88	0.0029	1.88	0.0024	1.87	0.0022	1.87	0.0022	1.87	0.0022	1.87	0.0022	1.87	0.0022
	31	31	1.74	1.79	0.0026	1.77	0.0012	1.76	0.0008	1.76	0.0007	1.76	0.0007	1.76	0.0007	1.76	0.0006
	32	32	1.75	1.60	0.0230	1.57	0.0339	1.56	0.0386	1.55	0.0398	1.55	0.0400	1.55	0.0402	1.55	0.0405
	33	33	1.55	1.56	0.0002	1.52	0.0005	1.51	0.0013	1.51	0.0016	1.50	0.0017	1.50	0.0017	1.50	0.0018
	34	34	1.37	1.58	0.0432	1.54	0.0292	1.53	0.0246	1.53	0.0235	1.52	0.0233	1.52	0.0231	1.52	0.0229
	35	35	1.56	1.35	0.0455	1.30	0.0664	1.29	0.0751	1.28	0.0773	1.28	0.0777	1.28	0.0782	1.28	0.0786
	36	36	1.67	1.49	0.0343	1.44	0.0524	1.43	0.0602	1.42	0.0621	1.42	0.0625	1.42	0.0629	1.42	0.0633
			SSR (All Sites)		0.4023		0.3403		0.3316		0.3306		0.3305		0.3304		0.3303

Table 1 (3 of 6) Calibration of global kw.

Inflow/Route Number	Sample Site Number	Node Number in SynerGEE (Oct 2011 Model)	Average Chlorine Concentration (After Adjustment) on October 5, 2011 (mg/L)	Kw = 0.0379 m/d		Kw = 0.038 m/d		Kw = 0.0381 m/d		Kw = 0.0382 m/d		Kw = 0.0383 m/d		Kw = 0.0384 m/d		Kw = 0.0385 m/d	
				Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual
Inflow 1	1	1	1.92	1.92	0.0000	1.92	0.0000	1.92	0.0000	1.92	0.0000	1.92	0.0000	1.92	0.0000	1.92	0.0000
Inflow 2	2	2	1.76	1.76	0.0000	1.76	0.0000	1.76	0.0000	1.76	0.0000	1.76	0.0000	1.76	0.0000	1.76	0.0000
Inflow 3	3	3	1.91	1.91	0.0000	1.91	0.0000	1.91	0.0000	1.91	0.0000	1.91	0.0000	1.91	0.0000	1.91	0.0000
Route 2 (West Side)	4	4	1.87	1.89	0.0009	1.89	0.0009	1.89	0.0009	1.89	0.0009	1.89	0.0009	1.89	0.0009	1.89	0.0009
	5	5	1.92	1.89	0.0011	1.89	0.0011	1.89	0.0011	1.89	0.0011	1.89	0.0011	1.89	0.0011	1.88	0.0011
	6	6	1.89	1.86	0.0014	1.86	0.0014	1.86	0.0014	1.86	0.0014	1.86	0.0014	1.86	0.0014	1.86	0.0014
	7	7	1.85	1.75	0.0109	1.75	0.0109	1.75	0.0110	1.75	0.0111	1.75	0.0112	1.75	0.0112	1.75	0.0113
	8	8	1.77	1.68	0.0087	1.68	0.0088	1.68	0.0089	1.68	0.0090	1.67	0.0090	1.67	0.0091	1.67	0.0092
	11	11	1.74	1.65	0.0082	1.64	0.0083	1.64	0.0084	1.64	0.0085	1.64	0.0086	1.64	0.0087	1.64	0.0088
	12	12	1.36	1.47	0.0104	1.47	0.0103	1.47	0.0101	1.46	0.0100	1.46	0.0099	1.46	0.0098	1.46	0.0096
Route 1 (West Side)	13	13	1.64	1.66	0.0003	1.66	0.0003	1.66	0.0003	1.66	0.0003	1.66	0.0003	1.65	0.0003	1.65	0.0002
	15	15	1.68	1.69	0.0002	1.69	0.0002	1.69	0.0002	1.69	0.0002	1.69	0.0002	1.69	0.0002	1.69	0.0002
	16	16	1.61	1.63	0.0002	1.63	0.0002	1.63	0.0002	1.63	0.0002	1.63	0.0002	1.63	0.0002	1.63	0.0002
	18	18	1.49	1.55	0.0043	1.55	0.0042	1.55	0.0041	1.55	0.0041	1.55	0.0040	1.55	0.0040	1.55	0.0039
	19	19	1.44	1.53	0.0075	1.53	0.0075	1.53	0.0074	1.53	0.0073	1.53	0.0072	1.53	0.0071	1.53	0.0070
	21	21	1.31	1.44	0.0171	1.44	0.0169	1.44	0.0168	1.44	0.0166	1.44	0.0164	1.44	0.0163	1.44	0.0161
	22	22	1.23	1.39	0.0261	1.39	0.0259	1.39	0.0257	1.39	0.0255	1.39	0.0252	1.39	0.0250	1.39	0.0248
	23	23	1.21	1.32	0.0126	1.32	0.0125	1.32	0.0123	1.32	0.0121	1.32	0.0119	1.32	0.0117	1.32	0.0116
	24	24	1.17	1.24	0.0045	1.24	0.0044	1.24	0.0043	1.24	0.0042	1.24	0.0041	1.24	0.0040	1.24	0.0038
	25	25	1.14	1.18	0.0020	1.18	0.0019	1.18	0.0018	1.18	0.0018	1.18	0.0017	1.18	0.0016	1.18	0.0015
	26	26	1.13	1.17	0.0014	1.16	0.0013	1.16	0.0013	1.16	0.0012	1.16	0.0011	1.16	0.0011	1.16	0.0010
	27	27	1.12	1.15	0.0015	1.15	0.0014	1.15	0.0014	1.15	0.0013	1.15	0.0012	1.15	0.0011	1.15	0.0011
Route 3 (East Side)	30	30	1.83	1.87	0.0022	1.87	0.0022	1.87	0.0022	1.87	0.0021	1.87	0.0021	1.87	0.0021	1.87	0.0021
	31	31	1.74	1.76	0.0006	1.76	0.0006	1.76	0.0006	1.76	0.0006	1.76	0.0006	1.76	0.0005	1.76	0.0005
	32	32	1.75	1.55	0.0407	1.55	0.0410	1.55	0.0412	1.55	0.0414	1.55	0.0417	1.55	0.0419	1.55	0.0422
	33	33	1.55	1.50	0.0018	1.50	0.0019	1.50	0.0019	1.50	0.0020	1.50	0.0021	1.50	0.0021	1.50	0.0022
	34	34	1.37	1.52	0.0227	1.52	0.0225	1.52	0.0223	1.52	0.0221	1.52	0.0219	1.52	0.0217	1.52	0.0215
	35	35	1.56	1.28	0.0791	1.28	0.0795	1.28	0.0800	1.28	0.0804	1.28	0.0808	1.28	0.0813	1.27	0.0817
	36	36	1.67	1.42	0.0637	1.42	0.0642	1.42	0.0646	1.42	0.0650	1.42	0.0654	1.41	0.0658	1.41	0.0662
			SSR (All Sites)		0.3303		0.3302006		0.3301689		0.3301565		0.3301629		0.3301872		0.3302304

Table 1 (4 of 6) Calibration of global kw.

Inflow/Route Number	Sample Site Number	Node Number in SynerGEE (Oct 2011 Model)	Average Chlorine Concentration (After Adjustment) on October 5, 2011 (mg/L)	Kw = 0.0386 m/d		Kw = 0.039 m/d		Kw = 0.04 m/d		Kw = 0.042 m/d		Kw = 0.045 m/d		Kw = 0.05 m/d		Kw = 0.06 m/d	
				Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual
Inflow 1	1	1	1.92	1.92	0.0000	1.92	0.0000	1.92	0.0000	1.92	0.0000	1.92	0.0000	1.92	0.0000	1.92	0.0000
Inflow 2	2	2	1.76	1.76	0.0000	1.76	0.0000	1.76	0.0000	1.76	0.0000	1.76	0.0000	1.76	0.0000	1.76	0.0000
Inflow 3	3	3	1.91	1.91	0.0000	1.91	0.0000	1.91	0.0000	1.91	0.0000	1.91	0.0000	1.91	0.0000	1.91	0.0000
Route 2 (West Side)	4	4	1.87	1.89	0.0009	1.89	0.0009	1.89	0.0008	1.89	0.0008	1.89	0.0007	1.89	0.0005	1.88	0.0003
	5	5	1.92	1.88	0.0011	1.88	0.0011	1.88	0.0012	1.88	0.0013	1.88	0.0014	1.88	0.0017	1.87	0.0023
	6	6	1.89	1.86	0.0015	1.86	0.0015	1.85	0.0016	1.85	0.0018	1.85	0.0021	1.84	0.0028	1.83	0.0041
	7	7	1.85	1.75	0.0114	1.75	0.0116	1.74	0.0123	1.74	0.0138	1.73	0.0160	1.71	0.0200	1.68	0.0286
	8	8	1.77	1.67	0.0093	1.67	0.0096	1.67	0.0105	1.66	0.0124	1.65	0.0154	1.63	0.0208	1.59	0.0329
	11	11	1.74	1.64	0.0089	1.64	0.0092	1.64	0.0102	1.63	0.0122	1.61	0.0155	1.59	0.0215	1.55	0.0352
	12	12	1.36	1.46	0.0095	1.46	0.0090	1.45	0.0079	1.44	0.0058	1.42	0.0034	1.40	0.0010	1.35	0.0004
Route 1 (West Side)	13	13	1.64	1.65	0.0002	1.65	0.0002	1.65	0.0001	1.65	0.0001	1.64	0.0000	1.63	0.0001	1.61	0.0009
	15	15	1.68	1.69	0.0002	1.69	0.0002	1.69	0.0001	1.69	0.0001	1.68	0.0000	1.67	0.0000	1.66	0.0005
	16	16	1.61	1.63	0.0002	1.63	0.0001	1.62	0.0001	1.62	0.0000	1.61	0.0000	1.59	0.0004	1.57	0.0022
	18	18	1.49	1.55	0.0039	1.55	0.0036	1.54	0.0031	1.53	0.0022	1.52	0.0012	1.50	0.0002	1.46	0.0005
	19	19	1.44	1.53	0.0070	1.53	0.0066	1.52	0.0059	1.51	0.0045	1.50	0.0029	1.48	0.0010	1.44	0.0001
	21	21	1.31	1.44	0.0160	1.44	0.0154	1.43	0.0139	1.42	0.0112	1.40	0.0078	1.37	0.0037	1.32	0.0001
	22	22	1.23	1.39	0.0246	1.39	0.0238	1.38	0.0217	1.37	0.0180	1.35	0.0133	1.32	0.0073	1.26	0.0010
	23	23	1.21	1.32	0.0114	1.31	0.0107	1.31	0.0092	1.29	0.0065	1.27	0.0034	1.23	0.0006	1.17	0.0015
	24	24	1.17	1.23	0.0037	1.23	0.0033	1.22	0.0024	1.21	0.0010	1.18	0.0000	1.14	0.0010	1.07	0.0100
	25	25	1.14	1.17	0.0014	1.17	0.0012	1.16	0.0006	1.14	0.0000	1.12	0.0004	1.08	0.0037	1.00	0.0175
	26	26	1.13	1.16	0.0009	1.15	0.0007	1.14	0.0003	1.13	0.0000	1.10	0.0008	1.06	0.0048	0.99	0.0202
	27	27	1.12	1.15	0.0010	1.14	0.0008	1.13	0.0003	1.12	0.0000	1.09	0.0007	1.05	0.0045	0.98	0.0191
Route 3 (East Side)	30	30	1.83	1.87	0.0021	1.87	0.0021	1.87	0.0020	1.87	0.0018	1.87	0.0016	1.86	0.0013	1.85	0.0008
	31	31	1.74	1.76	0.0005	1.76	0.0005	1.75	0.0003	1.75	0.0001	1.74	0.0000	1.73	0.0001	1.70	0.0015
	32	32	1.75	1.55	0.0424	1.54	0.0434	1.54	0.0458	1.53	0.0508	1.51	0.0585	1.49	0.0716	1.44	0.0988
	33	33	1.55	1.50	0.0022	1.50	0.0025	1.49	0.0032	1.48	0.0048	1.46	0.0076	1.43	0.0134	1.38	0.0281
	34	34	1.37	1.52	0.0213	1.52	0.0205	1.51	0.0186	1.50	0.0152	1.48	0.0109	1.45	0.0056	1.39	0.0004
	35	35	1.56	1.27	0.0822	1.27	0.0840	1.26	0.0884	1.25	0.0975	1.23	0.1111	1.19	0.1341	1.14	0.1797
	36	36	1.67	1.41	0.0666	1.41	0.0682	1.40	0.0723	1.39	0.0807	1.37	0.0935	1.33	0.1156	1.27	0.1611
			SSR (All Sites)		0.3303		0.3307		0.3330		0.3426		0.3685		0.4373		0.6479

Table 1 (5 of 6) Calibration of global kw.

Inflow/Route Number	Sample Site Number	Node Number in SynerGEE (Oct 2011 Model)	Average Chlorine Concentration (After Adjustment) on October 5, 2011 (mg/L)	Kw = 0.07 m/d		Kw = 0.08 m/d		Kw = 0.09 m/d		Kw = 0.1 m/d		Kw = 0.5 m/d		Kw = 1 m/d		Kw = 1.5 m/d	
				Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual
Inflow 1	1	1	1.92	1.92	0.0000	1.92	0.0000	1.92	0.0000	1.92	0.0000	1.92	0.0000	1.92	0.0000	1.92	0.0000
Inflow 2	2	2	1.76	1.76	0.0000	1.76	0.0000	1.76	0.0000	1.76	0.0000	1.76	0.0000	1.76	0.0000	1.76	0.0000
Inflow 3	3	3	1.91	1.91	0.0000	1.91	0.0000	1.91	0.0000	1.91	0.0000	1.91	0.0000	1.91	0.0000	1.91	0.0000
Route 2 (West Side)	4	4	1.87	1.88	0.0002	1.87	0.0001	1.87	0.0000	1.86	0.0000	1.77	0.0096	1.72	0.0206	1.70	0.0275
	5	5	1.92	1.86	0.0029	1.86	0.0036	1.85	0.0043	1.85	0.0050	1.73	0.0349	1.68	0.0569	1.65	0.0692
	6	6	1.89	1.82	0.0057	1.81	0.0074	1.80	0.0092	1.79	0.0111	1.60	0.0844	1.53	0.1330	1.50	0.1589
	7	7	1.85	1.66	0.0379	1.64	0.0476	1.61	0.0575	1.59	0.0676	1.26	0.3527	1.15	0.4935	1.10	0.5601
	8	8	1.77	1.55	0.0463	1.52	0.0606	1.50	0.0753	1.47	0.0903	1.07	0.4904	0.95	0.6695	0.90	0.7508
	11	11	1.74	1.51	0.0505	1.48	0.0666	1.45	0.0833	1.42	0.1002	1.01	0.5331	0.89	0.7176	0.84	0.7999
	12	12	1.36	1.30	0.0040	1.26	0.0104	1.23	0.0187	1.20	0.0283	0.78	0.3437	0.67	0.4773	0.63	0.5354
Route 1 (West Side)	13	13	1.64	1.59	0.0022	1.58	0.0040	1.56	0.0060	1.55	0.0082	1.34	0.0924	1.26	0.1409	1.23	0.1651
	15	15	1.68	1.64	0.0014	1.63	0.0026	1.61	0.0041	1.60	0.0059	1.36	0.1006	1.26	0.1749	1.21	0.2178
	16	16	1.61	1.54	0.0051	1.52	0.0089	1.50	0.0133	1.48	0.0182	1.15	0.2195	1.03	0.3433	0.98	0.4075
	18	18	1.49	1.43	0.0033	1.40	0.0078	1.37	0.0137	1.34	0.0204	0.95	0.2909	0.83	0.4343	0.78	0.5035
	19	19	1.44	1.40	0.0019	1.37	0.0059	1.34	0.0113	1.31	0.0179	0.91	0.2904	0.79	0.4321	0.74	0.4997
	21	21	1.31	1.28	0.0011	1.24	0.0053	1.20	0.0118	1.17	0.0198	0.74	0.3288	0.63	0.4690	0.58	0.5324
	22	22	1.23	1.22	0.0003	1.17	0.0034	1.14	0.0092	1.10	0.0169	0.67	0.3200	0.56	0.4515	0.52	0.5098
	23	23	1.21	1.12	0.0086	1.07	0.0197	1.03	0.0334	0.99	0.0486	0.54	0.4524	0.44	0.5955	0.40	0.6550
	24	24	1.17	1.01	0.0253	0.96	0.0442	0.92	0.0650	0.88	0.0868	0.43	0.5459	0.35	0.6844	0.31	0.7394
	25	25	1.14	0.94	0.0375	0.89	0.0607	0.84	0.0854	0.80	0.1105	0.37	0.5821	0.29	0.7112	0.26	0.7612
	26	26	1.13	0.92	0.0415	0.87	0.0659	0.83	0.0916	0.78	0.1177	0.36	0.5910	0.28	0.7174	0.25	0.7660
	27	27	1.12	0.92	0.0396	0.86	0.0630	0.82	0.0877	0.78	0.1127	0.36	0.5701	0.28	0.6933	0.26	0.7406
Route 3 (East Side)	30	30	1.83	1.85	0.0004	1.84	0.0002	1.83	0.0000	1.83	0.0000	1.69	0.0185	1.64	0.0365	1.61	0.0470
	31	31	1.74	1.67	0.0040	1.65	0.0075	1.63	0.0117	1.61	0.0164	1.28	0.2064	1.18	0.3114	1.13	0.3619
	32	32	1.75	1.40	0.1264	1.36	0.1539	1.33	0.1809	1.30	0.2072	0.89	0.7471	0.78	0.9457	0.74	1.0313
	33	33	1.55	1.33	0.0453	1.29	0.0640	1.26	0.0835	1.22	0.1032	0.80	0.5488	0.70	0.7124	0.66	0.7819
	34	34	1.37	1.34	0.0008	1.30	0.0051	1.26	0.0122	1.23	0.0212	0.76	0.3734	0.65	0.5240	0.61	0.5885
	35	35	1.56	1.09	0.2241	1.04	0.2668	1.01	0.3073	0.97	0.3458	0.57	0.9873	0.48	1.1746	0.44	1.2493
	36	36	1.67	1.22	0.2069	1.17	0.2520	1.13	0.2958	1.09	0.3379	0.63	1.0845	0.53	1.3080	0.49	1.3972
			SSR (All Sites)		0.9232		1.2370		1.5723		1.9178		10.1988		13.4289		14.8569

Table 1 (6 of 6) Calibration of global kw.

Inflow/Route Number	Sample Site Number	Node Number in SynerGEE (Oct 2011 Model)	Average Chlorine Concentration (After Adjustment) on October 5, 2011 (mg/L)	Kw = 2 m/d		Kw = 3 m/d		Kw = 5 m/d		Kw = 10 m/d		Kw = 20 m/d		Kw = 50 m/d		Kw = 70 m/d		Kw = 100 m/d	
				Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual
Inflow 1	1	1	1.92	1.92	0.0000	1.92	0.0000	1.92	0.0000	1.92	0.0000	1.92	0.0000	1.92	0.0000	1.92	0.0000	1.92	0.0000
Inflow 2	2	2	1.76	1.76	0.0000	1.76	0.0000	1.76	0.0000	1.76	0.0000	1.76	0.0000	1.76	0.0000	1.76	0.0000	1.76	0.0000
Inflow 3	3	3	1.91	1.91	0.0000	1.91	0.0000	1.91	0.0000	1.91	0.0000	1.91	0.0000	1.91	0.0000	1.91	0.0000	1.91	0.0000
Route 2 (West Side)	4	4	1.87	1.69	0.0319	1.67	0.0374	1.66	0.0427	1.65	0.0473	1.64	0.0499	1.64	0.0515	1.64	0.0518	1.64	0.0520
	5	5	1.92	1.64	0.0771	1.62	0.0864	1.61	0.0951	1.60	0.1026	1.59	0.1067	1.59	0.1093	1.59	0.1098	1.59	0.1102
	6	6	1.89	1.48	0.1748	1.46	0.1932	1.44	0.2102	1.42	0.2245	1.41	0.2322	1.41	0.2370	1.41	0.2379	1.41	0.2386
	7	7	1.85	1.08	0.5988	1.05	0.6419	1.03	0.6800	1.01	0.7110	1.00	0.7273	0.99	0.7374	0.99	0.7394	0.99	0.7409
	8	8	1.77	0.88	0.7970	0.85	0.8477	0.83	0.8918	0.81	0.9272	0.80	0.9458	0.79	0.9572	0.79	0.9594	0.79	0.9610
	11	11	1.74	0.82	0.8464	0.79	0.8971	0.77	0.9410	0.75	0.9761	0.74	0.9944	0.73	1.0056	0.73	1.0078	0.73	1.0094
	12	12	1.36	0.61	0.5677	0.59	0.6027	0.57	0.6327	0.55	0.6565	0.55	0.6688	0.54	0.6764	0.54	0.6779	0.54	0.6789
Route 1 (West Side)	13	13	1.64	1.22	0.1794	1.20	0.1957	1.18	0.2104	1.17	0.2225	1.16	0.2289	1.16	0.2329	1.16	0.2337	1.15	0.2343
	15	15	1.68	1.18	0.2454	1.15	0.2787	1.12	0.3105	1.10	0.3383	1.08	0.3537	1.08	0.3634	1.07	0.3653	1.07	0.3667
	16	16	1.61	0.95	0.4466	0.91	0.4919	0.88	0.5337	0.86	0.5689	0.85	0.5880	0.84	0.6000	0.84	0.6023	0.84	0.6040
	18	18	1.49	0.75	0.5444	0.72	0.5904	0.69	0.6319	0.67	0.6661	0.66	0.6844	0.65	0.6958	0.65	0.6980	0.65	0.6996
	19	19	1.44	0.71	0.5394	0.68	0.5840	0.65	0.6240	0.63	0.6569	0.62	0.6744	0.62	0.6853	0.62	0.6875	0.61	0.6890
	21	21	1.31	0.56	0.5686	0.53	0.6086	0.51	0.6437	0.49	0.6722	0.48	0.6873	0.48	0.6966	0.48	0.6984	0.47	0.6997
	22	22	1.23	0.50	0.5428	0.47	0.5790	0.45	0.6106	0.43	0.6361	0.43	0.6495	0.42	0.6578	0.42	0.6594	0.42	0.6606
	23	23	1.21	0.38	0.6877	0.36	0.7226	0.34	0.7525	0.33	0.7762	0.32	0.7885	0.32	0.7960	0.32	0.7974	0.32	0.7985
	24	24	1.17	0.30	0.7690	0.28	0.8003	0.26	0.8266	0.25	0.8472	0.25	0.8578	0.24	0.8643	0.24	0.8655	0.24	0.8665
	25	25	1.14	0.25	0.7877	0.23	0.8155	0.22	0.8388	0.21	0.8569	0.21	0.8662	0.20	0.8718	0.20	0.8729	0.20	0.8737
	26	26	1.13	0.24	0.7917	0.22	0.8186	0.21	0.8411	0.20	0.8585	0.20	0.8674	0.19	0.8729	0.19	0.8739	0.19	0.8747
	27	27	1.12	0.24	0.7658	0.23	0.7920	0.21	0.8139	0.20	0.8310	0.20	0.8397	0.20	0.8450	0.20	0.8460	0.20	0.8468
Route 3 (East Side)	30	30	1.83	1.60	0.0536	1.58	0.0616	1.56	0.0690	1.55	0.0755	1.55	0.0790	1.54	0.0812	1.54	0.0816	1.54	0.0820
	31	31	1.74	1.11	0.3914	1.08	0.4244	1.06	0.4536	1.05	0.4775	1.04	0.4901	1.03	0.4979	1.03	0.4994	1.03	0.5006
	32	32	1.75	0.71	1.0790	0.69	1.1305	0.67	1.1747	0.65	1.2099	0.64	1.2281	0.64	1.2393	0.64	1.2415	0.64	1.2431
	33	33	1.55	0.64	0.8204	0.62	0.8618	0.60	0.8972	0.58	0.9252	0.58	0.9397	0.57	0.9486	0.57	0.9503	0.57	0.9516
	34	34	1.37	0.58	0.6242	0.56	0.6625	0.54	0.6951	0.52	0.7209	0.52	0.7342	0.51	0.7424	0.51	0.7439	0.51	0.7451
	35	35	1.56	0.43	1.2894	0.41	1.3317	0.39	1.3671	0.38	1.3947	0.37	1.4088	0.37	1.4174	0.37	1.4191	0.37	1.4203
	36	36	1.67	0.47	1.4451	0.45	1.4955	0.43	1.5377	0.42	1.5706	0.41	1.5875	0.41	1.5977	0.41	1.5997	0.41	1.6011
			SSR (All Sites)		15.6656		16.5516		17.3256		17.9502		18.2783		18.4807		18.5197		18.5491

Table 2 (1 of 9) Calibration of kw for west side of Study Area.

Inflow/Route Number	Sample Site Number	Node Number in SynerGEE (Oct 2011 Model)	Average Chlorine Concentration (After Adjustment) on October 5, 2011 (mg/L)	Kw = 0		Kw = 0.0001 m/d		Kw = 0.0005 m/d		Kw = 0.001 m/d		Kw = 0.005 m/d		Kw = 0.01 m/d		Kw = 0.02 m/d	
				Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual
Inflow 1	1	1	1.92	1.92	0.0000	1.92	0.0000	1.92	0.0000	1.92	0.0000	1.92	0.0000	1.92	0.0000	1.92	0.0000
Inflow 2	2	2	1.76	1.76	0.0000	1.76	0.0000	1.76	0.0000	1.76	0.0000	1.76	0.0000	1.76	0.0000	1.76	0.0000
Inflow 3	3	3	1.91	1.91	0.0000	1.91	0.0000	1.91	0.0000	1.91	0.0000	1.91	0.0000	1.91	0.0000	1.91	0.0000
Route 2 (West Side)	4	4	1.87	1.92	0.0028	1.92	0.0027	1.92	0.0027	1.92	0.0027	1.91	0.0024	1.91	0.0021	1.91	0.0016
	5	5	1.92	1.92	0.0000	1.92	0.0000	1.92	0.0000	1.92	0.0000	1.91	0.0000	1.91	0.0001	1.90	0.0003
	6	6	1.89	1.91	0.0004	1.91	0.0004	1.91	0.0003	1.91	0.0003	1.91	0.0001	1.90	0.0000	1.88	0.0002
	7	7	1.85	1.90	0.0026	1.90	0.0026	1.90	0.0024	1.90	0.0021	1.88	0.0007	1.86	0.0000	1.81	0.0016
	8	8	1.77	1.90	0.0165	1.90	0.0163	1.89	0.0155	1.89	0.0145	1.86	0.0083	1.83	0.0032	1.77	0.0000
	11	11	1.74	1.90	0.0252	1.89	0.0250	1.89	0.0238	1.89	0.0225	1.85	0.0135	1.81	0.0060	1.75	0.0001
	12	12	1.36	1.87	0.2524	1.86	0.2503	1.86	0.2420	1.85	0.2322	1.78	0.1706	1.71	0.1188	1.60	0.0571
Route 1 (West Side)	13	13	1.64	1.88	0.0565	1.87	0.0556	1.87	0.0522	1.86	0.0483	1.81	0.0282	1.77	0.0159	1.71	0.0055
	15	15	1.68	1.78	0.0103	1.78	0.0103	1.78	0.0100	1.78	0.0097	1.77	0.0076	1.75	0.0055	1.73	0.0026
	16	16	1.61	1.78	0.0261	1.78	0.0259	1.77	0.0253	1.77	0.0245	1.75	0.0189	1.73	0.0133	1.69	0.0057
	18	18	1.49	1.77	0.0816	1.77	0.0812	1.77	0.0794	1.76	0.0773	1.74	0.0619	1.70	0.0463	1.64	0.0241
	19	19	1.44	1.77	0.1064	1.77	0.1059	1.77	0.1037	1.76	0.1010	1.73	0.0817	1.69	0.0621	1.63	0.0338
	21	21	1.31	1.77	0.2059	1.76	0.2048	1.76	0.2006	1.75	0.1954	1.71	0.1580	1.66	0.1203	1.57	0.0667
	22	22	1.23	1.76	0.2816	1.76	0.2801	1.76	0.2741	1.75	0.2668	1.70	0.2153	1.64	0.1641	1.54	0.0923
	23	23	1.21	1.77	0.3119	1.77	0.3099	1.76	0.3022	1.75	0.2928	1.69	0.2270	1.61	0.1634	1.49	0.0793
	24	24	1.17	1.76	0.3465	1.76	0.3440	1.75	0.3342	1.74	0.3223	1.66	0.2404	1.58	0.1637	1.43	0.0680
	25	25	1.14	1.76	0.3851	1.76	0.3822	1.75	0.3705	1.73	0.3563	1.65	0.2597	1.55	0.1710	1.39	0.0647
	26	26	1.13	1.76	0.3947	1.75	0.3916	1.74	0.3794	1.73	0.3646	1.64	0.2638	1.54	0.1720	1.38	0.0632
	27	27	1.12	1.76	0.4161	1.76	0.4125	1.75	0.3985	1.73	0.3817	1.64	0.2708	1.53	0.1740	1.37	0.0632
Route 3 (East Side)	30	30	1.83	1.91	0.0074	1.91	0.0073	1.91	0.0073	1.91	0.0072	1.91	0.0064	1.90	0.0055	1.89	0.0041
	31	31	1.74	1.91	0.0294	1.91	0.0292	1.91	0.0286	1.90	0.0278	1.88	0.0220	1.86	0.0161	1.82	0.0075
	32	32	1.75	1.88	0.0171	1.88	0.0168	1.88	0.0154	1.87	0.0137	1.82	0.0045	1.77	0.0002	1.67	0.0061
	33	33	1.55	1.88	0.1127	1.88	0.1116	1.87	0.1072	1.86	0.1020	1.81	0.0682	1.74	0.0396	1.64	0.0093
	34	34	1.37	1.88	0.2596	1.88	0.2582	1.87	0.2525	1.87	0.2457	1.82	0.1983	1.76	0.1511	1.66	0.0845
	35	35	1.56	1.85	0.0817	1.84	0.0797	1.83	0.0723	1.81	0.0638	1.71	0.0208	1.60	0.0018	1.45	0.0112
	36	36	1.67	1.87	0.0398	1.87	0.0390	1.86	0.0361	1.85	0.0327	1.78	0.0127	1.71	0.0015	1.59	0.0072
			SSR (West Side Only)		2.9228		2.9012		2.8168		2.7152		2.0289		1.4019		0.6300

Table 2 (2 of 9) Calibration of kw for west side of Study Area.

Inflow/Route Number	Sample Site Number	Node Number in SynerGEE (Oct 2011 Model)	Average Chlorine Concentration (After Adjustment) on October 5, 2011 (mg/L)	Kw = 0.03 m/d		Kw = 0.035 m/d		Kw = 0.037 m/d		Kw = 0.0375 m/d		Kw = 0.0376 m/d		Kw = 0.0377 m/d		Kw = 0.0378 m/d	
				Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual
Inflow 1	1	1	1.92	1.92	0.0000	1.92	0.0000	1.92	0.0000	1.92	0.0000	1.92	0.0000	1.92	0.0000	1.92	0.0000
Inflow 2	2	2	1.76	1.76	0.0000	1.76	0.0000	1.76	0.0000	1.76	0.0000	1.76	0.0000	1.76	0.0000	1.76	0.0000
Inflow 3	3	3	1.91	1.91	0.0000	1.91	0.0000	1.91	0.0000	1.91	0.0000	1.91	0.0000	1.91	0.0000	1.91	0.0000
Route 2 (West Side)	4	4	1.87	1.90	0.0012	1.90	0.0010	1.90	0.0009	1.90	0.0009	1.90	0.0009	1.89	0.0009	1.89	0.0009
	5	5	1.92	1.89	0.0007	1.89	0.0009	1.89	0.0010	1.89	0.0010	1.89	0.0010	1.89	0.0010	1.89	0.0011
	6	6	1.89	1.87	0.0007	1.86	0.0011	1.86	0.0013	1.86	0.0014	1.86	0.0014	1.86	0.0014	1.86	0.0014
	7	7	1.85	1.78	0.0060	1.76	0.0090	1.75	0.0103	1.75	0.0106	1.75	0.0107	1.75	0.0107	1.75	0.0108
	8	8	1.77	1.71	0.0032	1.69	0.0064	1.68	0.0080	1.68	0.0084	1.68	0.0085	1.68	0.0085	1.68	0.0086
	11	11	1.74	1.69	0.0024	1.66	0.0058	1.65	0.0074	1.65	0.0079	1.65	0.0080	1.65	0.0081	1.65	0.0081
	12	12	1.36	1.52	0.0245	1.49	0.0147	1.47	0.0116	1.47	0.0109	1.47	0.0108	1.47	0.0107	1.47	0.0105
Route 1 (West Side)	13	13	1.64	1.68	0.0015	1.66	0.0006	1.66	0.0004	1.66	0.0003	1.66	0.0003	1.66	0.0003	1.66	0.0003
	15	15	1.68	1.71	0.0009	1.70	0.0004	1.70	0.0003	1.69	0.0003	1.69	0.0003	1.69	0.0002	1.69	0.0002
	16	16	1.61	1.66	0.0016	1.64	0.0006	1.63	0.0003	1.63	0.0003	1.63	0.0003	1.63	0.0002	1.63	0.0002
	18	18	1.49	1.59	0.0105	1.56	0.0062	1.56	0.0048	1.55	0.0045	1.55	0.0044	1.55	0.0044	1.55	0.0043
	19	19	1.44	1.57	0.0161	1.55	0.0102	1.54	0.0083	1.53	0.0079	1.53	0.0078	1.53	0.0077	1.53	0.0076
	21	21	1.31	1.49	0.0334	1.46	0.0223	1.45	0.0186	1.44	0.0178	1.44	0.0176	1.44	0.0174	1.44	0.0173
	22	22	1.23	1.45	0.0481	1.41	0.0331	1.40	0.0282	1.40	0.0270	1.40	0.0268	1.40	0.0266	1.39	0.0263
	23	23	1.21	1.39	0.0326	1.35	0.0186	1.33	0.0143	1.33	0.0134	1.32	0.0132	1.32	0.0130	1.32	0.0128
	24	24	1.17	1.32	0.0209	1.27	0.0089	1.25	0.0057	1.24	0.0050	1.24	0.0049	1.24	0.0048	1.24	0.0047
	25	25	1.14	1.26	0.0163	1.21	0.0054	1.19	0.0029	1.19	0.0024	1.18	0.0023	1.18	0.0022	1.18	0.0021
	26	26	1.13	1.25	0.0149	1.19	0.0045	1.17	0.0022	1.17	0.0017	1.17	0.0016	1.17	0.0016	1.17	0.0015
	27	27	1.12	1.24	0.0150	1.18	0.0046	1.16	0.0023	1.16	0.0018	1.16	0.0017	1.16	0.0017	1.16	0.0016
Route 3 (East Side)	30	30	1.83	1.88	0.0029	1.88	0.0024	1.87	0.0022	1.87	0.0022	1.87	0.0022	1.87	0.0022	1.87	0.0022
	31	31	1.74	1.79	0.0026	1.77	0.0012	1.76	0.0008	1.76	0.0007	1.76	0.0007	1.76	0.0007	1.76	0.0006
	32	32	1.75	1.60	0.0230	1.57	0.0339	1.56	0.0386	1.55	0.0398	1.55	0.0400	1.55	0.0402	1.55	0.0405
	33	33	1.55	1.56	0.0002	1.52	0.0005	1.51	0.0013	1.51	0.0016	1.50	0.0017	1.50	0.0017	1.50	0.0018
	34	34	1.37	1.58	0.0432	1.54	0.0292	1.53	0.0246	1.53	0.0235	1.52	0.0233	1.52	0.0231	1.52	0.0229
	35	35	1.56	1.35	0.0455	1.30	0.0664	1.29	0.0751	1.28	0.0773	1.28	0.0777	1.28	0.0782	1.28	0.0786
	36	36	1.67	1.49	0.0343	1.44	0.0524	1.43	0.0602	1.42	0.0621	1.42	0.0625	1.42	0.0629	1.42	0.0633
			SSR (West Side Only)		0.2506		0.1543		0.1288		0.1234		0.1224		0.1214		0.1204

Table 2 (3 of 9) Calibration of kw for west side of Study Area.

Inflow/Route Number	Sample Site Number	Node Number in SynerGEE (Oct 2011 Model)	Average Chlorine Concentration (After Adjustment) on October 5, 2011 (mg/L)	Kw = 0.0379 m/d		Kw = 0.038 m/d		Kw = 0.0381 m/d		Kw = 0.0382 m/d		Kw = 0.0383 m/d		Kw = 0.0384 m/d		Kw = 0.0385 m/d	
				Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual
Inflow 1	1	1	1.92	1.92	0.0000	1.92	0.0000	1.92	0.0000	1.92	0.0000	1.92	0.0000	1.92	0.0000	1.92	0.0000
Inflow 2	2	2	1.76	1.76	0.0000	1.76	0.0000	1.76	0.0000	1.76	0.0000	1.76	0.0000	1.76	0.0000	1.76	0.0000
Inflow 3	3	3	1.91	1.91	0.0000	1.91	0.0000	1.91	0.0000	1.91	0.0000	1.91	0.0000	1.91	0.0000	1.91	0.0000
Route 2 (West Side)	4	4	1.87	1.89	0.0009	1.89	0.0009	1.89	0.0009	1.89	0.0009	1.89	0.0009	1.89	0.0009	1.89	0.0009
	5	5	1.92	1.89	0.0011	1.89	0.0011	1.89	0.0011	1.89	0.0011	1.89	0.0011	1.89	0.0011	1.88	0.0011
	6	6	1.89	1.86	0.0014	1.86	0.0014	1.86	0.0014	1.86	0.0014	1.86	0.0014	1.86	0.0014	1.86	0.0014
	7	7	1.85	1.75	0.0109	1.75	0.0109	1.75	0.0110	1.75	0.0111	1.75	0.0112	1.75	0.0112	1.75	0.0113
	8	8	1.77	1.68	0.0087	1.68	0.0088	1.68	0.0089	1.68	0.0090	1.67	0.0090	1.67	0.0091	1.67	0.0092
	11	11	1.74	1.65	0.0082	1.64	0.0083	1.64	0.0084	1.64	0.0085	1.64	0.0086	1.64	0.0087	1.64	0.0088
	12	12	1.36	1.47	0.0104	1.47	0.0103	1.47	0.0101	1.46	0.0100	1.46	0.0099	1.46	0.0098	1.46	0.0096
Route 1 (West Side)	13	13	1.64	1.66	0.0003	1.66	0.0003	1.66	0.0003	1.66	0.0003	1.66	0.0003	1.65	0.0003	1.65	0.0002
	15	15	1.68	1.69	0.0002	1.69	0.0002	1.69	0.0002	1.69	0.0002	1.69	0.0002	1.69	0.0002	1.69	0.0002
	16	16	1.61	1.63	0.0002	1.63	0.0002	1.63	0.0002	1.63	0.0002	1.63	0.0002	1.63	0.0002	1.63	0.0002
	18	18	1.49	1.55	0.0043	1.55	0.0042	1.55	0.0041	1.55	0.0041	1.55	0.0040	1.55	0.0040	1.55	0.0039
	19	19	1.44	1.53	0.0075	1.53	0.0075	1.53	0.0074	1.53	0.0073	1.53	0.0072	1.53	0.0071	1.53	0.0070
	21	21	1.31	1.44	0.0171	1.44	0.0169	1.44	0.0168	1.44	0.0166	1.44	0.0164	1.44	0.0163	1.44	0.0161
	22	22	1.23	1.39	0.0261	1.39	0.0259	1.39	0.0257	1.39	0.0255	1.39	0.0252	1.39	0.0250	1.39	0.0248
	23	23	1.21	1.32	0.0126	1.32	0.0125	1.32	0.0123	1.32	0.0121	1.32	0.0119	1.32	0.0117	1.32	0.0116
	24	24	1.17	1.24	0.0045	1.24	0.0044	1.24	0.0043	1.24	0.0042	1.24	0.0041	1.24	0.0040	1.24	0.0038
	25	25	1.14	1.18	0.0020	1.18	0.0019	1.18	0.0018	1.18	0.0018	1.18	0.0017	1.18	0.0016	1.18	0.0015
	26	26	1.13	1.17	0.0014	1.16	0.0013	1.16	0.0013	1.16	0.0012	1.16	0.0011	1.16	0.0011	1.16	0.0010
	27	27	1.12	1.15	0.0015	1.15	0.0014	1.15	0.0014	1.15	0.0013	1.15	0.0012	1.15	0.0011	1.15	0.0011
Route 3 (East Side)	30	30	1.83	1.87	0.0022	1.87	0.0022	1.87	0.0022	1.87	0.0021	1.87	0.0021	1.87	0.0021	1.87	0.0021
	31	31	1.74	1.76	0.0006	1.76	0.0006	1.76	0.0006	1.76	0.0006	1.76	0.0006	1.76	0.0005	1.76	0.0005
	32	32	1.75	1.55	0.0407	1.55	0.0410	1.55	0.0412	1.55	0.0414	1.55	0.0417	1.55	0.0419	1.55	0.0422
	33	33	1.55	1.50	0.0018	1.50	0.0019	1.50	0.0019	1.50	0.0020	1.50	0.0021	1.50	0.0021	1.50	0.0022
	34	34	1.37	1.52	0.0227	1.52	0.0225	1.52	0.0223	1.52	0.0221	1.52	0.0219	1.52	0.0217	1.52	0.0215
	35	35	1.56	1.28	0.0791	1.28	0.0795	1.28	0.0800	1.28	0.0804	1.28	0.0808	1.28	0.0813	1.27	0.0817
	36	36	1.67	1.42	0.0637	1.42	0.0642	1.42	0.0646	1.42	0.0650	1.42	0.0654	1.41	0.0658	1.41	0.0662
			SSR (West Side Only)		0.1194		0.1184		0.1175		0.1165		0.1156		0.1147		0.1138

Table 2 (4 of 9) Calibration of kw for west side of Study Area.

Inflow/Route Number	Sample Site Number	Node Number in SynerGEE (Oct 2011 Model)	Average Chlorine Concentration (After Adjustment) on October 5, 2011 (mg/L)	Kw = 0.0386 m/d		Kw = 0.039 m/d		Kw = 0.04 m/d		Kw = 0.042 m/d		Kw = 0.043 m/d		Kw = 0.044 m/d		Kw = 0.0445 m/d	
				Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual
Inflow 1	1	1	1.92	1.92	0.0000	1.92	0.0000	1.92	0.0000	1.92	0.0000	1.92	0.0000	1.92	0.0000	1.92	0.0000
Inflow 2	2	2	1.76	1.76	0.0000	1.76	0.0000	1.76	0.0000	1.76	0.0000	1.76	0.0000	1.76	0.0000	1.76	0.0000
Inflow 3	3	3	1.91	1.91	0.0000	1.91	0.0000	1.91	0.0000	1.91	0.0000	1.91	0.0000	1.91	0.0000	1.91	0.0000
Route 2 (West Side)	4	4	1.87	1.89	0.0009	1.89	0.0009	1.89	0.0008	1.89	0.0008	1.89	0.0007	1.89	0.0007	1.89	0.0007
	5	5	1.92	1.88	0.0011	1.88	0.0011	1.88	0.0012	1.88	0.0013	1.88	0.0013	1.88	0.0014	1.88	0.0014
	6	6	1.89	1.86	0.0015	1.86	0.0015	1.85	0.0016	1.85	0.0018	1.85	0.0019	1.85	0.0020	1.85	0.0021
	7	7	1.85	1.75	0.0114	1.75	0.0116	1.74	0.0123	1.74	0.0138	1.73	0.0145	1.73	0.0153	1.73	0.0157
	8	8	1.77	1.67	0.0093	1.67	0.0096	1.67	0.0105	1.66	0.0124	1.65	0.0134	1.65	0.0143	1.65	0.0148
	11	11	1.74	1.64	0.0089	1.64	0.0092	1.64	0.0102	1.63	0.0122	1.62	0.0133	1.62	0.0144	1.61	0.0150
	12	12	1.36	1.46	0.0095	1.46	0.0090	1.45	0.0079	1.44	0.0058	1.43	0.0050	1.43	0.0042	1.43	0.0038
Route 1 (West Side)	13	13	1.64	1.65	0.0002	1.65	0.0002	1.65	0.0001	1.65	0.0001	1.64	0.0000	1.64	0.0000	1.64	0.0000
	15	15	1.68	1.69	0.0002	1.69	0.0002	1.69	0.0001	1.69	0.0001	1.68	0.0000	1.68	0.0000	1.68	0.0000
	16	16	1.61	1.63	0.0002	1.63	0.0001	1.62	0.0001	1.62	0.0000	1.61	0.0000	1.61	0.0000	1.61	0.0000
	18	18	1.49	1.55	0.0039	1.55	0.0036	1.54	0.0031	1.53	0.0022	1.53	0.0018	1.52	0.0015	1.52	0.0013
	19	19	1.44	1.53	0.0070	1.53	0.0066	1.52	0.0059	1.51	0.0045	1.51	0.0040	1.50	0.0034	1.50	0.0031
	21	21	1.31	1.44	0.0160	1.44	0.0154	1.43	0.0139	1.42	0.0112	1.41	0.0100	1.41	0.0089	1.40	0.0083
	22	22	1.23	1.39	0.0246	1.39	0.0238	1.38	0.0217	1.37	0.0180	1.36	0.0164	1.35	0.0148	1.35	0.0140
	23	23	1.21	1.32	0.0114	1.31	0.0107	1.31	0.0092	1.29	0.0065	1.28	0.0053	1.28	0.0043	1.27	0.0038
	24	24	1.17	1.23	0.0037	1.23	0.0033	1.22	0.0024	1.21	0.0010	1.20	0.0005	1.19	0.0002	1.18	0.0001
	25	25	1.14	1.17	0.0014	1.17	0.0012	1.16	0.0006	1.14	0.0000	1.13	0.0000	1.13	0.0001	1.12	0.0002
	26	26	1.13	1.16	0.0009	1.15	0.0007	1.14	0.0003	1.13	0.0000	1.12	0.0001	1.11	0.0004	1.10	0.0006
	27	27	1.12	1.15	0.0010	1.14	0.0008	1.13	0.0003	1.12	0.0000	1.11	0.0001	1.10	0.0003	1.09	0.0005
Route 3 (East Side)	30	30	1.83	1.87	0.0021	1.87	0.0021	1.87	0.0020	1.87	0.0018	1.87	0.0018	1.87	0.0017	1.87	0.0016
	31	31	1.74	1.76	0.0005	1.76	0.0005	1.75	0.0003	1.75	0.0001	1.75	0.0001	1.74	0.0000	1.74	0.0000
	32	32	1.75	1.55	0.0424	1.54	0.0434	1.54	0.0458	1.53	0.0508	1.52	0.0533	1.52	0.0559	1.51	0.0572
	33	33	1.55	1.50	0.0022	1.50	0.0025	1.49	0.0032	1.48	0.0048	1.47	0.0056	1.46	0.0066	1.46	0.0071
	34	34	1.37	1.52	0.0213	1.52	0.0205	1.51	0.0186	1.50	0.0152	1.49	0.0137	1.48	0.0123	1.48	0.0116
	35	35	1.56	1.27	0.0822	1.27	0.0840	1.26	0.0884	1.25	0.0975	1.24	0.1020	1.23	0.1066	1.23	0.1088
	36	36	1.67	1.41	0.0666	1.41	0.0682	1.40	0.0723	1.39	0.0807	1.38	0.0849	1.37	0.0892	1.37	0.0914
			SSR (West Side Only)		0.1130		0.1096		0.1023		0.0917		0.0883		0.0862		0.0855

Table 2 (5 of 9) Calibration of kw for west side of Study Area.

Inflow/Route Number	Sample Site Number	Node Number in SynerGEE (Oct 2011 Model)	Average Chlorine Concentration (After Adjustment) on October 5, 2011 (mg/L)	Kw = 0.0446 m/d		Kw = 0.0447 m/d		Kw = 0.0448 m/d		Kw = 0.0449 m/d		Kw = 0.045 m/d		Kw = 0.0451 m/d		Kw = 0.0452 m/d	
				Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual
Inflow 1	1	1	1.92	1.92	0.0000	1.92	0.0000	1.92	0.0000	1.92	0.0000	1.92	0.0000	1.92	0.0000	1.92	0.0000
Inflow 2	2	2	1.76	1.76	0.0000	1.76	0.0000	1.76	0.0000	1.76	0.0000	1.76	0.0000	1.76	0.0000	1.76	0.0000
Inflow 3	3	3	1.91	1.91	0.0000	1.91	0.0000	1.91	0.0000	1.91	0.0000	1.91	0.0000	1.91	0.0000	1.91	0.0000
Route 2 (West Side)	4	4	1.87	1.89	0.0007	1.89	0.0007	1.89	0.0007	1.89	0.0007	1.89	0.0007	1.89	0.0007	1.89	0.0007
	5	5	1.92	1.88	0.0014	1.88	0.0014	1.88	0.0014	1.88	0.0014	1.88	0.0014	1.88	0.0014	1.88	0.0014
	6	6	1.89	1.85	0.0021	1.85	0.0021	1.85	0.0021	1.85	0.0021	1.85	0.0021	1.85	0.0022	1.85	0.0022
	7	7	1.85	1.73	0.0157	1.73	0.0158	1.73	0.0159	1.73	0.0160	1.73	0.0160	1.73	0.0161	1.73	0.0162
	8	8	1.77	1.65	0.0149	1.65	0.0150	1.65	0.0152	1.65	0.0153	1.65	0.0154	1.65	0.0155	1.64	0.0156
	11	11	1.74	1.61	0.0151	1.61	0.0152	1.61	0.0153	1.61	0.0154	1.61	0.0155	1.61	0.0156	1.61	0.0157
	12	12	1.36	1.43	0.0037	1.42	0.0037	1.42	0.0036	1.42	0.0035	1.42	0.0034	1.42	0.0034	1.42	0.0033
Route 1 (West Side)	13	13	1.64	1.64	0.0000	1.64	0.0000	1.64	0.0000	1.64	0.0000	1.64	0.0000	1.64	0.0000	1.64	0.0000
	15	15	1.68	1.68	0.0000	1.68	0.0000	1.68	0.0000	1.68	0.0000	1.68	0.0000	1.68	0.0000	1.68	0.0000
	16	16	1.61	1.61	0.0000	1.61	0.0000	1.61	0.0000	1.61	0.0000	1.61	0.0000	1.61	0.0000	1.61	0.0000
	18	18	1.49	1.52	0.0013	1.52	0.0013	1.52	0.0012	1.52	0.0012	1.52	0.0012	1.52	0.0012	1.52	0.0011
	19	19	1.44	1.50	0.0031	1.50	0.0030	1.50	0.0030	1.50	0.0029	1.50	0.0029	1.50	0.0029	1.50	0.0028
	21	21	1.31	1.40	0.0082	1.40	0.0081	1.40	0.0080	1.40	0.0079	1.40	0.0078	1.40	0.0077	1.40	0.0076
	22	22	1.23	1.35	0.0139	1.35	0.0137	1.35	0.0136	1.35	0.0134	1.35	0.0133	1.35	0.0132	1.35	0.0130
	23	23	1.21	1.27	0.0037	1.27	0.0037	1.27	0.0036	1.27	0.0035	1.27	0.0034	1.27	0.0033	1.27	0.0032
	24	24	1.17	1.18	0.0001	1.18	0.0001	1.18	0.0001	1.18	0.0001	1.18	0.0000	1.18	0.0000	1.18	0.0000
	25	25	1.14	1.12	0.0003	1.12	0.0003	1.12	0.0003	1.12	0.0004	1.12	0.0004	1.12	0.0004	1.12	0.0005
	26	26	1.13	1.10	0.0006	1.10	0.0006	1.10	0.0007	1.10	0.0007	1.10	0.0008	1.10	0.0008	1.10	0.0009
	27	27	1.12	1.09	0.0005	1.09	0.0006	1.09	0.0006	1.09	0.0006	1.09	0.0007	1.09	0.0007	1.09	0.0008
Route 3 (East Side)	30	30	1.83	1.87	0.0016	1.87	0.0016	1.87	0.0016	1.87	0.0016	1.87	0.0016	1.87	0.0016	1.87	0.0016
	31	31	1.74	1.74	0.0000	1.74	0.0000	1.74	0.0000	1.74	0.0000	1.74	0.0000	1.74	0.0000	1.74	0.0000
	32	32	1.75	1.51	0.0574	1.51	0.0577	1.51	0.0579	1.51	0.0582	1.51	0.0585	1.51	0.0587	1.51	0.0590
	33	33	1.55	1.46	0.0072	1.46	0.0073	1.46	0.0074	1.46	0.0075	1.46	0.0076	1.46	0.0077	1.46	0.0078
	34	34	1.37	1.48	0.0114	1.48	0.0113	1.48	0.0112	1.48	0.0111	1.48	0.0109	1.48	0.0108	1.48	0.0107
	35	35	1.56	1.23	0.1093	1.23	0.1098	1.23	0.1102	1.23	0.1107	1.23	0.1111	1.23	0.1116	1.23	0.1120
	36	36	1.67	1.37	0.0918	1.37	0.0922	1.37	0.0927	1.37	0.0931	1.37	0.0935	1.36	0.0940	1.36	0.0944
			SSR (West Side Only)		0.0854		0.0854		0.0853		0.0852		0.0852		0.0851259		0.0850968

Table 2 (6 of 9) Calibration of kw for west side of Study Area.

Inflow/Route Number	Sample Site Number	Node Number in SynerGEE (Oct 2011 Model)	Average Chlorine Concentration (After Adjustment) on October 5, 2011 (mg/L)	Kw = 0.0453 m/d		Kw = 0.0454 m/d		Kw = 0.0455 m/d		Kw = 0.0456 m/d		Kw = 0.0457 m/d		Kw = 0.0458 m/d		Kw = 0.046 m/d	
				Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual
Inflow 1	1	1	1.92	1.92	0.0000	1.92	0.0000	1.92	0.0000	1.92	0.0000	1.92	0.0000	1.92	0.0000	1.92	0.0000
Inflow 2	2	2	1.76	1.76	0.0000	1.76	0.0000	1.76	0.0000	1.76	0.0000	1.76	0.0000	1.76	0.0000	1.76	0.0000
Inflow 3	3	3	1.91	1.91	0.0000	1.91	0.0000	1.91	0.0000	1.91	0.0000	1.91	0.0000	1.91	0.0000	1.91	0.0000
Route 2 (West Side)	4	4	1.87	1.89	0.0007	1.89	0.0007	1.89	0.0007	1.89	0.0007	1.89	0.0007	1.89	0.0007	1.89	0.0006
	5	5	1.92	1.88	0.0014	1.88	0.0014	1.88	0.0014	1.88	0.0014	1.88	0.0014	1.88	0.0015	1.88	0.0015
	6	6	1.89	1.85	0.0022	1.85	0.0022	1.85	0.0022	1.85	0.0022	1.85	0.0022	1.85	0.0022	1.85	0.0023
	7	7	1.85	1.73	0.0163	1.73	0.0163	1.73	0.0164	1.72	0.0165	1.72	0.0166	1.72	0.0167	1.72	0.0168
	8	8	1.77	1.64	0.0157	1.64	0.0158	1.64	0.0159	1.64	0.0160	1.64	0.0161	1.64	0.0162	1.64	0.0164
	11	11	1.74	1.61	0.0159	1.61	0.0160	1.61	0.0161	1.61	0.0162	1.61	0.0163	1.61	0.0164	1.61	0.0167
	12	12	1.36	1.42	0.0032	1.42	0.0032	1.42	0.0031	1.42	0.0031	1.42	0.0030	1.42	0.0029	1.42	0.0028
Route 1 (West Side)	13	13	1.64	1.64	0.0000	1.64	0.0000	1.64	0.0000	1.64	0.0000	1.64	0.0000	1.64	0.0000	1.64	0.0000
	15	15	1.68	1.68	0.0000	1.68	0.0000	1.68	0.0000	1.68	0.0000	1.68	0.0000	1.68	0.0000	1.68	0.0000
	16	16	1.61	1.61	0.0001	1.61	0.0001	1.61	0.0001	1.61	0.0001	1.61	0.0001	1.61	0.0001	1.61	0.0001
	18	18	1.49	1.52	0.0011	1.52	0.0011	1.52	0.0010	1.52	0.0010	1.52	0.0010	1.52	0.0010	1.52	0.0009
	19	19	1.44	1.50	0.0028	1.50	0.0027	1.50	0.0027	1.50	0.0026	1.50	0.0026	1.49	0.0025	1.49	0.0024
	21	21	1.31	1.40	0.0075	1.40	0.0074	1.40	0.0073	1.40	0.0072	1.40	0.0072	1.40	0.0071	1.39	0.0069
	22	22	1.23	1.35	0.0129	1.35	0.0127	1.34	0.0126	1.34	0.0125	1.34	0.0123	1.34	0.0122	1.34	0.0119
	23	23	1.21	1.27	0.0031	1.27	0.0031	1.26	0.0030	1.26	0.0029	1.26	0.0028	1.26	0.0028	1.26	0.0026
	24	24	1.17	1.18	0.0000	1.18	0.0000	1.18	0.0000	1.18	0.0000	1.17	0.0000	1.17	0.0000	1.17	0.0000
	25	25	1.14	1.11	0.0005	1.11	0.0005	1.11	0.0006	1.11	0.0006	1.11	0.0007	1.11	0.0007	1.11	0.0008
	26	26	1.13	1.10	0.0009	1.10	0.0010	1.10	0.0010	1.09	0.0011	1.09	0.0012	1.09	0.0012	1.09	0.0013
	27	27	1.12	1.09	0.0008	1.09	0.0009	1.09	0.0009	1.08	0.0010	1.08	0.0010	1.08	0.0011	1.08	0.0012
Route 3 (East Side)	30	30	1.83	1.87	0.0016	1.87	0.0016	1.87	0.0016	1.87	0.0016	1.87	0.0016	1.87	0.0016	1.87	0.0015
	31	31	1.74	1.74	0.0000	1.74	0.0000	1.74	0.0000	1.74	0.0000	1.74	0.0000	1.74	0.0000	1.74	0.0000
	32	32	1.75	1.51	0.0592	1.51	0.0595	1.51	0.0598	1.51	0.0600	1.51	0.0603	1.51	0.0605	1.51	0.0611
	33	33	1.55	1.46	0.0079	1.46	0.0080	1.46	0.0081	1.45	0.0082	1.45	0.0083	1.45	0.0085	1.45	0.0087
	34	34	1.37	1.47	0.0105	1.47	0.0104	1.47	0.0103	1.47	0.0102	1.47	0.0100	1.47	0.0099	1.47	0.0097
	35	35	1.56	1.23	0.1125	1.22	0.1130	1.22	0.1134	1.22	0.1139	1.22	0.1143	1.22	0.1148	1.22	0.1157
	36	36	1.67	1.36	0.0948	1.36	0.0953	1.36	0.0957	1.36	0.0962	1.36	0.0966	1.36	0.0970	1.36	0.0979
			SSR (West Side Only)		0.0850787		0.0850719		0.0850751		0.0850899		0.0851145		0.0852		0.0853

Table 2 (7 of 9) Calibration of kw for west side of Study Area.

Inflow/Route Number	Sample Site Number	Node Number in SynerGEE (Oct 2011 Model)	Average Chlorine Concentration (After Adjustment) on October 5, 2011 (mg/L)	Kw = 0.047 m/d		Kw = 0.05 m/d		Kw = 0.06 m/d		Kw = 0.07 m/d		Kw = 0.08 m/d		Kw = 0.09 m/d		Kw = 0.1 m/d	
				Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual
Inflow 1	1	1	1.92	1.92	0.0000	1.92	0.0000	1.92	0.0000	1.92	0.0000	1.92	0.0000	1.92	0.0000	1.92	0.0000
Inflow 2	2	2	1.76	1.76	0.0000	1.76	0.0000	1.76	0.0000	1.76	0.0000	1.76	0.0000	1.76	0.0000	1.76	0.0000
Inflow 3	3	3	1.91	1.91	0.0000	1.91	0.0000	1.91	0.0000	1.91	0.0000	1.91	0.0000	1.91	0.0000	1.91	0.0000
Route 2 (West Side)	4	4	1.87	1.89	0.0006	1.89	0.0005	1.88	0.0003	1.88	0.0002	1.87	0.0001	1.87	0.0000	1.86	0.0000
	5	5	1.92	1.88	0.0015	1.88	0.0017	1.87	0.0023	1.86	0.0029	1.86	0.0036	1.85	0.0043	1.85	0.0050
	6	6	1.89	1.85	0.0024	1.84	0.0028	1.83	0.0041	1.82	0.0057	1.81	0.0074	1.80	0.0092	1.79	0.0111
	7	7	1.85	1.72	0.0176	1.71	0.0200	1.68	0.0286	1.66	0.0379	1.64	0.0476	1.61	0.0575	1.59	0.0676
	8	8	1.77	1.64	0.0175	1.63	0.0208	1.59	0.0329	1.55	0.0463	1.52	0.0606	1.50	0.0753	1.47	0.0903
	11	11	1.74	1.60	0.0179	1.59	0.0215	1.55	0.0352	1.51	0.0505	1.48	0.0666	1.45	0.0833	1.42	0.1002
	12	12	1.36	1.41	0.0022	1.40	0.0010	1.35	0.0004	1.30	0.0040	1.26	0.0104	1.23	0.0187	1.20	0.0283
Route 1 (West Side)	13	13	1.64	1.63	0.0000	1.63	0.0001	1.61	0.0009	1.59	0.0022	1.58	0.0040	1.56	0.0060	1.55	0.0082
	15	15	1.68	1.68	0.0000	1.67	0.0000	1.66	0.0005	1.64	0.0014	1.63	0.0026	1.61	0.0041	1.60	0.0059
	16	16	1.61	1.60	0.0001	1.59	0.0004	1.57	0.0022	1.54	0.0051	1.52	0.0089	1.50	0.0133	1.48	0.0182
	18	18	1.49	1.51	0.0007	1.50	0.0002	1.46	0.0005	1.43	0.0033	1.40	0.0078	1.37	0.0137	1.34	0.0204
	19	19	1.44	1.49	0.0020	1.48	0.0010	1.44	0.0001	1.40	0.0019	1.37	0.0059	1.34	0.0113	1.31	0.0179
	21	21	1.31	1.39	0.0060	1.37	0.0037	1.32	0.0001	1.28	0.0011	1.24	0.0053	1.20	0.0118	1.17	0.0198
	22	22	1.23	1.34	0.0106	1.32	0.0073	1.26	0.0010	1.22	0.0003	1.17	0.0034	1.14	0.0092	1.10	0.0169
	23	23	1.21	1.25	0.0019	1.23	0.0006	1.17	0.0015	1.12	0.0086	1.07	0.0197	1.03	0.0334	0.99	0.0486
	24	24	1.17	1.16	0.0001	1.14	0.0010	1.07	0.0100	1.01	0.0253	0.96	0.0442	0.92	0.0650	0.88	0.0868
	25	25	1.14	1.10	0.0013	1.08	0.0037	1.00	0.0175	0.94	0.0375	0.89	0.0607	0.84	0.0854	0.80	0.1105
	26	26	1.13	1.08	0.0020	1.06	0.0048	0.99	0.0202	0.92	0.0415	0.87	0.0659	0.83	0.0916	0.78	0.1177
	27	27	1.12	1.07	0.0018	1.05	0.0045	0.98	0.0191	0.92	0.0396	0.86	0.0630	0.82	0.0877	0.78	0.1127
Route 3 (East Side)	30	30	1.83	1.87	0.0015	1.86	0.0013	1.85	0.0008	1.85	0.0004	1.84	0.0002	1.83	0.0000	1.83	0.0000
	31	31	1.74	1.73	0.0000	1.73	0.0001	1.70	0.0015	1.67	0.0040	1.65	0.0075	1.63	0.0117	1.61	0.0164
	32	32	1.75	1.50	0.0637	1.49	0.0716	1.44	0.0988	1.40	0.1264	1.36	0.1539	1.33	0.1809	1.30	0.2072
	33	33	1.55	1.45	0.0098	1.43	0.0134	1.38	0.0281	1.33	0.0453	1.29	0.0640	1.26	0.0835	1.22	0.1032
	34	34	1.37	1.46	0.0085	1.45	0.0056	1.39	0.0004	1.34	0.0008	1.30	0.0051	1.26	0.0122	1.23	0.0212
	35	35	1.56	1.21	0.1203	1.19	0.1341	1.14	0.1797	1.09	0.2241	1.04	0.2668	1.01	0.3073	0.97	0.3458
	36	36	1.67	1.35	0.1023	1.33	0.1156	1.27	0.1611	1.22	0.2069	1.17	0.2520	1.13	0.2958	1.09	0.3379
			SSR (West Side Only)		0.0864		0.0956		0.1776		0.3152		0.4876		0.6809		0.8862

Table 2 (8 of 9) Calibration of kw for west side of Study Area.

Inflow/Route Number	Sample Site Number	Node Number in SynerGEE (Oct 2011 Model)	Average Chlorine Concentration (After Adjustment) on October 5, 2011 (mg/L)	Kw = 0.5 m/d		Kw = 1 m/d		Kw = 1.5 m/d		Kw = 2 m/d		Kw = 3 m/d		Kw = 5 m/d		Kw = 10 m/d	
				Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual
Inflow 1	1	1	1.92	1.92	0.0000	1.92	0.0000	1.92	0.0000	1.92	0.0000	1.92	0.0000	1.92	0.0000	1.92	0.0000
Inflow 2	2	2	1.76	1.76	0.0000	1.76	0.0000	1.76	0.0000	1.76	0.0000	1.76	0.0000	1.76	0.0000	1.76	0.0000
Inflow 3	3	3	1.91	1.91	0.0000	1.91	0.0000	1.91	0.0000	1.91	0.0000	1.91	0.0000	1.91	0.0000	1.91	0.0000
Route 2 (West Side)	4	4	1.87	1.77	0.0096	1.72	0.0206	1.70	0.0275	1.69	0.0319	1.67	0.0374	1.66	0.0427	1.65	0.0473
	5	5	1.92	1.73	0.0349	1.68	0.0569	1.65	0.0692	1.64	0.0771	1.62	0.0864	1.61	0.0951	1.60	0.1026
	6	6	1.89	1.60	0.0844	1.53	0.1330	1.50	0.1589	1.48	0.1748	1.46	0.1932	1.44	0.2102	1.42	0.2245
	7	7	1.85	1.26	0.3527	1.15	0.4935	1.10	0.5601	1.08	0.5988	1.05	0.6419	1.03	0.6800	1.01	0.7110
	8	8	1.77	1.07	0.4904	0.95	0.6695	0.90	0.7508	0.88	0.7970	0.85	0.8477	0.83	0.8918	0.81	0.9272
	11	11	1.74	1.01	0.5331	0.89	0.7176	0.84	0.7999	0.82	0.8464	0.79	0.8971	0.77	0.9410	0.75	0.9761
	12	12	1.36	0.78	0.3437	0.67	0.4773	0.63	0.5354	0.61	0.5677	0.59	0.6027	0.57	0.6327	0.55	0.6565
Route 1 (West Side)	13	13	1.64	1.34	0.0924	1.26	0.1409	1.23	0.1651	1.22	0.1794	1.20	0.1957	1.18	0.2104	1.17	0.2225
	15	15	1.68	1.36	0.1006	1.26	0.1749	1.21	0.2178	1.18	0.2454	1.15	0.2787	1.12	0.3105	1.10	0.3383
	16	16	1.61	1.15	0.2195	1.03	0.3433	0.98	0.4075	0.95	0.4466	0.91	0.4919	0.88	0.5337	0.86	0.5689
	18	18	1.49	0.95	0.2909	0.83	0.4343	0.78	0.5035	0.75	0.5444	0.72	0.5904	0.69	0.6319	0.67	0.6661
	19	19	1.44	0.91	0.2904	0.79	0.4321	0.74	0.4997	0.71	0.5394	0.68	0.5840	0.65	0.6240	0.63	0.6569
	21	21	1.31	0.74	0.3288	0.63	0.4690	0.58	0.5324	0.56	0.5686	0.53	0.6086	0.51	0.6437	0.49	0.6722
	22	22	1.23	0.67	0.3200	0.56	0.4515	0.52	0.5098	0.50	0.5428	0.47	0.5790	0.45	0.6106	0.43	0.6361
	23	23	1.21	0.54	0.4524	0.44	0.5955	0.40	0.6550	0.38	0.6877	0.36	0.7226	0.34	0.7525	0.33	0.7762
	24	24	1.17	0.43	0.5459	0.35	0.6844	0.31	0.7394	0.30	0.7690	0.28	0.8003	0.26	0.8266	0.25	0.8472
	25	25	1.14	0.37	0.5821	0.29	0.7112	0.26	0.7612	0.25	0.7877	0.23	0.8155	0.22	0.8388	0.21	0.8569
	26	26	1.13	0.36	0.5910	0.28	0.7174	0.25	0.7660	0.24	0.7917	0.22	0.8186	0.21	0.8411	0.20	0.8585
	27	27	1.12	0.36	0.5701	0.28	0.6933	0.26	0.7406	0.24	0.7658	0.23	0.7920	0.21	0.8139	0.20	0.8310
Route 3 (East Side)	30	30	1.83	1.69	0.0185	1.64	0.0365	1.61	0.0470	1.60	0.0536	1.58	0.0616	1.56	0.0690	1.55	0.0755
	31	31	1.74	1.28	0.2064	1.18	0.3114	1.13	0.3619	1.11	0.3914	1.08	0.4244	1.06	0.4536	1.05	0.4775
	32	32	1.75	0.89	0.7471	0.78	0.9457	0.74	1.0313	0.71	1.0790	0.69	1.1305	0.67	1.1747	0.65	1.2099
	33	33	1.55	0.80	0.5488	0.70	0.7124	0.66	0.7819	0.64	0.8204	0.62	0.8618	0.60	0.8972	0.58	0.9252
	34	34	1.37	0.76	0.3734	0.65	0.5240	0.61	0.5885	0.58	0.6242	0.56	0.6625	0.54	0.6951	0.52	0.7209
	35	35	1.56	0.57	0.9873	0.48	1.1746	0.44	1.2493	0.43	1.2894	0.41	1.3317	0.39	1.3671	0.38	1.3947
	36	36	1.67	0.63	1.0845	0.53	1.3080	0.49	1.3972	0.47	1.4451	0.45	1.4955	0.43	1.5377	0.42	1.5706
			SSR (West Side Only)		6.2328		8.4163		9.3998		9.9624		10.5837		11.1310		11.5759

Table 2 (9 of 9) Calibration of kw for west side of Study Area.

Inflow/Route Number	Sample Site Number	Node Number in SynerGEE (Oct 2011 Model)	Average Chlorine Concentration (After Adjustment) on October 5, 2011 (mg/L)	Kw = 20 m/d		Kw = 50 m/d		Kw = 70 m/d		Kw = 100 m/d	
				Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual
Inflow 1	1	1	1.92	1.92	0.0000	1.92	0.0000	1.92	0.0000	1.92	0.0000
Inflow 2	2	2	1.76	1.76	0.0000	1.76	0.0000	1.76	0.0000	1.76	0.0000
Inflow 3	3	3	1.91	1.91	0.0000	1.91	0.0000	1.91	0.0000	1.91	0.0000
Route 2 (West Side)	4	4	1.87	1.64	0.0499	1.64	0.0515	1.64	0.0518	1.64	0.0520
	5	5	1.92	1.59	0.1067	1.59	0.1093	1.59	0.1098	1.59	0.1102
	6	6	1.89	1.41	0.2322	1.41	0.2370	1.41	0.2379	1.41	0.2386
	7	7	1.85	1.00	0.7273	0.99	0.7374	0.99	0.7394	0.99	0.7409
	8	8	1.77	0.80	0.9458	0.79	0.9572	0.79	0.9594	0.79	0.9610
	11	11	1.74	0.74	0.9944	0.73	1.0056	0.73	1.0078	0.73	1.0094
	12	12	1.36	0.55	0.6688	0.54	0.6764	0.54	0.6779	0.54	0.6789
Route 1 (West Side)	13	13	1.64	1.16	0.2289	1.16	0.2329	1.16	0.2337	1.15	0.2343
	15	15	1.68	1.08	0.3537	1.08	0.3634	1.07	0.3653	1.07	0.3667
	16	16	1.61	0.85	0.5880	0.84	0.6000	0.84	0.6023	0.84	0.6040
	18	18	1.49	0.66	0.6844	0.65	0.6958	0.65	0.6980	0.65	0.6996
	19	19	1.44	0.62	0.6744	0.62	0.6853	0.62	0.6875	0.61	0.6890
	21	21	1.31	0.48	0.6873	0.48	0.6966	0.48	0.6984	0.47	0.6997
	22	22	1.23	0.43	0.6495	0.42	0.6578	0.42	0.6594	0.42	0.6606
	23	23	1.21	0.32	0.7885	0.32	0.7960	0.32	0.7974	0.32	0.7985
	24	24	1.17	0.25	0.8578	0.24	0.8643	0.24	0.8655	0.24	0.8665
	25	25	1.14	0.21	0.8662	0.20	0.8718	0.20	0.8729	0.20	0.8737
	26	26	1.13	0.20	0.8674	0.19	0.8729	0.19	0.8739	0.19	0.8747
	27	27	1.12	0.20	0.8397	0.20	0.8450	0.20	0.8460	0.20	0.8468
Route 3 (East Side)	30	30	1.83	1.55	0.0790	1.54	0.0812	1.54	0.0816	1.54	0.0820
	31	31	1.74	1.04	0.4901	1.03	0.4979	1.03	0.4994	1.03	0.5006
	32	32	1.75	0.64	1.2281	0.64	1.2393	0.64	1.2415	0.64	1.2431
	33	33	1.55	0.58	0.9397	0.57	0.9486	0.57	0.9503	0.57	0.9516
	34	34	1.37	0.52	0.7342	0.51	0.7424	0.51	0.7439	0.51	0.7451
	35	35	1.56	0.37	1.4088	0.37	1.4174	0.37	1.4191	0.37	1.4203
	36	36	1.67	0.41	1.5875	0.41	1.5977	0.41	1.5997	0.41	1.6011
			SSR (West Side Only)		11.8108		11.9561		11.9842		12.0053

Table 3 (1 of 7) Calibration of kw for east side of Study Area.

Inflow/Route Number	Sample Site Number	Node Number in SynerGEE (Oct 2011 Model)	Average Chlorine Concentration (After Adjustment) on October 5, 2011 (mg/L)	Kw = 0		Kw = 0.0001 m/d		Kw = 0.0005 m/d		Kw = 0.001 m/d		Kw = 0.005 m/d		Kw = 0.01 m/d		Kw = 0.015 m/d	
				Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual
Inflow 1	1	1	1.92	1.92	0.0000	1.92	0.0000	1.92	0.0000	1.92	0.0000	1.92	0.0000	1.92	0.0000	1.92	0.0000
Inflow 2	2	2	1.76	1.76	0.0000	1.76	0.0000	1.76	0.0000	1.76	0.0000	1.76	0.0000	1.76	0.0000	1.76	0.0000
Inflow 3	3	3	1.91	1.91	0.0000	1.91	0.0000	1.91	0.0000	1.91	0.0000	1.91	0.0000	1.91	0.0000	1.91	0.0000
Route 2 (West Side)	4	4	1.87	1.92	0.0028	1.92	0.0027	1.92	0.0027	1.92	0.0027	1.91	0.0024	1.91	0.0021	1.91	0.0019
	5	5	1.92	1.92	0.0000	1.92	0.0000	1.92	0.0000	1.92	0.0000	1.91	0.0000	1.91	0.0001	1.90	0.0002
	6	6	1.89	1.91	0.0004	1.91	0.0004	1.91	0.0003	1.91	0.0003	1.91	0.0001	1.90	0.0000	1.89	0.0000
	7	7	1.85	1.90	0.0026	1.90	0.0026	1.90	0.0024	1.90	0.0021	1.88	0.0007	1.86	0.0000	1.83	0.0004
	8	8	1.77	1.90	0.0165	1.90	0.0163	1.89	0.0155	1.89	0.0145	1.86	0.0083	1.83	0.0032	1.80	0.0006
	11	11	1.74	1.90	0.0252	1.89	0.0250	1.89	0.0238	1.89	0.0225	1.85	0.0135	1.81	0.0060	1.78	0.0018
	12	12	1.36	1.87	0.2524	1.86	0.2503	1.86	0.2420	1.85	0.2322	1.78	0.1706	1.71	0.1188	1.65	0.0829
Route 1 (West Side)	13	13	1.64	1.88	0.0565	1.87	0.0556	1.87	0.0522	1.86	0.0483	1.81	0.0282	1.77	0.0159	1.74	0.0094
	15	15	1.68	1.78	0.0103	1.78	0.0103	1.78	0.0100	1.78	0.0097	1.77	0.0076	1.75	0.0055	1.74	0.0039
	16	16	1.61	1.78	0.0261	1.78	0.0259	1.77	0.0253	1.77	0.0245	1.75	0.0189	1.73	0.0133	1.71	0.0090
	18	18	1.49	1.77	0.0816	1.77	0.0812	1.77	0.0794	1.76	0.0773	1.74	0.0619	1.70	0.0463	1.67	0.0339
	19	19	1.44	1.77	0.1064	1.77	0.1059	1.77	0.1037	1.76	0.1010	1.73	0.0817	1.69	0.0621	1.66	0.0463
	21	21	1.31	1.77	0.2059	1.76	0.2048	1.76	0.2006	1.75	0.1954	1.71	0.1580	1.66	0.1203	1.61	0.0904
	22	22	1.23	1.76	0.2816	1.76	0.2801	1.76	0.2741	1.75	0.2668	1.70	0.2153	1.64	0.1641	1.58	0.1239
	23	23	1.21	1.77	0.3119	1.77	0.3099	1.76	0.3022	1.75	0.2928	1.69	0.2270	1.61	0.1634	1.55	0.1154
	24	24	1.17	1.76	0.3465	1.76	0.3440	1.75	0.3342	1.74	0.3223	1.66	0.2404	1.58	0.1637	1.50	0.1080
	25	25	1.14	1.76	0.3851	1.76	0.3822	1.75	0.3705	1.73	0.3563	1.65	0.2597	1.55	0.1710	1.47	0.1084
	26	26	1.13	1.76	0.3947	1.75	0.3916	1.74	0.3794	1.73	0.3646	1.64	0.2638	1.54	0.1720	1.46	0.1076
	27	27	1.12	1.76	0.4161	1.76	0.4125	1.75	0.3985	1.73	0.3817	1.64	0.2708	1.53	0.1740	1.44	0.1080
Route 3 (East Side)	30	30	1.83	1.91	0.0074	1.91	0.0073	1.91	0.0073	1.91	0.0072	1.91	0.0064	1.90	0.0055	1.90	0.0048
	31	31	1.74	1.91	0.0294	1.91	0.0292	1.91	0.0286	1.90	0.0278	1.88	0.0220	1.86	0.0161	1.84	0.0113
	32	32	1.75	1.88	0.0171	1.88	0.0168	1.88	0.0154	1.87	0.0137	1.82	0.0045	1.77	0.0002	1.72	0.0012
	33	33	1.55	1.88	0.1127	1.88	0.1116	1.87	0.1072	1.86	0.1020	1.81	0.0682	1.74	0.0396	1.69	0.0210
	34	34	1.37	1.88	0.2596	1.88	0.2582	1.87	0.2525	1.87	0.2457	1.82	0.1983	1.76	0.1511	1.71	0.1139
	35	35	1.56	1.85	0.0817	1.84	0.0797	1.83	0.0723	1.81	0.0638	1.71	0.0208	1.60	0.0018	1.52	0.0015
	36	36	1.67	1.87	0.0398	1.87	0.0390	1.86	0.0361	1.85	0.0327	1.78	0.0127	1.71	0.0015	1.64	0.0007
			SSR (East Side Only)		0.5477		0.5418		0.5193		0.4929		0.3329		0.2157		0.1544

Table 3 (2 of 7) Calibration of kw for east side of Study Area.

Inflow/Route Number	Sample Site Number	Node Number in SynerGEE (Oct 2011 Model)	Average Chlorine Concentration (After Adjustment) on October 5, 2011 (mg/L)	Kw = 0.018 m/d		Kw = 0.019 m/d		Kw = 0.02 m/d		Kw = 0.021 m/d		Kw = 0.0215 m/d		Kw = 0.0216 m/d		Kw = 0.0217 m/d	
				Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual
Inflow 1	1	1	1.92	1.92	0.0000	1.92	0.0000	1.92	0.0000	1.92	0.0000	1.92	0.0000	1.92	0.0000	1.92	0.0000
Inflow 2	2	2	1.76	1.76	0.0000	1.76	0.0000	1.76	0.0000	1.76	0.0000	1.76	0.0000	1.76	0.0000	1.76	0.0000
Inflow 3	3	3	1.91	1.91	0.0000	1.91	0.0000	1.91	0.0000	1.91	0.0000	1.91	0.0000	1.91	0.0000	1.91	0.0000
Route 2 (West Side)	4	4	1.87	1.91	0.0017	1.91	0.0017	1.91	0.0016	1.90	0.0016	1.90	0.0015	1.90	0.0015	1.90	0.0015
	5	5	1.92	1.90	0.0003	1.90	0.0003	1.90	0.0003	1.90	0.0004	1.90	0.0004	1.90	0.0004	1.90	0.0004
	6	6	1.89	1.89	0.0001	1.88	0.0001	1.88	0.0002	1.88	0.0002	1.88	0.0002	1.88	0.0002	1.88	0.0002
	7	7	1.85	1.82	0.0010	1.82	0.0013	1.81	0.0016	1.81	0.0019	1.81	0.0021	1.81	0.0021	1.81	0.0022
	8	8	1.77	1.78	0.0001	1.77	0.0000	1.77	0.0000	1.76	0.0001	1.76	0.0001	1.76	0.0002	1.76	0.0002
	11	11	1.74	1.76	0.0005	1.75	0.0003	1.75	0.0001	1.74	0.0000	1.74	0.0000	1.74	0.0000	1.74	0.0000
	12	12	1.36	1.62	0.0664	1.61	0.0616	1.60	0.0571	1.59	0.0528	1.59	0.0508	1.59	0.0504	1.59	0.0500
Route 1 (West Side)	13	13	1.64	1.72	0.0068	1.72	0.0061	1.71	0.0055	1.71	0.0049	1.71	0.0046	1.71	0.0046	1.71	0.0045
	15	15	1.68	1.73	0.0031	1.73	0.0028	1.73	0.0026	1.73	0.0024	1.73	0.0023	1.73	0.0023	1.73	0.0022
	16	16	1.61	1.70	0.0069	1.69	0.0063	1.69	0.0057	1.69	0.0052	1.68	0.0049	1.68	0.0049	1.68	0.0048
	18	18	1.49	1.65	0.0277	1.65	0.0258	1.64	0.0241	1.64	0.0224	1.63	0.0215	1.63	0.0214	1.63	0.0212
	19	19	1.44	1.64	0.0385	1.63	0.0361	1.63	0.0338	1.62	0.0316	1.62	0.0305	1.62	0.0303	1.62	0.0301
	21	21	1.31	1.59	0.0755	1.58	0.0710	1.57	0.0667	1.56	0.0626	1.56	0.0606	1.56	0.0602	1.56	0.0598
	22	22	1.23	1.55	0.1041	1.55	0.0980	1.54	0.0923	1.53	0.0868	1.52	0.0842	1.52	0.0837	1.52	0.0832
	23	23	1.21	1.51	0.0925	1.50	0.0857	1.49	0.0793	1.48	0.0732	1.48	0.0703	1.47	0.0697	1.47	0.0692
	24	24	1.17	1.46	0.0824	1.45	0.0749	1.43	0.0680	1.42	0.0615	1.42	0.0585	1.41	0.0579	1.41	0.0573
	25	25	1.14	1.42	0.0803	1.41	0.0722	1.39	0.0647	1.38	0.0578	1.37	0.0546	1.37	0.0540	1.37	0.0533
	26	26	1.13	1.41	0.0789	1.39	0.0708	1.38	0.0632	1.36	0.0562	1.36	0.0530	1.36	0.0523	1.36	0.0517
	27	27	1.12	1.40	0.0790	1.38	0.0708	1.37	0.0632	1.35	0.0562	1.35	0.0530	1.34	0.0523	1.34	0.0517
Route 3 (East Side)	30	30	1.83	1.89	0.0044	1.89	0.0042	1.89	0.0041	1.89	0.0040	1.89	0.0039	1.89	0.0039	1.89	0.0039
	31	31	1.74	1.83	0.0089	1.83	0.0082	1.82	0.0075	1.82	0.0069	1.82	0.0066	1.82	0.0065	1.82	0.0065
	32	32	1.75	1.69	0.0038	1.68	0.0049	1.67	0.0061	1.67	0.0074	1.66	0.0081	1.66	0.0082	1.66	0.0084
	33	33	1.55	1.66	0.0133	1.65	0.0112	1.64	0.0093	1.63	0.0076	1.63	0.0069	1.63	0.0067	1.63	0.0066
	34	34	1.37	1.68	0.0954	1.67	0.0898	1.66	0.0845	1.65	0.0794	1.65	0.0769	1.65	0.0764	1.65	0.0760
	35	35	1.56	1.48	0.0065	1.47	0.0087	1.45	0.0112	1.44	0.0140	1.44	0.0154	1.44	0.0157	1.43	0.0160
	36	36	1.67	1.61	0.0039	1.60	0.0054	1.59	0.0072	1.57	0.0092	1.57	0.0102	1.57	0.0105	1.57	0.0107
			SSR (East Side Only)		0.1361		0.1325		0.1299		0.1284		0.1280		0.1280		0.1279

Table 3 (3 of 7) Calibration of kw for east side of Study Area.

Inflow/Route Number	Sample Site Number	Node Number in SynerGEE (Oct 2011 Model)	Average Chlorine Concentration (After Adjustment) on October 5, 2011 (mg/L)	Kw = 0.0218 m/d		Kw = 0.0219 m/d		Kw = 0.022 m/d		Kw = 0.0221 m/d		Kw = 0.0222 m/d		Kw = 0.023 m/d		Kw = 0.025 m/d	
				Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual
Inflow 1	1	1	1.92	1.92	0.0000	1.92	0.0000	1.92	0.0000	1.92	0.0000	1.92	0.0000	1.92	0.0000	1.92	0.0000
Inflow 2	2	2	1.76	1.76	0.0000	1.76	0.0000	1.76	0.0000	1.76	0.0000	1.76	0.0000	1.76	0.0000	1.76	0.0000
Inflow 3	3	3	1.91	1.91	0.0000	1.91	0.0000	1.91	0.0000	1.91	0.0000	1.91	0.0000	1.91	0.0000	1.91	0.0000
Route 2 (West Side)	4	4	1.87	1.90	0.0015	1.90	0.0015	1.90	0.0015	1.90	0.0015	1.90	0.0015	1.90	0.0015	1.90	0.0014
	5	5	1.92	1.90	0.0004	1.90	0.0004	1.90	0.0004	1.90	0.0004	1.90	0.0004	1.90	0.0004	1.90	0.0005
	6	6	1.89	1.88	0.0002	1.88	0.0002	1.88	0.0002	1.88	0.0002	1.88	0.0002	1.88	0.0003	1.88	0.0004
	7	7	1.85	1.81	0.0022	1.81	0.0023	1.81	0.0023	1.81	0.0023	1.80	0.0024	1.80	0.0027	1.79	0.0035
	8	8	1.77	1.76	0.0002	1.76	0.0002	1.75	0.0002	1.75	0.0002	1.75	0.0002	1.75	0.0004	1.74	0.0009
	11	11	1.74	1.73	0.0000	1.73	0.0000	1.73	0.0000	1.73	0.0000	1.73	0.0000	1.73	0.0001	1.72	0.0004
	12	12	1.36	1.59	0.0496	1.59	0.0492	1.59	0.0488	1.58	0.0484	1.58	0.0481	1.58	0.0451	1.56	0.0382
Route 1 (West Side)	13	13	1.64	1.71	0.0045	1.71	0.0044	1.71	0.0044	1.70	0.0043	1.70	0.0043	1.70	0.0039	1.69	0.0031
	15	15	1.68	1.73	0.0022	1.73	0.0022	1.72	0.0022	1.72	0.0022	1.72	0.0021	1.72	0.0020	1.72	0.0016
	16	16	1.61	1.68	0.0048	1.68	0.0047	1.68	0.0047	1.68	0.0046	1.68	0.0046	1.68	0.0042	1.67	0.0033
	18	18	1.49	1.63	0.0211	1.63	0.0209	1.63	0.0207	1.63	0.0206	1.63	0.0204	1.62	0.0192	1.61	0.0164
	19	19	1.44	1.62	0.0299	1.62	0.0297	1.62	0.0295	1.62	0.0293	1.62	0.0291	1.61	0.0275	1.60	0.0238
	21	21	1.31	1.56	0.0594	1.55	0.0590	1.55	0.0587	1.55	0.0583	1.55	0.0579	1.55	0.0549	1.53	0.0480
	22	22	1.23	1.52	0.0827	1.52	0.0822	1.52	0.0816	1.52	0.0811	1.52	0.0806	1.51	0.0767	1.49	0.0675
	23	23	1.21	1.47	0.0686	1.47	0.0681	1.47	0.0675	1.47	0.0669	1.47	0.0664	1.46	0.0621	1.44	0.0523
	24	24	1.17	1.41	0.0567	1.41	0.0561	1.41	0.0555	1.41	0.0549	1.41	0.0544	1.40	0.0499	1.37	0.0399
	25	25	1.14	1.37	0.0527	1.37	0.0521	1.36	0.0515	1.36	0.0509	1.36	0.0503	1.35	0.0456	1.32	0.0352
	26	26	1.13	1.35	0.0511	1.35	0.0504	1.35	0.0498	1.35	0.0492	1.35	0.0486	1.34	0.0439	1.31	0.0336
	27	27	1.12	1.34	0.0510	1.34	0.0504	1.34	0.0498	1.34	0.0492	1.34	0.0486	1.33	0.0439	1.30	0.0336
Route 3 (East Side)	30	30	1.83	1.89	0.0039	1.89	0.0038	1.89	0.0038	1.89	0.0038	1.89	0.0038	1.89	0.0037	1.89	0.0035
	31	31	1.74	1.82	0.0064	1.82	0.0064	1.82	0.0063	1.82	0.0062	1.81	0.0062	1.81	0.0057	1.80	0.0047
	32	32	1.75	1.66	0.0085	1.66	0.0087	1.66	0.0088	1.66	0.0089	1.66	0.0091	1.65	0.0103	1.64	0.0136
	33	33	1.55	1.63	0.0065	1.62	0.0063	1.62	0.0062	1.62	0.0060	1.62	0.0059	1.62	0.0049	1.60	0.0028
	34	34	1.37	1.65	0.0755	1.65	0.0750	1.65	0.0745	1.64	0.0741	1.64	0.0736	1.64	0.0699	1.62	0.0613
	35	35	1.56	1.43	0.0163	1.43	0.0166	1.43	0.0169	1.43	0.0172	1.43	0.0175	1.42	0.0200	1.40	0.0267
	36	36	1.67	1.57	0.0109	1.57	0.0111	1.56	0.0114	1.56	0.0116	1.56	0.0118	1.55	0.0137	1.53	0.0189
			SSR (East Side Only)		0.1279		0.1279		0.1278547		0.1278496		0.1278540		0.1282		0.1314

Table 3 (4 of 7) Calibration of kw for east side of Study Area.

Inflow/Route Number	Sample Site Number	Node Number in SynerGEE (Oct 2011 Model)	Average Chlorine Concentration (After Adjustment) on October 5, 2011 (mg/L)	Kw = 0.03 m/d		Kw = 0.035 m/d		Kw = 0.037 m/d		Kw = 0.038 m/d		Kw = 0.039 m/d		Kw = 0.04 m/d		Kw = 0.042 m/d	
				Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual
Inflow 1	1	1	1.92	1.92	0.0000	1.92	0.0000	1.92	0.0000	1.92	0.0000	1.92	0.0000	1.92	0.0000	1.92	0.0000
Inflow 2	2	2	1.76	1.76	0.0000	1.76	0.0000	1.76	0.0000	1.76	0.0000	1.76	0.0000	1.76	0.0000	1.76	0.0000
Inflow 3	3	3	1.91	1.91	0.0000	1.91	0.0000	1.91	0.0000	1.91	0.0000	1.91	0.0000	1.91	0.0000	1.91	0.0000
Route 2 (West Side)	4	4	1.87	1.90	0.0012	1.90	0.0010	1.90	0.0009	1.89	0.0009	1.89	0.0009	1.89	0.0008	1.89	0.0008
	5	5	1.92	1.89	0.0007	1.89	0.0009	1.89	0.0010	1.89	0.0011	1.88	0.0011	1.88	0.0012	1.88	0.0013
	6	6	1.89	1.87	0.0007	1.86	0.0011	1.86	0.0013	1.86	0.0014	1.86	0.0015	1.85	0.0016	1.85	0.0018
	7	7	1.85	1.78	0.0060	1.76	0.0090	1.75	0.0103	1.75	0.0109	1.75	0.0116	1.74	0.0123	1.74	0.0138
	8	8	1.77	1.71	0.0032	1.69	0.0064	1.68	0.0080	1.68	0.0088	1.67	0.0096	1.67	0.0105	1.66	0.0124
	11	11	1.74	1.69	0.0024	1.66	0.0058	1.65	0.0074	1.64	0.0083	1.64	0.0092	1.64	0.0102	1.63	0.0122
	12	12	1.36	1.52	0.0245	1.49	0.0147	1.47	0.0116	1.47	0.0103	1.46	0.0090	1.45	0.0079	1.44	0.0058
Route 1 (West Side)	13	13	1.64	1.68	0.0015	1.66	0.0006	1.66	0.0004	1.66	0.0003	1.65	0.0002	1.65	0.0001	1.65	0.0001
	15	15	1.68	1.71	0.0009	1.70	0.0004	1.70	0.0003	1.69	0.0002	1.69	0.0002	1.69	0.0001	1.69	0.0001
	16	16	1.61	1.66	0.0016	1.64	0.0006	1.63	0.0003	1.63	0.0002	1.63	0.0001	1.62	0.0001	1.62	0.0000
	18	18	1.49	1.59	0.0105	1.56	0.0062	1.56	0.0048	1.55	0.0042	1.55	0.0036	1.54	0.0031	1.53	0.0022
	19	19	1.44	1.57	0.0161	1.55	0.0102	1.54	0.0083	1.53	0.0075	1.53	0.0066	1.52	0.0059	1.51	0.0045
	21	21	1.31	1.49	0.0334	1.46	0.0223	1.45	0.0186	1.44	0.0169	1.44	0.0154	1.43	0.0139	1.42	0.0112
	22	22	1.23	1.45	0.0481	1.41	0.0331	1.40	0.0282	1.39	0.0259	1.39	0.0238	1.38	0.0217	1.37	0.0180
	23	23	1.21	1.39	0.0326	1.35	0.0186	1.33	0.0143	1.32	0.0125	1.31	0.0107	1.31	0.0092	1.29	0.0065
	24	24	1.17	1.32	0.0209	1.27	0.0089	1.25	0.0057	1.24	0.0044	1.23	0.0033	1.22	0.0024	1.21	0.0010
	25	25	1.14	1.26	0.0163	1.21	0.0054	1.19	0.0029	1.18	0.0019	1.17	0.0012	1.16	0.0006	1.14	0.0000
	26	26	1.13	1.25	0.0149	1.19	0.0045	1.17	0.0022	1.16	0.0013	1.15	0.0007	1.14	0.0003	1.13	0.0000
	27	27	1.12	1.24	0.0150	1.18	0.0046	1.16	0.0023	1.15	0.0014	1.14	0.0008	1.13	0.0003	1.12	0.0000
Route 3 (East Side)	30	30	1.83	1.88	0.0029	1.88	0.0024	1.87	0.0022	1.87	0.0022	1.87	0.0021	1.87	0.0020	1.87	0.0018
	31	31	1.74	1.79	0.0026	1.77	0.0012	1.76	0.0008	1.76	0.0006	1.76	0.0005	1.75	0.0003	1.75	0.0001
	32	32	1.75	1.60	0.0230	1.57	0.0339	1.56	0.0386	1.55	0.0410	1.54	0.0434	1.54	0.0458	1.53	0.0508
	33	33	1.55	1.56	0.0002	1.52	0.0005	1.51	0.0013	1.50	0.0019	1.50	0.0025	1.49	0.0032	1.48	0.0048
	34	34	1.37	1.58	0.0432	1.54	0.0292	1.53	0.0246	1.52	0.0225	1.52	0.0205	1.51	0.0186	1.50	0.0152
	35	35	1.56	1.35	0.0455	1.30	0.0664	1.29	0.0751	1.28	0.0795	1.27	0.0840	1.26	0.0884	1.25	0.0975
	36	36	1.67	1.49	0.0343	1.44	0.0524	1.43	0.0602	1.42	0.0642	1.41	0.0682	1.40	0.0723	1.39	0.0807
			SSR (East Side Only)		0.1517		0.1860		0.2028		0.2118		0.2211		0.2307		0.2509

Table 3 (5 of 7) Calibration of kw for east side of Study Area.

Inflow/Route Number	Sample Site Number	Node Number in SynerGEE (Oct 2011 Model)	Average Chlorine Concentration (After Adjustment) on October 5, 2011 (mg/L)	Kw = 0.045 m/d		Kw = 0.05 m/d		Kw = 0.06 m/d		Kw = 0.07 m/d		Kw = 0.08 m/d		Kw = 0.09 m/d		Kw = 0.1 m/d	
				Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual
Inflow 1	1	1	1.92	1.92	0.0000	1.92	0.0000	1.92	0.0000	1.92	0.0000	1.92	0.0000	1.92	0.0000	1.92	0.0000
Inflow 2	2	2	1.76	1.76	0.0000	1.76	0.0000	1.76	0.0000	1.76	0.0000	1.76	0.0000	1.76	0.0000	1.76	0.0000
Inflow 3	3	3	1.91	1.91	0.0000	1.91	0.0000	1.91	0.0000	1.91	0.0000	1.91	0.0000	1.91	0.0000	1.91	0.0000
Route 2 (West Side)	4	4	1.87	1.89	0.0007	1.89	0.0005	1.88	0.0003	1.88	0.0002	1.87	0.0001	1.87	0.0000	1.86	0.0000
	5	5	1.92	1.88	0.0014	1.88	0.0017	1.87	0.0023	1.86	0.0029	1.86	0.0036	1.85	0.0043	1.85	0.0050
	6	6	1.89	1.85	0.0021	1.84	0.0028	1.83	0.0041	1.82	0.0057	1.81	0.0074	1.80	0.0092	1.79	0.0111
	7	7	1.85	1.73	0.0160	1.71	0.0200	1.68	0.0286	1.66	0.0379	1.64	0.0476	1.61	0.0575	1.59	0.0676
	8	8	1.77	1.65	0.0154	1.63	0.0208	1.59	0.0329	1.55	0.0463	1.52	0.0606	1.50	0.0753	1.47	0.0903
	11	11	1.74	1.61	0.0155	1.59	0.0215	1.55	0.0352	1.51	0.0505	1.48	0.0666	1.45	0.0833	1.42	0.1002
	12	12	1.36	1.42	0.0034	1.40	0.0010	1.35	0.0004	1.30	0.0040	1.26	0.0104	1.23	0.0187	1.20	0.0283
Route 1 (West Side)	13	13	1.64	1.64	0.0000	1.63	0.0001	1.61	0.0009	1.59	0.0022	1.58	0.0040	1.56	0.0060	1.55	0.0082
	15	15	1.68	1.68	0.0000	1.67	0.0000	1.66	0.0005	1.64	0.0014	1.63	0.0026	1.61	0.0041	1.60	0.0059
	16	16	1.61	1.61	0.0000	1.59	0.0004	1.57	0.0022	1.54	0.0051	1.52	0.0089	1.50	0.0133	1.48	0.0182
	18	18	1.49	1.52	0.0012	1.50	0.0002	1.46	0.0005	1.43	0.0033	1.40	0.0078	1.37	0.0137	1.34	0.0204
	19	19	1.44	1.50	0.0029	1.48	0.0010	1.44	0.0001	1.40	0.0019	1.37	0.0059	1.34	0.0113	1.31	0.0179
	21	21	1.31	1.40	0.0078	1.37	0.0037	1.32	0.0001	1.28	0.0011	1.24	0.0053	1.20	0.0118	1.17	0.0198
	22	22	1.23	1.35	0.0133	1.32	0.0073	1.26	0.0010	1.22	0.0003	1.17	0.0034	1.14	0.0092	1.10	0.0169
	23	23	1.21	1.27	0.0034	1.23	0.0006	1.17	0.0015	1.12	0.0086	1.07	0.0197	1.03	0.0334	0.99	0.0486
	24	24	1.17	1.18	0.0000	1.14	0.0010	1.07	0.0100	1.01	0.0253	0.96	0.0442	0.92	0.0650	0.88	0.0868
	25	25	1.14	1.12	0.0004	1.08	0.0037	1.00	0.0175	0.94	0.0375	0.89	0.0607	0.84	0.0854	0.80	0.1105
	26	26	1.13	1.10	0.0008	1.06	0.0048	0.99	0.0202	0.92	0.0415	0.87	0.0659	0.83	0.0916	0.78	0.1177
	27	27	1.12	1.09	0.0007	1.05	0.0045	0.98	0.0191	0.92	0.0396	0.86	0.0630	0.82	0.0877	0.78	0.1127
Route 3 (East Side)	30	30	1.83	1.87	0.0016	1.86	0.0013	1.85	0.0008	1.85	0.0004	1.84	0.0002	1.83	0.0000	1.83	0.0000
	31	31	1.74	1.74	0.0000	1.73	0.0001	1.70	0.0015	1.67	0.0040	1.65	0.0075	1.63	0.0117	1.61	0.0164
	32	32	1.75	1.51	0.0585	1.49	0.0716	1.44	0.0988	1.40	0.1264	1.36	0.1539	1.33	0.1809	1.30	0.2072
	33	33	1.55	1.46	0.0076	1.43	0.0134	1.38	0.0281	1.33	0.0453	1.29	0.0640	1.26	0.0835	1.22	0.1032
	34	34	1.37	1.48	0.0109	1.45	0.0056	1.39	0.0004	1.34	0.0008	1.30	0.0051	1.26	0.0122	1.23	0.0212
	35	35	1.56	1.23	0.1111	1.19	0.1341	1.14	0.1797	1.09	0.2241	1.04	0.2668	1.01	0.3073	0.97	0.3458
	36	36	1.67	1.37	0.0935	1.33	0.1156	1.27	0.1611	1.22	0.2069	1.17	0.2520	1.13	0.2958	1.09	0.3379
			SSR (East Side Only)		0.2833		0.3417		0.4703		0.6080		0.7495		0.8914		1.0316

Table 3 (6 of 7) Calibration of kw for east side of Study Area.

Inflow/Route Number	Sample Site Number	Node Number in SynerGEE (Oct 2011 Model)	Average Chlorine Concentration (After Adjustment) on October 5, 2011 (mg/L)	Kw = 0.5 m/d		Kw = 1 m/d		Kw = 1.5 m/d		Kw = 2 m/d		Kw = 3 m/d		Kw = 5 m/d		Kw = 10 m/d	
				Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual
Inflow 1	1	1	1.92	1.92	0.0000	1.92	0.0000	1.92	0.0000	1.92	0.0000	1.92	0.0000	1.92	0.0000	1.92	0.0000
Inflow 2	2	2	1.76	1.76	0.0000	1.76	0.0000	1.76	0.0000	1.76	0.0000	1.76	0.0000	1.76	0.0000	1.76	0.0000
Inflow 3	3	3	1.91	1.91	0.0000	1.91	0.0000	1.91	0.0000	1.91	0.0000	1.91	0.0000	1.91	0.0000	1.91	0.0000
Route 2 (West Side)	4	4	1.87	1.77	0.0096	1.72	0.0206	1.70	0.0275	1.69	0.0319	1.67	0.0374	1.66	0.0427	1.65	0.0473
	5	5	1.92	1.73	0.0349	1.68	0.0569	1.65	0.0692	1.64	0.0771	1.62	0.0864	1.61	0.0951	1.60	0.1026
	6	6	1.89	1.60	0.0844	1.53	0.1330	1.50	0.1589	1.48	0.1748	1.46	0.1932	1.44	0.2102	1.42	0.2245
	7	7	1.85	1.26	0.3527	1.15	0.4935	1.10	0.5601	1.08	0.5988	1.05	0.6419	1.03	0.6800	1.01	0.7110
	8	8	1.77	1.07	0.4904	0.95	0.6695	0.90	0.7508	0.88	0.7970	0.85	0.8477	0.83	0.8918	0.81	0.9272
	11	11	1.74	1.01	0.5331	0.89	0.7176	0.84	0.7999	0.82	0.8464	0.79	0.8971	0.77	0.9410	0.75	0.9761
	12	12	1.36	0.78	0.3437	0.67	0.4773	0.63	0.5354	0.61	0.5677	0.59	0.6027	0.57	0.6327	0.55	0.6565
Route 1 (West Side)	13	13	1.64	1.34	0.0924	1.26	0.1409	1.23	0.1651	1.22	0.1794	1.20	0.1957	1.18	0.2104	1.17	0.2225
	15	15	1.68	1.36	0.1006	1.26	0.1749	1.21	0.2178	1.18	0.2454	1.15	0.2787	1.12	0.3105	1.10	0.3383
	16	16	1.61	1.15	0.2195	1.03	0.3433	0.98	0.4075	0.95	0.4466	0.91	0.4919	0.88	0.5337	0.86	0.5689
	18	18	1.49	0.95	0.2909	0.83	0.4343	0.78	0.5035	0.75	0.5444	0.72	0.5904	0.69	0.6319	0.67	0.6661
	19	19	1.44	0.91	0.2904	0.79	0.4321	0.74	0.4997	0.71	0.5394	0.68	0.5840	0.65	0.6240	0.63	0.6569
	21	21	1.31	0.74	0.3288	0.63	0.4690	0.58	0.5324	0.56	0.5686	0.53	0.6086	0.51	0.6437	0.49	0.6722
	22	22	1.23	0.67	0.3200	0.56	0.4515	0.52	0.5098	0.50	0.5428	0.47	0.5790	0.45	0.6106	0.43	0.6361
	23	23	1.21	0.54	0.4524	0.44	0.5955	0.40	0.6550	0.38	0.6877	0.36	0.7226	0.34	0.7525	0.33	0.7762
	24	24	1.17	0.43	0.5459	0.35	0.6844	0.31	0.7394	0.30	0.7690	0.28	0.8003	0.26	0.8266	0.25	0.8472
	25	25	1.14	0.37	0.5821	0.29	0.7112	0.26	0.7612	0.25	0.7877	0.23	0.8155	0.22	0.8388	0.21	0.8569
	26	26	1.13	0.36	0.5910	0.28	0.7174	0.25	0.7660	0.24	0.7917	0.22	0.8186	0.21	0.8411	0.20	0.8585
	27	27	1.12	0.36	0.5701	0.28	0.6933	0.26	0.7406	0.24	0.7658	0.23	0.7920	0.21	0.8139	0.20	0.8310
Route 3 (East Side)	30	30	1.83	1.69	0.0185	1.64	0.0365	1.61	0.0470	1.60	0.0536	1.58	0.0616	1.56	0.0690	1.55	0.0755
	31	31	1.74	1.28	0.2064	1.18	0.3114	1.13	0.3619	1.11	0.3914	1.08	0.4244	1.06	0.4536	1.05	0.4775
	32	32	1.75	0.89	0.7471	0.78	0.9457	0.74	1.0313	0.71	1.0790	0.69	1.1305	0.67	1.1747	0.65	1.2099
	33	33	1.55	0.80	0.5488	0.70	0.7124	0.66	0.7819	0.64	0.8204	0.62	0.8618	0.60	0.8972	0.58	0.9252
	34	34	1.37	0.76	0.3734	0.65	0.5240	0.61	0.5885	0.58	0.6242	0.56	0.6625	0.54	0.6951	0.52	0.7209
	35	35	1.56	0.57	0.9873	0.48	1.1746	0.44	1.2493	0.43	1.2894	0.41	1.3317	0.39	1.3671	0.38	1.3947
	36	36	1.67	0.63	1.0845	0.53	1.3080	0.49	1.3972	0.47	1.4451	0.45	1.4955	0.43	1.5377	0.42	1.5706
			SSR (East Side Only)		3.9660		5.0126		5.4571		5.7032		5.9679		6.1945		6.3743

Table 3 (7 of 7) Calibration of kw for east side of Study Area.

Inflow/Route Number	Sample Site Number	Node Number in SynerGEE (Oct 2011 Model)	Average Chlorine Concentration (After Adjustment) on October 5, 2011 (mg/L)	Kw = 20 m/d		Kw = 50 m/d		Kw = 70 m/d		Kw = 100 m/d	
				Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual
Inflow 1	1	1	1.92	1.92	0.0000	1.92	0.0000	1.92	0.0000	1.92	0.0000
Inflow 2	2	2	1.76	1.76	0.0000	1.76	0.0000	1.76	0.0000	1.76	0.0000
Inflow 3	3	3	1.91	1.91	0.0000	1.91	0.0000	1.91	0.0000	1.91	0.0000
Route 2 (West Side)	4	4	1.87	1.64	0.0499	1.64	0.0515	1.64	0.0518	1.64	0.0520
	5	5	1.92	1.59	0.1067	1.59	0.1093	1.59	0.1098	1.59	0.1102
	6	6	1.89	1.41	0.2322	1.41	0.2370	1.41	0.2379	1.41	0.2386
	7	7	1.85	1.00	0.7273	0.99	0.7374	0.99	0.7394	0.99	0.7409
	8	8	1.77	0.80	0.9458	0.79	0.9572	0.79	0.9594	0.79	0.9610
	11	11	1.74	0.74	0.9944	0.73	1.0056	0.73	1.0078	0.73	1.0094
	12	12	1.36	0.55	0.6688	0.54	0.6764	0.54	0.6779	0.54	0.6789
Route 1 (West Side)	13	13	1.64	1.16	0.2289	1.16	0.2329	1.16	0.2337	1.15	0.2343
	15	15	1.68	1.08	0.3537	1.08	0.3634	1.07	0.3653	1.07	0.3667
	16	16	1.61	0.85	0.5880	0.84	0.6000	0.84	0.6023	0.84	0.6040
	18	18	1.49	0.66	0.6844	0.65	0.6958	0.65	0.6980	0.65	0.6996
	19	19	1.44	0.62	0.6744	0.62	0.6853	0.62	0.6875	0.61	0.6890
	21	21	1.31	0.48	0.6873	0.48	0.6966	0.48	0.6984	0.47	0.6997
	22	22	1.23	0.43	0.6495	0.42	0.6578	0.42	0.6594	0.42	0.6606
	23	23	1.21	0.32	0.7885	0.32	0.7960	0.32	0.7974	0.32	0.7985
	24	24	1.17	0.25	0.8578	0.24	0.8643	0.24	0.8655	0.24	0.8665
	25	25	1.14	0.21	0.8662	0.20	0.8718	0.20	0.8729	0.20	0.8737
	26	26	1.13	0.20	0.8674	0.19	0.8729	0.19	0.8739	0.19	0.8747
	27	27	1.12	0.20	0.8397	0.20	0.8450	0.20	0.8460	0.20	0.8468
Route 3 (East Side)	30	30	1.83	1.55	0.0790	1.54	0.0812	1.54	0.0816	1.54	0.0820
	31	31	1.74	1.04	0.4901	1.03	0.4979	1.03	0.4994	1.03	0.5006
	32	32	1.75	0.64	1.2281	0.64	1.2393	0.64	1.2415	0.64	1.2431
	33	33	1.55	0.58	0.9397	0.57	0.9486	0.57	0.9503	0.57	0.9516
	34	34	1.37	0.52	0.7342	0.51	0.7424	0.51	0.7439	0.51	0.7451
	35	35	1.56	0.37	1.4088	0.37	1.4174	0.37	1.4191	0.37	1.4203
	36	36	1.67	0.41	1.5875	0.41	1.5977	0.41	1.5997	0.41	1.6011
			SSR (East Side Only)		6.4675		6.5246		6.5355		6.5438

Table 4 (1 of 3) Calibration of global kw for no bulk decay scenario.

Inflow/Route Number	Sample Site Number	Node Number in SynerGEE (Oct 2011 Model)	Average Chlorine Concentration (After Adjustment) on October 5, 2011 (mg/L)	Kw = 0		Kw = 0.02 m/d		Kw = 0.03 m/d		Kw = 0.035 m/d		Kw = 0.038 m/d		Kw = 0.04 m/d		Kw = 0.041 m/d	
				Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual
Inflow 1	1	1	1.92	1.92	0.0000	1.92	0.0000	1.92	0.0000	1.92	0.0000	1.92	0.0000	1.92	0.0000	1.92	0.0000
Inflow 2	2	2	1.76	1.76	0.0000	1.76	0.0000	1.76	0.0000	1.76	0.0000	1.76	0.0000	1.76	0.0000	1.76	0.0000
Inflow 3	3	3	1.91	1.91	0.0000	1.91	0.0000	1.91	0.0000	1.91	0.0000	1.91	0.0000	1.91	0.0000	1.91	0.0000
Route 2 (West Side)	4	4	1.87	1.92	0.0030	1.91	0.0018	1.90	0.0013	1.90	0.0011	1.90	0.0010	1.90	0.0010	1.90	0.0009
	5	5	1.92	1.92	0.0000	1.90	0.0002	1.89	0.0005	1.89	0.0007	1.89	0.0009	1.89	0.0010	1.89	0.0010
	6	6	1.89	1.92	0.0006	1.89	0.0000	1.87	0.0004	1.87	0.0008	1.86	0.0010	1.86	0.0012	1.86	0.0013
	7	7	1.85	1.92	0.0044	1.83	0.0007	1.79	0.0041	1.77	0.0066	1.76	0.0083	1.76	0.0095	1.75	0.0102
	8	8	1.77	1.92	0.0225	1.79	0.0003	1.73	0.0014	1.71	0.0038	1.69	0.0057	1.69	0.0071	1.68	0.0079
	11	11	1.74	1.92	0.0336	1.77	0.0010	1.71	0.0008	1.68	0.0030	1.67	0.0050	1.66	0.0065	1.65	0.0073
	12	12	1.36	1.92	0.3063	1.65	0.0796	1.56	0.0390	1.53	0.0259	1.51	0.0198	1.49	0.0163	1.49	0.0147
Route 1 (West Side)	13	13	1.64	1.92	0.0790	1.75	0.0129	1.72	0.0061	1.70	0.0040	1.69	0.0031	1.69	0.0025	1.69	0.0023
	15	15	1.68	1.79	0.0116	1.73	0.0032	1.71	0.0013	1.70	0.0007	1.70	0.0004	1.70	0.0003	1.69	0.0002
	16	16	1.61	1.79	0.0293	1.70	0.0071	1.66	0.0024	1.65	0.0011	1.64	0.0005	1.63	0.0003	1.63	0.0002
	18	18	1.49	1.79	0.0898	1.65	0.0281	1.60	0.0131	1.58	0.0082	1.56	0.0059	1.55	0.0046	1.55	0.0040
	19	19	1.44	1.79	0.1165	1.64	0.0390	1.58	0.0196	1.56	0.0130	1.54	0.0098	1.53	0.0080	1.53	0.0072
	21	21	1.31	1.79	0.2251	1.59	0.0764	1.51	0.0400	1.48	0.0276	1.46	0.0215	1.45	0.0180	1.44	0.0164
	22	22	1.23	1.79	0.3064	1.56	0.1047	1.47	0.0566	1.43	0.0400	1.41	0.0319	1.40	0.0272	1.39	0.0251
	23	23	1.21	1.80	0.3466	1.52	0.0941	1.41	0.0416	1.37	0.0253	1.34	0.0179	1.33	0.0139	1.32	0.0121
	24	24	1.17	1.80	0.3905	1.46	0.0841	1.35	0.0294	1.29	0.0145	1.27	0.0084	1.25	0.0054	1.24	0.0042
	25	25	1.14	1.80	0.4379	1.42	0.0822	1.29	0.0247	1.24	0.0104	1.21	0.0051	1.19	0.0027	1.18	0.0018
	26	26	1.13	1.80	0.4500	1.41	0.0810	1.28	0.0231	1.22	0.0092	1.19	0.0042	1.17	0.0020	1.16	0.0012
	27	27	1.12	1.81	0.4799	1.40	0.0830	1.27	0.0242	1.22	0.0099	1.18	0.0047	1.16	0.0024	1.16	0.0016
Route 3 (East Side)	30	30	1.83	1.92	0.0080	1.89	0.0045	1.88	0.0033	1.88	0.0028	1.88	0.0025	1.87	0.0023	1.87	0.0022
	31	31	1.74	1.92	0.0328	1.83	0.0092	1.80	0.0036	1.78	0.0019	1.77	0.0011	1.76	0.0007	1.76	0.0006
	32	32	1.75	1.91	0.0260	1.70	0.0026	1.63	0.0159	1.59	0.0253	1.57	0.0316	1.56	0.0359	1.56	0.0382
	33	33	1.55	1.91	0.1359	1.67	0.0156	1.59	0.0016	1.55	0.0000	1.53	0.0003	1.51	0.0009	1.51	0.0014
	34	34	1.37	1.91	0.2932	1.69	0.1014	1.61	0.0548	1.57	0.0386	1.55	0.0307	1.53	0.0261	1.53	0.0240
	35	35	1.56	1.91	0.1245	1.51	0.0029	1.40	0.0272	1.35	0.0445	1.32	0.0558	1.31	0.0636	1.30	0.0675
	36	36	1.67	1.91	0.0590	1.62	0.0024	1.52	0.0229	1.47	0.0384	1.45	0.0488	1.43	0.0561	1.43	0.0599
			SSR (All Sites)		4.0126		0.9182		0.4591		0.3572		0.3258		0.3155		0.3131

Table 4 (2 of 3) Calibration of global kw for no bulk decay scenario.

Inflow/Route Number	Sample Site Number	Node Number in SynerGEE (Oct 2011 Model)	Average Chlorine Concentration (After Adjustment) on October 5, 2011 (mg/L)	Kw = 0.0415 m/d		Kw = 0.0416 m/d		Kw = 0.0417 m/d		Kw = 0.0418 m/d		Kw = 0.0419 m/d		Kw = 0.042 m/d		Kw = 0.0421 m/d	
				Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual
Inflow 1	1	1	1.92	1.92	0.0000	1.92	0.0000	1.92	0.0000	1.92	0.0000	1.92	0.0000	1.92	0.0000	1.92	0.0000
Inflow 2	2	2	1.76	1.76	0.0000	1.76	0.0000	1.76	0.0000	1.76	0.0000	1.76	0.0000	1.76	0.0000	1.76	0.0000
Inflow 3	3	3	1.91	1.91	0.0000	1.91	0.0000	1.91	0.0000	1.91	0.0000	1.91	0.0000	1.91	0.0000	1.91	0.0000
Route 2 (West Side)	4	4	1.87	1.90	0.0009	1.90	0.0009	1.90	0.0009	1.90	0.0009	1.90	0.0009	1.90	0.0009	1.90	0.0009
	5	5	1.92	1.89	0.0010	1.89	0.0010	1.89	0.0010	1.89	0.0010	1.89	0.0010	1.89	0.0010	1.89	0.0010
	6	6	1.89	1.86	0.0013	1.86	0.0013	1.86	0.0013	1.86	0.0013	1.86	0.0014	1.86	0.0014	1.86	0.0014
	7	7	1.85	1.75	0.0105	1.75	0.0106	1.75	0.0106	1.75	0.0107	1.75	0.0108	1.75	0.0108	1.75	0.0109
	8	8	1.77	1.68	0.0082	1.68	0.0083	1.68	0.0084	1.68	0.0085	1.68	0.0086	1.68	0.0086	1.68	0.0087
	11	11	1.74	1.65	0.0077	1.65	0.0078	1.65	0.0079	1.65	0.0079	1.65	0.0080	1.65	0.0081	1.65	0.0082
	12	12	1.36	1.48	0.0140	1.48	0.0138	1.48	0.0137	1.48	0.0135	1.48	0.0134	1.48	0.0132	1.48	0.0131
Route 1 (West Side)	13	13	1.64	1.69	0.0022	1.69	0.0021	1.68	0.0021	1.68	0.0021	1.68	0.0021	1.68	0.0020	1.68	0.0020
	15	15	1.68	1.69	0.0002	1.69	0.0002	1.69	0.0002	1.69	0.0002	1.69	0.0002	1.69	0.0002	1.69	0.0002
	16	16	1.61	1.63	0.0001	1.63	0.0001	1.63	0.0001	1.63	0.0001	1.63	0.0001	1.63	0.0001	1.63	0.0001
	18	18	1.49	1.55	0.0037	1.55	0.0037	1.55	0.0036	1.55	0.0036	1.55	0.0035	1.55	0.0035	1.54	0.0034
	19	19	1.44	1.53	0.0068	1.53	0.0067	1.53	0.0066	1.53	0.0065	1.52	0.0065	1.52	0.0064	1.52	0.0063
	21	21	1.31	1.44	0.0157	1.44	0.0155	1.44	0.0154	1.43	0.0152	1.43	0.0151	1.43	0.0149	1.43	0.0148
	22	22	1.23	1.39	0.0240	1.39	0.0238	1.39	0.0236	1.39	0.0234	1.38	0.0232	1.38	0.0230	1.38	0.0228
	23	23	1.21	1.32	0.0112	1.32	0.0111	1.31	0.0109	1.31	0.0107	1.31	0.0106	1.31	0.0104	1.31	0.0103
	24	24	1.17	1.23	0.0036	1.23	0.0035	1.23	0.0034	1.23	0.0033	1.23	0.0032	1.23	0.0031	1.23	0.0030
	25	25	1.14	1.17	0.0014	1.17	0.0013	1.17	0.0013	1.17	0.0012	1.17	0.0011	1.17	0.0011	1.17	0.0010
	26	26	1.13	1.16	0.0009	1.16	0.0009	1.16	0.0008	1.16	0.0008	1.15	0.0007	1.15	0.0007	1.15	0.0006
	27	27	1.12	1.15	0.0012	1.15	0.0011	1.15	0.0011	1.15	0.0010	1.15	0.0010	1.15	0.0009	1.14	0.0008
Route 3 (East Side)	30	30	1.83	1.87	0.0022	1.87	0.0022	1.87	0.0022	1.87	0.0021	1.87	0.0021	1.87	0.0021	1.87	0.0021
	31	31	1.74	1.76	0.0005	1.76	0.0005	1.76	0.0005	1.76	0.0005	1.76	0.0005	1.76	0.0004	1.76	0.0004
	32	32	1.75	1.55	0.0393	1.55	0.0395	1.55	0.0397	1.55	0.0400	1.55	0.0402	1.55	0.0404	1.55	0.0407
	33	33	1.55	1.50	0.0016	1.50	0.0017	1.50	0.0017	1.50	0.0018	1.50	0.0018	1.50	0.0019	1.50	0.0020
	34	34	1.37	1.52	0.0230	1.52	0.0228	1.52	0.0226	1.52	0.0224	1.52	0.0222	1.52	0.0220	1.52	0.0218
	35	35	1.56	1.30	0.0695	1.30	0.0699	1.30	0.0703	1.29	0.0707	1.29	0.0711	1.29	0.0715	1.29	0.0719
	36	36	1.67	1.42	0.0618	1.42	0.0621	1.42	0.0625	1.42	0.0629	1.42	0.0633	1.42	0.0637	1.42	0.0641
			SSR (All Sites)		0.3127		0.3126098		0.3125833		0.3125732		0.3125818		0.3126072		0.3126498

Table 4 (3 of 3) Calibration of global kw for no bulk decay scenario.

Inflow/Route Number	Sample Site Number	Node Number in SynerGEE (Oct 2011 Model)	Average Chlorine Concentration (After Adjustment) on October 5, 2011 (mg/L)	Kw = 0.0422 m/d		Kw = 0.0425 m/d		Kw = 0.043 m/d		Kw = 0.045 m/d		Kw = 0.05 m/d		Kw = 0.06 m/d	
				Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual
Inflow 1	1	1	1.92	1.92	0.0000	1.92	0.0000	1.92	0.0000	1.92	0.0000	1.92	0.0000	1.92	0.0000
Inflow 2	2	2	1.76	1.76	0.0000	1.76	0.0000	1.76	0.0000	1.76	0.0000	1.76	0.0000	1.76	0.0000
Inflow 3	3	3	1.91	1.91	0.0000	1.91	0.0000	1.91	0.0000	1.91	0.0000	1.91	0.0000	1.91	0.0000
Route 2 (West Side)	4	4	1.87	1.89	0.0009	1.89	0.0009	1.89	0.0009	1.89	0.0008	1.89	0.0007	1.89	0.0004
	5	5	1.92	1.89	0.0010	1.89	0.0011	1.88	0.0011	1.88	0.0012	1.88	0.0014	1.87	0.0020
	6	6	1.89	1.86	0.0014	1.86	0.0014	1.86	0.0015	1.85	0.0017	1.85	0.0022	1.84	0.0034
	7	7	1.85	1.75	0.0110	1.75	0.0112	1.75	0.0115	1.74	0.0129	1.72	0.0165	1.70	0.0244
	8	8	1.77	1.68	0.0088	1.67	0.0090	1.67	0.0095	1.66	0.0112	1.64	0.0159	1.61	0.0269
	11	11	1.74	1.65	0.0083	1.64	0.0086	1.64	0.0090	1.63	0.0109	1.61	0.0161	1.57	0.0283
	12	12	1.36	1.48	0.0129	1.48	0.0125	1.47	0.0118	1.46	0.0094	1.43	0.0047	1.38	0.0003
Route 1 (West Side)	13	13	1.64	1.68	0.0020	1.68	0.0019	1.68	0.0018	1.68	0.0015	1.67	0.0007	1.65	0.0001
	15	15	1.68	1.69	0.0002	1.69	0.0002	1.69	0.0001	1.69	0.0001	1.68	0.0000	1.66	0.0003
	16	16	1.61	1.62	0.0001	1.62	0.0001	1.62	0.0001	1.62	0.0000	1.60	0.0002	1.58	0.0015
	18	18	1.49	1.54	0.0034	1.54	0.0032	1.54	0.0030	1.53	0.0021	1.51	0.0007	1.47	0.0002
	19	19	1.44	1.52	0.0063	1.52	0.0060	1.52	0.0057	1.51	0.0044	1.49	0.0020	1.45	0.0000
	21	21	1.31	1.43	0.0146	1.43	0.0142	1.43	0.0135	1.42	0.0109	1.39	0.0059	1.34	0.0007
	22	22	1.23	1.38	0.0226	1.38	0.0220	1.38	0.0211	1.36	0.0176	1.33	0.0105	1.28	0.0023
	23	23	1.21	1.31	0.0101	1.31	0.0097	1.30	0.0089	1.29	0.0063	1.25	0.0020	1.19	0.0004
	24	24	1.17	1.23	0.0029	1.23	0.0027	1.22	0.0022	1.20	0.0009	1.17	0.0001	1.10	0.0061
	25	25	1.14	1.17	0.0010	1.17	0.0008	1.16	0.0006	1.14	0.0000	1.10	0.0013	1.03	0.0119
	26	26	1.13	1.15	0.0006	1.15	0.0004	1.14	0.0003	1.13	0.0000	1.08	0.0019	1.01	0.0140
	27	27	1.12	1.14	0.0008	1.14	0.0006	1.14	0.0004	1.12	0.0000	1.08	0.0015	1.00	0.0126
Route 3 (East Side)	30	30	1.83	1.87	0.0021	1.87	0.0021	1.87	0.0020	1.87	0.0019	1.87	0.0015	1.86	0.0010
	31	31	1.74	1.76	0.0004	1.76	0.0004	1.75	0.0003	1.75	0.0001	1.73	0.0000	1.71	0.0009
	32	32	1.75	1.55	0.0409	1.55	0.0416	1.55	0.0427	1.53	0.0474	1.51	0.0595	1.46	0.0849
	33	33	1.55	1.50	0.0020	1.50	0.0022	1.50	0.0025	1.48	0.0039	1.45	0.0083	1.40	0.0207
	34	34	1.37	1.52	0.0216	1.52	0.0211	1.51	0.0201	1.50	0.0167	1.47	0.0097	1.42	0.0019
	35	35	1.56	1.29	0.0723	1.29	0.0736	1.29	0.0756	1.27	0.0838	1.24	0.1046	1.18	0.1468
	36	36	1.67	1.42	0.0645	1.41	0.0656	1.41	0.0676	1.40	0.0754	1.36	0.0959	1.30	0.1387
			SSR (All Sites)		0.3127		0.3130		0.3138		0.3209		0.3636		0.5306

Table 5 (1 of 3) Calibration of global kw for the demand multiplier of 1.23.

Inflow/Route Number	Sample Site Number	Node Number in SynerGEE (Oct 2011 Model)	Average Chlorine Concentration (After Adjustment) on October 5, 2011 (mg/L)	Kw = 0 m/d		Kw = 0.01 m/d		Kw = 0.02 m/d		Kw = 0.03 m/d		Kw = 0.04 m/d		Kw = 0.045 m/d		Kw = 0.0455 m/d	
				Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual
Inflow 1	1	1	1.92	1.92	0.0000	1.92	0.0000	1.92	0.0000	1.92	0.0000	1.92	0.0000	1.92	0.0000	1.92	0.0000
Inflow 2	2	2	1.76	1.76	0.0000	1.76	0.0000	1.76	0.0000	1.76	0.0000	1.76	0.0000	1.76	0.0000	1.76	0.0000
Inflow 3	3	3	1.91	1.91	0.0000	1.91	0.0000	1.91	0.0000	1.91	0.0000	1.91	0.0000	1.91	0.0000	1.91	0.0000
Route 2 (West Side)	4	4	1.87	1.92	0.0028	1.91	0.0023	1.91	0.0019	1.90	0.0015	1.90	0.0011	1.90	0.0010	1.90	0.0010
	5	5	1.92	1.92	0.0000	1.91	0.0001	1.90	0.0002	1.90	0.0005	1.89	0.0008	1.89	0.0009	1.89	0.0009
	6	6	1.89	1.92	0.0004	1.90	0.0001	1.89	0.0000	1.88	0.0003	1.87	0.0008	1.86	0.0012	1.86	0.0012
	7	7	1.85	1.91	0.0029	1.87	0.0002	1.83	0.0005	1.80	0.0030	1.77	0.0071	1.76	0.0096	1.75	0.0099
	8	8	1.77	1.90	0.0176	1.84	0.0055	1.79	0.0005	1.75	0.0005	1.71	0.0041	1.69	0.0068	1.69	0.0071
	11	11	1.74	1.90	0.0268	1.83	0.0094	1.78	0.0015	1.72	0.0001	1.68	0.0033	1.66	0.0062	1.66	0.0065
	12	12	1.36	1.88	0.2644	1.75	0.1496	1.66	0.0875	1.59	0.0498	1.53	0.0262	1.50	0.0181	1.50	0.0174
Route 1 (West Side)	13	13	1.64	1.91	0.0722	1.86	0.0486	1.82	0.0324	1.78	0.0211	1.75	0.0133	1.74	0.0103	1.74	0.0100
	15	15	1.68	1.79	0.0128	1.76	0.0073	1.74	0.0038	1.72	0.0016	1.70	0.0004	1.69	0.0001	1.69	0.0001
	16	16	1.61	1.79	0.0301	1.74	0.0169	1.71	0.0084	1.67	0.0033	1.64	0.0007	1.63	0.0001	1.63	0.0001
	18	18	1.49	1.78	0.0889	1.72	0.0548	1.66	0.0318	1.62	0.0166	1.57	0.0072	1.55	0.0041	1.55	0.0039
	19	19	1.44	1.78	0.1148	1.71	0.0725	1.65	0.0436	1.60	0.0242	1.55	0.0117	1.53	0.0075	1.53	0.0071
	21	21	1.31	1.78	0.2183	1.68	0.1385	1.60	0.0849	1.53	0.0490	1.47	0.0257	1.44	0.0176	1.44	0.0168
	22	22	1.23	1.78	0.2965	1.67	0.1880	1.57	0.1166	1.50	0.0692	1.43	0.0382	1.40	0.0272	1.39	0.0263
	23	23	1.21	1.79	0.3320	1.65	0.1962	1.54	0.1110	1.45	0.0579	1.37	0.0261	1.34	0.0159	1.33	0.0150
	24	24	1.17	1.78	0.3703	1.62	0.2022	1.49	0.1029	1.39	0.0457	1.30	0.0153	1.26	0.0070	1.25	0.0064
	25	25	1.14	1.78	0.4125	1.60	0.2147	1.46	0.1026	1.34	0.0413	1.24	0.0112	1.20	0.0039	1.20	0.0034
	26	26	1.13	1.78	0.4230	1.59	0.2170	1.45	0.1017	1.33	0.0396	1.23	0.0099	1.18	0.0031	1.18	0.0027
	27	27	1.12	1.78	0.4462	1.59	0.2222	1.44	0.1038	1.32	0.0410	1.22	0.0108	1.18	0.0037	1.17	0.0032
Route 3 (East Side)	30	30	1.83	1.91	0.0074	1.90	0.0060	1.90	0.0047	1.89	0.0037	1.88	0.0028	1.88	0.0025	1.88	0.0024
	31	31	1.74	1.91	0.0299	1.87	0.0186	1.84	0.0108	1.81	0.0054	1.78	0.0021	1.77	0.0011	1.77	0.0010
	32	32	1.75	1.89	0.0189	1.80	0.0021	1.73	0.0007	1.66	0.0079	1.61	0.0202	1.59	0.0276	1.58	0.0284
	33	33	1.55	1.60	0.0032	1.21	0.1116	1.12	0.1801	1.07	0.2283	1.03	0.2682	1.01	0.2862	1.01	0.2880
	34	34	1.37	1.89	0.2686	1.80	0.1806	1.72	0.1188	1.65	0.0754	1.59	0.0454	1.56	0.0342	1.55	0.0332
	35	35	1.56	1.86	0.0907	1.66	0.0101	1.53	0.0009	1.43	0.0163	1.35	0.0426	1.32	0.0579	1.32	0.0594
	36	36	1.67	1.88	0.0443	1.75	0.0065	1.64	0.0007	1.55	0.0137	1.48	0.0380	1.44	0.0528	1.44	0.0544
			SSR (All Sites)		3.5956		2.0815		1.2523		0.8171		0.6331		0.6066		0.6059

Table 5 (2 of 3) Calibration of global kw for the demand multiplier of 1.23.

Inflow/Route Number	Sample Site Number	Node Number in SynerGEE (Oct 2011 Model)	Average Chlorine Concentration (After Adjustment) on October 5, 2011 (mg/L)	Kw = 0.0456 m/d		Kw = 0.0457 m/d		Kw = 0.0458 m/d		Kw = 0.0459 m/d		Kw = 0.046 m/d		Kw = 0.0461 m/d		Kw = 0.0462 m/d	
				Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual
Inflow 1	1	1	1.92	1.92	0.0000	1.92	0.0000	1.92	0.0000	1.92	0.0000	1.92	0.0000	1.92	0.0000	1.92	0.0000
Inflow 2	2	2	1.76	1.76	0.0000	1.76	0.0000	1.76	0.0000	1.76	0.0000	1.76	0.0000	1.76	0.0000	1.76	0.0000
Inflow 3	3	3	1.91	1.91	0.0000	1.91	0.0000	1.91	0.0000	1.91	0.0000	1.91	0.0000	1.91	0.0000	1.91	0.0000
Route 2 (West Side)	4	4	1.87	1.90	0.0010	1.90	0.0010	1.90	0.0010	1.90	0.0010	1.90	0.0010	1.90	0.0010	1.90	0.0010
	5	5	1.92	1.89	0.0009	1.89	0.0010	1.89	0.0010	1.89	0.0010	1.89	0.0010	1.89	0.0010	1.89	0.0010
	6	6	1.89	1.86	0.0012	1.86	0.0012	1.86	0.0012	1.86	0.0012	1.86	0.0012	1.86	0.0012	1.86	0.0012
	7	7	1.85	1.75	0.0099	1.75	0.0100	1.75	0.0100	1.75	0.0101	1.75	0.0101	1.75	0.0102	1.75	0.0103
	8	8	1.77	1.68	0.0072	1.68	0.0073	1.68	0.0073	1.68	0.0074	1.68	0.0075	1.68	0.0075	1.68	0.0076
	11	11	1.74	1.66	0.0066	1.65	0.0066	1.65	0.0067	1.65	0.0068	1.65	0.0068	1.65	0.0069	1.65	0.0070
	12	12	1.36	1.50	0.0173	1.50	0.0171	1.49	0.0170	1.49	0.0168	1.49	0.0167	1.49	0.0166	1.49	0.0164
Route 1 (West Side)	13	13	1.64	1.74	0.0100	1.74	0.0099	1.74	0.0099	1.74	0.0098	1.74	0.0098	1.74	0.0097	1.74	0.0097
	15	15	1.68	1.69	0.0001	1.69	0.0001	1.69	0.0001	1.69	0.0001	1.69	0.0001	1.69	0.0001	1.69	0.0001
	16	16	1.61	1.63	0.0001	1.62	0.0001	1.62	0.0001	1.62	0.0001	1.62	0.0001	1.62	0.0001	1.62	0.0001
	18	18	1.49	1.55	0.0038	1.55	0.0038	1.55	0.0037	1.55	0.0037	1.55	0.0036	1.55	0.0036	1.55	0.0035
	19	19	1.44	1.53	0.0070	1.53	0.0070	1.53	0.0069	1.53	0.0068	1.53	0.0067	1.53	0.0067	1.53	0.0066
	21	21	1.31	1.44	0.0167	1.44	0.0166	1.44	0.0164	1.44	0.0163	1.44	0.0162	1.44	0.0160	1.44	0.0159
	22	22	1.23	1.39	0.0261	1.39	0.0259	1.39	0.0257	1.39	0.0255	1.39	0.0253	1.39	0.0251	1.39	0.0250
	23	23	1.21	1.33	0.0149	1.33	0.0147	1.33	0.0145	1.33	0.0144	1.33	0.0142	1.33	0.0140	1.33	0.0139
	24	24	1.17	1.25	0.0063	1.25	0.0061	1.25	0.0060	1.25	0.0059	1.25	0.0058	1.25	0.0057	1.25	0.0056
	25	25	1.14	1.19	0.0033	1.19	0.0033	1.19	0.0032	1.19	0.0031	1.19	0.0030	1.19	0.0029	1.19	0.0028
	26	26	1.13	1.18	0.0026	1.18	0.0025	1.18	0.0024	1.18	0.0023	1.18	0.0023	1.17	0.0022	1.17	0.0021
	27	27	1.12	1.17	0.0031	1.17	0.0030	1.17	0.0029	1.17	0.0028	1.17	0.0027	1.17	0.0027	1.17	0.0026
Route 3 (East Side)	30	30	1.83	1.88	0.0024	1.88	0.0024	1.88	0.0024	1.88	0.0024	1.88	0.0024	1.88	0.0024	1.88	0.0024
	31	31	1.74	1.77	0.0010	1.77	0.0010	1.77	0.0010	1.77	0.0010	1.77	0.0009	1.77	0.0009	1.77	0.0009
	32	32	1.75	1.58	0.0285	1.58	0.0287	1.58	0.0289	1.58	0.0290	1.58	0.0292	1.58	0.0293	1.58	0.0295
	33	33	1.55	1.01	0.2883	1.01	0.2887	1.01	0.2890	1.01	0.2894	1.01	0.2897	1.01	0.2901	1.01	0.2904
	34	34	1.37	1.55	0.0330	1.55	0.0328	1.55	0.0326	1.55	0.0324	1.55	0.0322	1.55	0.0320	1.55	0.0318
	35	35	1.56	1.32	0.0598	1.32	0.0601	1.32	0.0604	1.31	0.0607	1.31	0.0610	1.31	0.0613	1.31	0.0617
	36	36	1.67	1.44	0.0547	1.44	0.0550	1.44	0.0553	1.43	0.0557	1.43	0.0560	1.43	0.0563	1.43	0.0566
			SSR (All Sites)		0.6058		0.6057		0.6056		0.6056		0.6055		0.6055		0.6054486

Table 5 (3 of 3) Calibration of global kw for the demand multiplier of 1.23.

Inflow/Route Number	Sample Site Number	Node Number in SynerGEE (Oct 2011 Model)	Average Chlorine Concentration (After Adjustment) on October 5, 2011 (mg/L)	Kw = 0.0463 m/d		Kw = 0.0464 m/d		Kw = 0.0465 m/d		Kw = 0.0466 m/d		Kw = 0.047 m/d		Kw = 0.05 m/d		Kw = 0.06 m/d		Kw = 0.07 m/d	
				Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual
Inflow 1	1	1	1.92	1.92	0.0000	1.92	0.0000	1.92	0.0000	1.92	0.0000	1.92	0.0000	1.92	0.0000	1.92	0.0000	1.92	0.0000
Inflow 2	2	2	1.76	1.76	0.0000	1.76	0.0000	1.76	0.0000	1.76	0.0000	1.76	0.0000	1.76	0.0000	1.76	0.0000	1.76	0.0000
Inflow 3	3	3	1.91	1.91	0.0000	1.91	0.0000	1.91	0.0000	1.91	0.0000	1.91	0.0000	1.91	0.0000	1.91	0.0000	1.91	0.0000
Route 2 (West Side)	4	4	1.87	1.90	0.0010	1.90	0.0010	1.90	0.0010	1.90	0.0010	1.90	0.0009	1.89	0.0009	1.89	0.0006	1.89	0.0004
	5	5	1.92	1.89	0.0010	1.89	0.0010	1.89	0.0010	1.89	0.0010	1.89	0.0010	1.88	0.0011	1.88	0.0015	1.87	0.0020
	6	6	1.89	1.86	0.0012	1.86	0.0013	1.86	0.0013	1.86	0.0013	1.86	0.0013	1.86	0.0015	1.85	0.0024	1.84	0.0035
	7	7	1.85	1.75	0.0103	1.75	0.0104	1.75	0.0104	1.75	0.0105	1.75	0.0107	1.74	0.0124	1.72	0.0186	1.69	0.0254
	8	8	1.77	1.68	0.0077	1.68	0.0077	1.68	0.0078	1.68	0.0078	1.68	0.0081	1.67	0.0102	1.64	0.0181	1.60	0.0274
	11	11	1.74	1.65	0.0070	1.65	0.0071	1.65	0.0072	1.65	0.0072	1.65	0.0075	1.64	0.0097	1.60	0.0184	1.57	0.0288
	12	12	1.36	1.49	0.0163	1.49	0.0162	1.49	0.0160	1.49	0.0159	1.49	0.0154	1.47	0.0119	1.43	0.0039	1.39	0.0004
Route 1 (West Side)	13	13	1.64	1.74	0.0096	1.74	0.0096	1.74	0.0095	1.74	0.0095	1.74	0.0093	1.73	0.0079	1.70	0.0042	1.68	0.0019
	15	15	1.68	1.69	0.0001	1.69	0.0001	1.69	0.0001	1.69	0.0001	1.69	0.0001	1.68	0.0000	1.66	0.0002	1.65	0.0009
	16	16	1.61	1.62	0.0001	1.62	0.0001	1.62	0.0001	1.62	0.0001	1.62	0.0000	1.61	0.0000	1.59	0.0008	1.56	0.0027
	18	18	1.49	1.55	0.0035	1.54	0.0034	1.54	0.0034	1.54	0.0034	1.54	0.0032	1.53	0.0020	1.49	0.0001	1.46	0.0006
	19	19	1.44	1.53	0.0065	1.53	0.0065	1.52	0.0064	1.52	0.0063	1.52	0.0061	1.51	0.0043	1.47	0.0007	1.44	0.0001
	21	21	1.31	1.44	0.0158	1.44	0.0156	1.44	0.0155	1.44	0.0154	1.43	0.0148	1.42	0.0113	1.37	0.0034	1.33	0.0002
	22	22	1.23	1.39	0.0248	1.39	0.0246	1.39	0.0244	1.39	0.0242	1.39	0.0235	1.37	0.0186	1.32	0.0071	1.27	0.0014
	23	23	1.21	1.33	0.0137	1.33	0.0136	1.33	0.0134	1.33	0.0133	1.32	0.0126	1.30	0.0086	1.24	0.0011	1.19	0.0004
	24	24	1.17	1.25	0.0054	1.25	0.0053	1.25	0.0052	1.25	0.0051	1.24	0.0047	1.22	0.0022	1.15	0.0004	1.10	0.0061
	25	25	1.14	1.19	0.0027	1.19	0.0026	1.19	0.0026	1.19	0.0025	1.18	0.0022	1.16	0.0005	1.09	0.0023	1.03	0.0118
	26	26	1.13	1.17	0.0020	1.17	0.0020	1.17	0.0019	1.17	0.0018	1.17	0.0016	1.14	0.0002	1.07	0.0031	1.01	0.0139
	27	27	1.12	1.17	0.0025	1.16	0.0024	1.16	0.0023	1.16	0.0023	1.16	0.0020	1.14	0.0004	1.07	0.0025	1.01	0.0122
Route 3 (East Side)	30	30	1.83	1.88	0.0024	1.88	0.0024	1.88	0.0024	1.88	0.0024	1.88	0.0023	1.87	0.0021	1.87	0.0016	1.86	0.0011
	31	31	1.74	1.77	0.0009	1.77	0.0009	1.77	0.0009	1.77	0.0009	1.76	0.0008	1.76	0.0004	1.73	0.0000	1.71	0.0006
	32	32	1.75	1.58	0.0296	1.58	0.0298	1.58	0.0300	1.58	0.0301	1.58	0.0308	1.56	0.0357	1.52	0.0532	1.48	0.0719
	33	33	1.55	1.01	0.2908	1.01	0.2911	1.01	0.2915	1.01	0.2918	1.00	0.2932	0.99	0.3034	0.97	0.3354	0.94	0.3651
	34	34	1.37	1.55	0.0316	1.55	0.0314	1.55	0.0312	1.55	0.0310	1.55	0.0303	1.53	0.0250	1.48	0.0119	1.44	0.0042
	35	35	1.56	1.31	0.0620	1.31	0.0623	1.31	0.0626	1.31	0.0629	1.31	0.0642	1.29	0.0740	1.23	0.1076	1.18	0.1419
	36	36	1.67	1.43	0.0569	1.43	0.0572	1.43	0.0575	1.43	0.0579	1.43	0.0591	1.41	0.0689	1.35	0.1034	1.30	0.1398
			SSR (All Sites)		0.6054337		0.6054302		0.6054400		0.6055		0.6057		0.6132		0.7025		0.8645

Table 6 (1 of 2) Calibration of global kw for the demand multiplier of 0.59.

Inflow/Route Number	Sample Site Number	Node Number in SynerGEE (Oct 2011 Model)	Average Chlorine Concentration (After Adjustment) on October 5, 2011 (mg/L)	Kw = 0 m/d		Kw = 0.01 m/d		Kw = 0.02 m/d		Kw = 0.021 m/d		Kw = 0.0211 m/d		Kw = 0.0212 m/d		Kw = 0.0213 m/d	
				Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual
Inflow 1	1	1	1.92	1.92	0.0000	1.92	0.0000	1.92	0.0000	1.92	0.0000	1.92	0.0000	1.92	0.0000	1.92	0.0000
Inflow 2	2	2	1.76	1.76	0.0000	1.76	0.0000	1.76	0.0000	1.76	0.0000	1.76	0.0000	1.76	0.0000	1.76	0.0000
Inflow 3	3	3	1.91	1.91	0.0000	1.91	0.0000	1.91	0.0000	1.91	0.0000	1.91	0.0000	1.91	0.0000	1.91	0.0000
Route 2 (West Side)	4	4	1.87	1.92	0.0026	1.90	0.0016	1.89	0.0009	1.89	0.0008	1.89	0.0008	1.89	0.0008	1.89	0.0008
	5	5	1.92	1.92	0.0000	1.90	0.0002	1.89	0.0007	1.89	0.0008	1.89	0.0008	1.89	0.0008	1.89	0.0008
	6	6	1.89	1.91	0.0003	1.89	0.0001	1.86	0.0009	1.86	0.0010	1.86	0.0011	1.86	0.0011	1.86	0.0011
	7	7	1.85	1.90	0.0018	1.82	0.0008	1.77	0.0072	1.76	0.0081	1.76	0.0082	1.76	0.0083	1.76	0.0084
	8	8	1.77	1.88	0.0127	1.77	0.0000	1.69	0.0060	1.68	0.0072	1.68	0.0074	1.68	0.0075	1.68	0.0076
	11	11	1.74	1.88	0.0198	1.75	0.0003	1.66	0.0061	1.65	0.0074	1.65	0.0076	1.65	0.0077	1.65	0.0078
	12	12	1.36	1.81	0.1959	1.55	0.0336	1.40	0.0016	1.39	0.0008	1.39	0.0007	1.39	0.0007	1.39	0.0006
Route 1 (West Side)	13	13	1.64	1.75	0.0131	1.71	0.0055	1.68	0.0016	1.68	0.0013	1.68	0.0013	1.67	0.0013	1.67	0.0013
	15	15	1.68	1.76	0.0062	1.73	0.0030	1.71	0.0013	1.71	0.0011	1.71	0.0011	1.71	0.0011	1.71	0.0011
	16	16	1.61	1.75	0.0189	1.70	0.0073	1.66	0.0018	1.65	0.0015	1.65	0.0015	1.65	0.0014	1.65	0.0014
	18	18	1.49	1.75	0.0673	1.66	0.0294	1.59	0.0101	1.58	0.0088	1.58	0.0087	1.58	0.0086	1.58	0.0085
	19	19	1.44	1.74	0.0897	1.65	0.0408	1.57	0.0154	1.56	0.0137	1.56	0.0135	1.56	0.0134	1.56	0.0132
	21	21	1.31	1.74	0.1804	1.60	0.0811	1.49	0.0311	1.48	0.0278	1.48	0.0275	1.48	0.0272	1.48	0.0269
	22	22	1.23	1.73	0.2508	1.57	0.1123	1.44	0.0445	1.43	0.0401	1.43	0.0397	1.43	0.0392	1.43	0.0388
	23	23	1.21	1.73	0.2677	1.51	0.0928	1.36	0.0231	1.35	0.0193	1.35	0.0190	1.35	0.0186	1.35	0.0183
	24	24	1.17	1.72	0.2961	1.46	0.0815	1.28	0.0111	1.26	0.0081	1.26	0.0079	1.26	0.0076	1.26	0.0074
	25	25	1.14	1.71	0.3287	1.42	0.0792	1.22	0.0072	1.21	0.0047	1.20	0.0045	1.20	0.0043	1.20	0.0041
	26	26	1.13	1.71	0.3366	1.41	0.0779	1.21	0.0062	1.19	0.0039	1.19	0.0037	1.19	0.0035	1.18	0.0033
	27	27	1.12	1.71	0.3488	1.39	0.0776	1.20	0.0074	1.19	0.0050	1.18	0.0048	1.18	0.0046	1.18	0.0044
Route 3 (East Side)	30	30	1.83	1.91	0.0075	1.90	0.0047	1.88	0.0026	1.88	0.0025	1.88	0.0024	1.88	0.0024	1.88	0.0024
	31	31	1.74	1.90	0.0276	1.83	0.0082	1.76	0.0007	1.76	0.0005	1.76	0.0004	1.76	0.0004	1.76	0.0004
	32	32	1.75	1.82	0.0050	1.57	0.0347	1.44	0.0978	1.43	0.1041	1.43	0.1047	1.43	0.1053	1.43	0.1059
	33	33	1.55	1.86	0.1012	1.67	0.0162	1.56	0.0001	1.55	0.0000	1.55	0.0000	1.54	0.0000	1.54	0.0000
	34	34	1.37	1.85	0.2315	1.64	0.0702	1.49	0.0142	1.48	0.0114	1.48	0.0112	1.48	0.0109	1.48	0.0107
	35	35	1.56	1.79	0.0527	1.40	0.0246	1.22	0.1174	1.20	0.1273	1.20	0.1283	1.20	0.1293	1.20	0.1302
	36	36	1.67	1.84	0.0272	1.58	0.0091	1.41	0.0655	1.40	0.0724	1.40	0.0731	1.40	0.0738	1.40	0.0745
			SSR (All Sites)		2.8901		0.8924		0.4827		0.4797771		0.4797548		0.4797779		0.4798492

Table 6 (2 of 2) Calibration of global kw for the demand multiplier of 0.59.

				Kw = 0.0214 m/d		Kw = 0.0215 m/d		Kw = 0.022 m/d		Kw = 0.023 m/d		Kw = 0.025 m/d		Kw = 0.03 m/d		Kw = 0.04 m/d	
Inflow/Route Number	Sample Site Number	Node Number in SynerGEE (Oct 2011 Model)	Average Chlorine Concentration (After Adjustment) on October 5, 2011 (mg/L)	Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual
Inflow 1	1	1	1.92	1.92	0.0000	1.92	0.0000	1.92	0.0000	1.92	0.0000	1.92	0.0000	1.92	0.0000	1.92	0.0000
Inflow 2	2	2	1.76	1.76	0.0000	1.76	0.0000	1.76	0.0000	1.76	0.0000	1.76	0.0000	1.76	0.0000	1.76	0.0000
Inflow 3	3	3	1.91	1.91	0.0000	1.91	0.0000	1.91	0.0000	1.91	0.0000	1.91	0.0000	1.91	0.0000	1.91	0.0000
Route 2 (West Side)	4	4	1.87	1.89	0.0008	1.89	0.0008	1.89	0.0008	1.89	0.0007	1.89	0.0006	1.88	0.0004	1.88	0.0001
	5	5	1.92	1.89	0.0008	1.89	0.0008	1.89	0.0009	1.89	0.0009	1.89	0.0011	1.88	0.0014	1.87	0.0023
	6	6	1.89	1.86	0.0011	1.86	0.0011	1.86	0.0012	1.86	0.0013	1.85	0.0017	1.84	0.0026	1.83	0.0048
	7	7	1.85	1.76	0.0085	1.76	0.0086	1.76	0.0091	1.75	0.0100	1.74	0.0121	1.72	0.0177	1.68	0.0304
	8	8	1.77	1.68	0.0077	1.68	0.0079	1.68	0.0085	1.67	0.0099	1.66	0.0128	1.62	0.0212	1.57	0.0412
	11	11	1.74	1.65	0.0080	1.65	0.0081	1.64	0.0089	1.63	0.0105	1.62	0.0139	1.58	0.0237	1.52	0.0475
	12	12	1.36	1.39	0.0006	1.39	0.0005	1.38	0.0003	1.37	0.0000	1.35	0.0002	1.30	0.0039	1.22	0.0200
Route 1 (West Side)	13	13	1.64	1.67	0.0013	1.67	0.0012	1.67	0.0011	1.67	0.0009	1.66	0.0006	1.65	0.0001	1.62	0.0002
	15	15	1.68	1.71	0.0011	1.71	0.0011	1.71	0.0010	1.71	0.0009	1.71	0.0007	1.70	0.0003	1.68	0.0000
	16	16	1.61	1.65	0.0014	1.65	0.0013	1.65	0.0012	1.65	0.0009	1.64	0.0005	1.62	0.0000	1.59	0.0008
	18	18	1.49	1.58	0.0084	1.58	0.0083	1.57	0.0077	1.57	0.0066	1.56	0.0048	1.53	0.0016	1.48	0.0001
	19	19	1.44	1.56	0.0131	1.56	0.0129	1.55	0.0121	1.55	0.0107	1.53	0.0081	1.50	0.0035	1.45	0.0000
	21	21	1.31	1.47	0.0266	1.47	0.0263	1.47	0.0248	1.46	0.0220	1.44	0.0170	1.40	0.0079	1.33	0.0003
	22	22	1.23	1.43	0.0384	1.43	0.0380	1.42	0.0360	1.41	0.0321	1.39	0.0254	1.35	0.0128	1.27	0.0011
	23	23	1.21	1.34	0.0179	1.34	0.0176	1.34	0.0160	1.32	0.0130	1.30	0.0081	1.25	0.0012	1.15	0.0033
	24	24	1.17	1.26	0.0071	1.26	0.0069	1.25	0.0057	1.23	0.0038	1.21	0.0011	1.15	0.0008	1.04	0.0175
	25	25	1.14	1.20	0.0039	1.20	0.0037	1.19	0.0028	1.17	0.0014	1.15	0.0001	1.08	0.0034	0.97	0.0277
	26	26	1.13	1.18	0.0031	1.18	0.0029	1.17	0.0021	1.16	0.0009	1.13	0.0000	1.06	0.0043	0.95	0.0306
	27	27	1.12	1.18	0.0042	1.18	0.0040	1.17	0.0031	1.16	0.0017	1.13	0.0002	1.07	0.0024	0.97	0.0225
Route 3 (East Side)	30	30	1.83	1.88	0.0024	1.88	0.0024	1.88	0.0023	1.87	0.0022	1.87	0.0019	1.86	0.0013	1.85	0.0005
	31	31	1.74	1.76	0.0004	1.75	0.0003	1.75	0.0002	1.75	0.0001	1.74	0.0000	1.71	0.0007	1.66	0.0055
	32	32	1.75	1.43	0.1065	1.43	0.1072	1.42	0.1103	1.41	0.1164	1.39	0.1286	1.36	0.1580	1.29	0.2128
	33	33	1.55	1.54	0.0000	1.54	0.0000	1.54	0.0001	1.53	0.0003	1.51	0.0012	1.47	0.0054	1.41	0.0194
	34	34	1.37	1.47	0.0104	1.47	0.0102	1.47	0.0090	1.46	0.0069	1.43	0.0037	1.38	0.0001	1.29	0.0060
	35	35	1.56	1.20	0.1312	1.20	0.1322	1.19	0.1371	1.18	0.1470	1.15	0.1664	1.10	0.2139	1.01	0.3017
	36	36	1.67	1.40	0.0752	1.40	0.0759	1.39	0.0795	1.38	0.0866	1.35	0.1011	1.30	0.1381	1.21	0.2122
			SSR (All Sites)		0.4800		0.4801		0.4816		0.4878		0.5118		0.6267		1.0085

APPENDIX K

Model Calibration of K_w (July 2011 Conditions)

Table 1 (1 of 3)   Calibration of global kw.

Inflow/Quadrant Number	Sample Site Number	Node Number in SynerGEE (July 2011 Model)	Average Chlorine Concentration (After Adjustment) on July 28, 2011 (mg/L)	Kw = 0		Kw = 0.02		Kw = 0.025		Kw = 0.028		Kw = 0.0285		Kw = 0.029		Kw = 0.0291	
				Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual
Inflow 1	1	1	1.62	1.62	0.0000	1.62	0.0000	1.62	0.0000	1.62	0.0000	1.62	0.0000	1.62	0.0000	1.62	0.0000
Inflow 2	2	2	1.36	1.36	0.0000	1.36	0.0000	1.36	0.0000	1.36	0.0000	1.36	0.0000	1.36	0.0000	1.36	0.0000
Inflow 3	3	3	1.62	1.62	0.0000	1.62	0.0000	1.62	0.0000	1.62	0.0000	1.62	0.0000	1.62	0.0000	1.62	0.0000
Quadrant 4 (West Side)	4	4	1.29	1.37	0.0061	1.35	0.0034	1.34	0.0029	1.34	0.0026	1.34	0.0026	1.34	0.0026	1.34	0.0026
	5	5	1.61	1.62	0.0002	1.61	0.0000	1.61	0.0000	1.60	0.0000	1.60	0.0000	1.60	0.0000	1.60	0.0000
	6	6	1.52	1.61	0.0085	1.53	0.0003	1.52	0.0000	1.51	0.0000	1.51	0.0001	1.51	0.0001	1.51	0.0001
	8	8	1.42	1.61	0.0362	1.54	0.0147	1.53	0.0112	1.52	0.0094	1.51	0.0091	1.51	0.0089	1.51	0.0088
	9	9	1.34	1.47	0.0162	1.39	0.0021	1.37	0.0008	1.36	0.0003	1.36	0.0003	1.35	0.0002	1.35	0.0002
	10	10	1.20	1.49	0.0848	1.23	0.0013	1.20	0.0000	1.18	0.0004	1.18	0.0005	1.17	0.0006	1.17	0.0007
Quadrant 1 (West Side)	11	11	1.06	1.46	0.1534	1.27	0.0420	1.23	0.0289	1.21	0.0227	1.21	0.0217	1.21	0.0208	1.21	0.0206
	12	12	1.19	1.49	0.0920	1.28	0.0082	1.24	0.0028	1.22	0.0010	1.22	0.0008	1.21	0.0007	1.21	0.0006
	13	13	0.90	1.49	0.3439	1.28	0.1403	1.24	0.1112	1.21	0.0963	1.21	0.0940	1.21	0.0917	1.21	0.0913
	14	14	0.99	1.40	0.1726	1.18	0.0384	1.14	0.0234	1.12	0.0167	1.11	0.0157	1.11	0.0147	1.11	0.0145
	15	15	0.94	1.41	0.2199	1.10	0.0266	1.04	0.0114	1.01	0.0058	1.01	0.0050	1.00	0.0044	1.00	0.0042
Quadrant 3 (East Side)	19	19	1.44	1.58	0.0198	1.35	0.0080	1.31	0.0177	1.29	0.0248	1.28	0.0261	1.28	0.0274	1.28	0.0276
	20	20	1.27	1.56	0.0839	1.25	0.0005	1.20	0.0051	1.18	0.0096	1.17	0.0104	1.17	0.0113	1.17	0.0115
	21	21	1.30	1.58	0.0815	1.36	0.0034	1.31	0.0002	1.29	0.0001	1.28	0.0002	1.28	0.0004	1.28	0.0004
Quadrant 2 (East Side)	22	22	1.43	1.59	0.0252	1.35	0.0059	1.30	0.0151	1.28	0.0221	1.27	0.0234	1.27	0.0247	1.27	0.0249
	24	24	1.46	1.59	0.0173	1.38	0.0058	1.34	0.0138	1.32	0.0198	1.31	0.0209	1.31	0.0220	1.31	0.0223
			SSR (All Sites)		1.3614		0.3007		0.2445		0.2317		0.2309		0.2304		0.2304

Table 1 (2 of 3) Calibration of global kw.

Inflow/Quadrant Number	Sample Site Number	Node Number in SynerGEE (July 2011 Model)	Average Chlorine Concentration (After Adjustment) on July 28, 2011 (mg/L)	Kw = 0.0292		Kw = 0.0293		Kw = 0.0294		Kw = 0.0295		Kw = 0.0296		Kw = 0.0297		Kw = 0.0298	
				Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual
Inflow 1	1	1	1.62	1.62	0.0000	1.62	0.0000	1.62	0.0000	1.62	0.0000	1.62	0.0000	1.62	0.0000	1.62	0.0000
Inflow 2	2	2	1.36	1.36	0.0000	1.36	0.0000	1.36	0.0000	1.36	0.0000	1.36	0.0000	1.36	0.0000	1.36	0.0000
Inflow 3	3	3	1.62	1.62	0.0000	1.62	0.0000	1.62	0.0000	1.62	0.0000	1.62	0.0000	1.62	0.0000	1.62	0.0000
Quadrant 4 (West Side)	4	4	1.29	1.34	0.0025	1.34	0.0025	1.34	0.0025	1.34	0.0025	1.34	0.0025	1.34	0.0025	1.34	0.0025
	5	5	1.61	1.60	0.0000	1.60	0.0000	1.60	0.0000	1.60	0.0000	1.60	0.0000	1.60	0.0000	1.60	0.0000
	6	6	1.52	1.51	0.0001	1.50	0.0001	1.50	0.0001	1.50	0.0001	1.50	0.0001	1.50	0.0001	1.50	0.0001
	8	8	1.42	1.51	0.0087	1.51	0.0087	1.51	0.0086	1.51	0.0086	1.51	0.0085	1.51	0.0085	1.51	0.0084
	9	9	1.34	1.35	0.0002	1.35	0.0002	1.35	0.0002	1.35	0.0002	1.35	0.0002	1.35	0.0002	1.35	0.0001
	10	10	1.20	1.17	0.0007	1.17	0.0007	1.17	0.0008	1.17	0.0008	1.17	0.0008	1.17	0.0009	1.17	0.0009
Quadrant 1 (West Side)	11	11	1.06	1.21	0.0205	1.21	0.0203	1.21	0.0201	1.21	0.0199	1.20	0.0198	1.20	0.0196	1.20	0.0194
	12	12	1.19	1.21	0.0006	1.21	0.0006	1.21	0.0005	1.21	0.0005	1.21	0.0005	1.21	0.0004	1.21	0.0004
	13	13	0.90	1.20	0.0908	1.20	0.0904	1.20	0.0900	1.20	0.0895	1.20	0.0891	1.20	0.0886	1.20	0.0882
	14	14	0.99	1.11	0.0143	1.11	0.0142	1.11	0.0140	1.11	0.0138	1.10	0.0136	1.10	0.0134	1.10	0.0133
	15	15	0.94	1.00	0.0041	1.00	0.0040	1.00	0.0039	1.00	0.0038	1.00	0.0036	1.00	0.0035	1.00	0.0034
Quadrant 3 (East Side)	19	19	1.44	1.28	0.0279	1.28	0.0282	1.28	0.0284	1.27	0.0287	1.27	0.0289	1.27	0.0292	1.27	0.0295
	20	20	1.27	1.17	0.0117	1.16	0.0119	1.16	0.0120	1.16	0.0122	1.16	0.0124	1.16	0.0126	1.16	0.0128
	21	21	1.30	1.28	0.0004	1.28	0.0005	1.28	0.0005	1.27	0.0006	1.27	0.0006	1.27	0.0006	1.27	0.0007
Quadrant 2 (East Side)	22	22	1.43	1.27	0.0252	1.27	0.0255	1.27	0.0257	1.27	0.0260	1.27	0.0262	1.26	0.0265	1.26	0.0268
	24	24	1.46	1.31	0.0225	1.31	0.0227	1.31	0.0229	1.30	0.0232	1.30	0.0234	1.30	0.0236	1.30	0.0239
			SSR (All Sites)		0.2303311		0.2303035		0.2302889		0.2302880		0.2302998		0.2303257		0.2304

Table 1 (3 of 3) Calibration of global kw.

Inflow/Quadrant Number	Sample Site Number	Node Number in SynerGEE (July 2011 Model)	Average Chlorine Concentration (After Adjustment) on July 28, 2011 (mg/L)	Kw = 0.03		Kw = 0.031		Kw = 0.032		Kw = 0.035		Kw = 0.04		Kw = 0.05	
				Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual
Inflow 1	1	1	1.62	1.62	0.0000	1.62	0.0000	1.62	0.0000	1.62	0.0000	1.62	0.0000	1.62	0.0000
Inflow 2	2	2	1.36	1.36	0.0000	1.36	0.0000	1.36	0.0000	1.36	0.0000	1.36	0.0000	1.36	0.0000
Inflow 3	3	3	1.62	1.62	0.0000	1.62	0.0000	1.62	0.0000	1.62	0.0000	1.62	0.0000	1.62	0.0000
Quadrant 4 (West Side)	4	4	1.29	1.34	0.0025	1.34	0.0024	1.34	0.0023	1.34	0.0021	1.33	0.0018	1.33	0.0012
	5	5	1.61	1.60	0.0000	1.60	0.0000	1.60	0.0000	1.60	0.0000	1.60	0.0000	1.60	0.0001
	6	6	1.52	1.50	0.0002	1.50	0.0002	1.50	0.0003	1.49	0.0007	1.48	0.0016	1.45	0.0041
	8	8	1.42	1.51	0.0083	1.51	0.0078	1.50	0.0073	1.50	0.0060	1.48	0.0041	1.46	0.0015
	9	9	1.34	1.35	0.0001	1.35	0.0001	1.34	0.0000	1.34	0.0000	1.32	0.0004	1.29	0.0022
	10	10	1.20	1.17	0.0010	1.16	0.0014	1.16	0.0018	1.14	0.0035	1.11	0.0071	1.07	0.0167
Quadrant 1 (West Side)	11	11	1.06	1.20	0.0191	1.20	0.0174	1.19	0.0159	1.17	0.0118	1.15	0.0066	1.10	0.0010
	12	12	1.19	1.21	0.0004	1.20	0.0002	1.19	0.0000	1.17	0.0001	1.15	0.0016	1.10	0.0083
	13	13	0.90	1.20	0.0873	1.19	0.0831	1.18	0.0791	1.16	0.0679	1.13	0.0520	1.07	0.0288
	14	14	0.99	1.10	0.0129	1.09	0.0113	1.09	0.0098	1.07	0.0060	1.03	0.0019	0.97	0.0003
	15	15	0.94	0.99	0.0032	0.98	0.0022	0.97	0.0014	0.95	0.0001	0.91	0.0010	0.83	0.0108
Quadrant 3 (East Side)	19	19	1.44	1.27	0.0300	1.26	0.0327	1.26	0.0355	1.23	0.0441	1.20	0.0596	1.14	0.0929
	20	20	1.27	1.16	0.0131	1.15	0.0150	1.14	0.0170	1.12	0.0235	1.09	0.0353	1.02	0.0619
	21	21	1.30	1.27	0.0008	1.26	0.0013	1.25	0.0019	1.23	0.0043	1.20	0.0102	1.13	0.0271
Quadrant 2 (East Side)	22	22	1.43	1.26	0.0273	1.25	0.0301	1.25	0.0329	1.22	0.0419	1.19	0.0582	1.12	0.0944
	24	24	1.46	1.30	0.0243	1.29	0.0267	1.29	0.0291	1.26	0.0368	1.23	0.0509	1.17	0.0823
			SSR (All Sites)		0.2305		0.2318		0.2344		0.2488		0.2923		0.4337

Table 2 (1 of 4) Calibration of kw for west side of Study Area.

Inflow/Quadrant Number	Sample Site Number	Node Number in SynerGEE (July 2011 Model)	Average Chlorine Concentration (After Adjustment) on July 28, 2011 (mg/L)	Kw = 0		Kw = 0.01		Kw = 0.02		Kw = 0.025		Kw = 0.028		Kw = 0.0285		Kw = 0.029	
				Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual
Inflow 1	1	28069	1.62	1.62	0.0000	1.62	0.0000	1.62	0.0000	1.62	0.0000	1.62	0.0000	1.62	0.0000	1.62	0.0000
Inflow 2	2	20139	1.36	1.36	0.0000	1.36	0.0000	1.36	0.0000	1.36	0.0000	1.36	0.0000	1.36	0.0000	1.36	0.0000
Inflow 3	3	28043	1.62	1.62	0.0000	1.62	0.0000	1.62	0.0000	1.62	0.0000	1.62	0.0000	1.62	0.0000	1.62	0.0000
Quadrant 4 (West Side)	4	4	1.29	1.37	0.0061	1.36	0.0045	1.35	0.0034	1.34	0.0029	1.34	0.0026	1.34	0.0026	1.34	0.0026
	5	5	1.61	1.62	0.0002	1.61	0.0001	1.61	0.0000	1.61	0.0000	1.60	0.0000	1.60	0.0000	1.60	0.0000
	6	6	1.52	1.61	0.0085	1.57	0.0026	1.53	0.0003	1.52	0.0000	1.51	0.0000	1.51	0.0001	1.51	0.0001
	8	8	1.42	1.61	0.0362	1.57	0.0237	1.54	0.0147	1.53	0.0112	1.52	0.0094	1.51	0.0091	1.51	0.0089
	9	9	1.34	1.47	0.0162	1.42	0.0069	1.39	0.0021	1.37	0.0008	1.36	0.0003	1.36	0.0003	1.35	0.0002
	10	10	1.20	1.49	0.0848	1.33	0.0164	1.23	0.0013	1.20	0.0000	1.18	0.0004	1.18	0.0005	1.17	0.0006
Quadrant 1 (West Side)	11	11	1.06	1.46	0.1534	1.35	0.0820	1.27	0.0420	1.23	0.0289	1.21	0.0227	1.21	0.0217	1.21	0.0208
	12	12	1.19	1.49	0.0920	1.37	0.0322	1.28	0.0082	1.24	0.0028	1.22	0.0010	1.22	0.0008	1.21	0.0007
	13	13	0.90	1.49	0.3439	1.37	0.2199	1.28	0.1403	1.24	0.1112	1.21	0.0963	1.21	0.0940	1.21	0.0917
	14	14	0.99	1.40	0.1726	1.28	0.0866	1.18	0.0384	1.14	0.0234	1.12	0.0167	1.11	0.0157	1.11	0.0147
	15	15	0.94	1.41	0.2199	1.23	0.0878	1.10	0.0266	1.04	0.0114	1.01	0.0058	1.01	0.0050	1.00	0.0044
Quadrant 3 (East Side)	19	19	1.44	1.58	0.0198	1.46	0.0002	1.35	0.0080	1.31	0.0177	1.29	0.0248	1.28	0.0261	1.28	0.0274
	20	20	1.27	1.56	0.0839	1.37	0.0101	1.25	0.0005	1.20	0.0051	1.18	0.0096	1.17	0.0104	1.17	0.0113
	21	21	1.30	1.58	0.0815	1.46	0.0260	1.36	0.0034	1.31	0.0002	1.29	0.0001	1.28	0.0002	1.28	0.0004
Quadrant 2 (East Side)	22	22	1.43	1.59	0.0252	1.46	0.0008	1.35	0.0059	1.30	0.0151	1.28	0.0221	1.27	0.0234	1.27	0.0247
	24	24	1.46	1.59	0.0173	1.47	0.0003	1.38	0.0058	1.34	0.0138	1.32	0.0198	1.31	0.0209	1.31	0.0220
			SSR (West Side Only)		1.1339		0.5626		0.2772		0.1927		0.1552		0.1498		0.1446

Table 2 (2 of 4) Calibration of kw for west side of Study Area.

Inflow/Quadrant Number	Sample Site Number	Node Number in SynerGEE (July 2011 Model)	Average Chlorine Concentration (After Adjustment) on July 28, 2011 (mg/L)	Kw = 0.03		Kw = 0.031		Kw = 0.032		Kw = 0.035		Kw = 0.04		Kw = 0.042		Kw = 0.043	
				Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual
Inflow 1	1	28069	1.62	1.62	0.0000	1.62	0.0000	1.62	0.0000	1.62	0.0000	1.62	0.0000	1.62	0.0000	1.62	0.0000
Inflow 2	2	20139	1.36	1.36	0.0000	1.36	0.0000	1.36	0.0000	1.36	0.0000	1.36	0.0000	1.36	0.0000	1.36	0.0000
Inflow 3	3	28043	1.62	1.62	0.0000	1.62	0.0000	1.62	0.0000	1.62	0.0000	1.62	0.0000	1.62	0.0000	1.62	0.0000
Quadrant 4 (West Side)	4	4	1.29	1.34	0.0025	1.34	0.0024	1.34	0.0023	1.34	0.0021	1.33	0.0018	1.33	0.0017	1.33	0.0016
	5	5	1.61	1.60	0.0000	1.60	0.0000	1.60	0.0000	1.60	0.0000	1.60	0.0000	1.60	0.0000	1.60	0.0001
	6	6	1.52	1.50	0.0002	1.50	0.0002	1.50	0.0003	1.49	0.0007	1.48	0.0016	1.47	0.0020	1.47	0.0022
	8	8	1.42	1.51	0.0083	1.51	0.0078	1.50	0.0073	1.50	0.0060	1.48	0.0041	1.48	0.0034	1.48	0.0031
	9	9	1.34	1.35	0.0001	1.35	0.0001	1.34	0.0000	1.34	0.0000	1.32	0.0004	1.32	0.0006	1.31	0.0008
	10	10	1.20	1.17	0.0010	1.16	0.0014	1.16	0.0018	1.14	0.0035	1.11	0.0071	1.10	0.0088	1.10	0.0097
Quadrant 1 (West Side)	11	11	1.06	1.20	0.0191	1.20	0.0174	1.19	0.0159	1.17	0.0118	1.15	0.0066	1.14	0.0050	1.13	0.0043
	12	12	1.19	1.21	0.0004	1.20	0.0002	1.19	0.0000	1.17	0.0001	1.15	0.0016	1.14	0.0026	1.13	0.0032
	13	13	0.90	1.20	0.0873	1.19	0.0831	1.18	0.0791	1.16	0.0679	1.13	0.0520	1.12	0.0465	1.11	0.0440
	14	14	0.99	1.10	0.0129	1.09	0.0113	1.09	0.0098	1.07	0.0060	1.03	0.0019	1.02	0.0009	1.01	0.0006
	15	15	0.94	0.99	0.0032	0.98	0.0022	0.97	0.0014	0.95	0.0001	0.91	0.0010	0.89	0.0022	0.88	0.0029
Quadrant 3 (East Side)	19	19	1.44	1.27	0.0300	1.26	0.0327	1.26	0.0355	1.23	0.0441	1.20	0.0596	1.19	0.0660	1.18	0.0693
	20	20	1.27	1.16	0.0131	1.15	0.0150	1.14	0.0170	1.12	0.0235	1.09	0.0353	1.07	0.0404	1.07	0.0430
	21	21	1.30	1.27	0.0008	1.26	0.0013	1.25	0.0019	1.23	0.0043	1.20	0.0102	1.18	0.0131	1.18	0.0146
Quadrant 2 (East Side)	22	22	1.43	1.26	0.0273	1.25	0.0301	1.25	0.0329	1.22	0.0419	1.19	0.0582	1.17	0.0651	1.17	0.0687
	24	24	1.46	1.30	0.0243	1.29	0.0267	1.29	0.0291	1.26	0.0368	1.23	0.0509	1.22	0.0569	1.21	0.0599
			SSR (West Side Only)		0.1349		0.1261		0.1180		0.0982		0.0780		0.0739		0.0725

Table 2 (3 of 4) Calibration of kw for west side of Study Area.

Inflow/Quadrant Number	Sample Site Number	Node Number in SynerGEE (July 2011 Model)	Average Chlorine Concentration (After Adjustment) on July 28, 2011 (mg/L)	Kw = 0.044		Kw = 0.0445		Kw = 0.045		Kw = 0.0452		Kw = 0.0453		Kw = 0.0454		Kw = 0.0455	
				Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual
Inflow 1	1	28069	1.62	1.62	0.0000	1.62	0.0000	1.62	0.0000	1.62	0.0000	1.62	0.0000	1.62	0.0000	1.62	0.0000
Inflow 2	2	20139	1.36	1.36	0.0000	1.36	0.0000	1.36	0.0000	1.36	0.0000	1.36	0.0000	1.36	0.0000	1.36	0.0000
Inflow 3	3	28043	1.62	1.62	0.0000	1.62	0.0000	1.62	0.0000	1.62	0.0000	1.62	0.0000	1.62	0.0000	1.62	0.0000
Quadrant 4 (West Side)	4	4	1.29	1.33	0.0016	1.33	0.0015	1.33	0.0015	1.33	0.0015	1.33	0.0015	1.33	0.0015	1.33	0.0015
	5	5	1.61	1.60	0.0001	1.60	0.0001	1.60	0.0001	1.60	0.0001	1.60	0.0001	1.60	0.0001	1.60	0.0001
	6	6	1.52	1.47	0.0025	1.46	0.0026	1.46	0.0027	1.46	0.0028	1.46	0.0028	1.46	0.0028	1.46	0.0029
	8	8	1.42	1.47	0.0029	1.47	0.0027	1.47	0.0026	1.47	0.0025	1.47	0.0025	1.47	0.0025	1.47	0.0025
	9	9	1.34	1.31	0.0009	1.31	0.0010	1.31	0.0011	1.31	0.0011	1.31	0.0012	1.31	0.0012	1.31	0.0012
	10	10	1.20	1.10	0.0107	1.09	0.0111	1.09	0.0116	1.09	0.0118	1.09	0.0119	1.09	0.0120	1.09	0.0121
Quadrant 1 (West Side)	11	11	1.06	1.13	0.0037	1.12	0.0034	1.12	0.0031	1.12	0.0030	1.12	0.0030	1.12	0.0029	1.12	0.0029
	12	12	1.19	1.12	0.0038	1.12	0.0041	1.12	0.0044	1.12	0.0046	1.12	0.0046	1.12	0.0047	1.12	0.0048
	13	13	0.90	1.11	0.0415	1.10	0.0403	1.10	0.0391	1.10	0.0387	1.10	0.0384	1.10	0.0382	1.10	0.0380
	14	14	0.99	1.01	0.0003	1.00	0.0002	1.00	0.0002	1.00	0.0001	1.00	0.0001	1.00	0.0001	1.00	0.0001
	15	15	0.94	0.88	0.0038	0.87	0.0043	0.87	0.0048	0.87	0.0050	0.87	0.0051	0.87	0.0052	0.86	0.0053
Quadrant 3 (East Side)	19	19	1.44	1.17	0.0726	1.17	0.0743	1.17	0.0759	1.17	0.0766	1.17	0.0769	1.17	0.0773	1.17	0.0776
	20	20	1.27	1.06	0.0456	1.06	0.0470	1.05	0.0483	1.05	0.0488	1.05	0.0491	1.05	0.0494	1.05	0.0496
	21	21	1.30	1.17	0.0163	1.17	0.0171	1.16	0.0179	1.16	0.0183	1.16	0.0184	1.16	0.0186	1.16	0.0188
Quadrant 2 (East Side)	22	22	1.43	1.16	0.0722	1.16	0.0740	1.15	0.0759	1.15	0.0766	1.15	0.0770	1.15	0.0773	1.15	0.0777
	24	24	1.46	1.21	0.0630	1.20	0.0646	1.20	0.0662	1.20	0.0668	1.20	0.0671	1.20	0.0674	1.20	0.0677
			SSR (West Side Only)		0.0716		0.0714		0.0712		0.0712		0.0711480		0.0711402		0.0711369

Table 2 (4 of 4) Calibration of kw for west side of Study Area.

Inflow/Quadrant Number	Sample Site Number	Node Number in SynerGEE (July 2011 Model)	Average Chlorine Concentration (After Adjustment) on July 28, 2011 (mg/L)	Kw = 0.0456		Kw = 0.0457		Kw = 0.0458		Kw = 0.046		Kw = 0.047		Kw = 0.05		Kw = 0.055		Kw = 0.06	
				Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual
Inflow 1	1	28069	1.62	1.62	0.0000	1.62	0.0000	1.62	0.0000	1.62	0.0000	1.62	0.0000	1.62	0.0000	1.62	0.0000	1.62	0.0000
Inflow 2	2	20139	1.36	1.36	0.0000	1.36	0.0000	1.36	0.0000	1.36	0.0000	1.36	0.0000	1.36	0.0000	1.36	0.0000	1.36	0.0000
Inflow 3	3	28043	1.62	1.62	0.0000	1.62	0.0000	1.62	0.0000	1.62	0.0000	1.62	0.0000	1.62	0.0000	1.62	0.0000	1.62	0.0000
Quadrant 4 (West Side)	4	4	1.29	1.33	0.0015	1.33	0.0015	1.33	0.0015	1.33	0.0014	1.33	0.0014	1.33	0.0012	1.32	0.0010	1.32	0.0008
	5	5	1.61	1.60	0.0001	1.60	0.0001	1.60	0.0001	1.60	0.0001	1.60	0.0001	1.60	0.0001	1.59	0.0001	1.59	0.0002
	6	6	1.52	1.46	0.0029	1.46	0.0029	1.46	0.0029	1.46	0.0030	1.46	0.0033	1.45	0.0041	1.44	0.0057	1.43	0.0076
	8	8	1.42	1.47	0.0024	1.47	0.0024	1.47	0.0024	1.47	0.0023	1.47	0.0021	1.46	0.0015	1.45	0.0007	1.43	0.0002
	9	9	1.34	1.30	0.0012	1.30	0.0012	1.30	0.0013	1.30	0.0013	1.30	0.0015	1.29	0.0022	1.28	0.0036	1.27	0.0052
	10	10	1.20	1.09	0.0122	1.09	0.0123	1.09	0.0124	1.09	0.0126	1.08	0.0136	1.07	0.0167	1.05	0.0223	1.03	0.0283
Quadrant 1 (West Side)	11	11	1.06	1.12	0.0028	1.12	0.0028	1.12	0.0027	1.12	0.0026	1.11	0.0021	1.10	0.0010	1.07	0.0001	1.05	0.0001
	12	12	1.19	1.12	0.0048	1.12	0.0049	1.12	0.0050	1.11	0.0051	1.11	0.0059	1.10	0.0083	1.07	0.0130	1.05	0.0184
	13	13	0.90	1.10	0.0378	1.10	0.0375	1.10	0.0373	1.10	0.0369	1.09	0.0347	1.07	0.0288	1.05	0.0205	1.02	0.0140
	14	14	0.99	1.00	0.0001	1.00	0.0001	1.00	0.0001	0.99	0.0000	0.99	0.0000	0.97	0.0003	0.94	0.0019	0.92	0.0048
	15	15	0.94	0.86	0.0054	0.86	0.0055	0.86	0.0056	0.86	0.0058	0.85	0.0069	0.83	0.0108	0.80	0.0185	0.77	0.0274
Quadrant 3 (East Side)	19	19	1.44	1.16	0.0779	1.16	0.0783	1.16	0.0786	1.16	0.0793	1.16	0.0827	1.14	0.0929	1.11	0.1103	1.09	0.1279
	20	20	1.27	1.05	0.0499	1.05	0.0502	1.05	0.0504	1.05	0.0510	1.04	0.0537	1.02	0.0619	1.00	0.0760	0.97	0.0903
	21	21	1.30	1.16	0.0190	1.16	0.0191	1.16	0.0193	1.16	0.0196	1.15	0.0214	1.13	0.0271	1.11	0.0373	1.08	0.0483
Quadrant 2 (East Side)	22	22	1.43	1.15	0.0780	1.15	0.0784	1.15	0.0788	1.15	0.0795	1.14	0.0832	1.12	0.0944	1.09	0.1137	1.06	0.1334
	24	24	1.46	1.20	0.0681	1.20	0.0684	1.19	0.0687	1.19	0.0693	1.19	0.0725	1.17	0.0823	1.14	0.0992	1.12	0.1166
			SSR (West Side Only)		0.0711377		0.0711426		0.0712		0.0712		0.0716		0.0750		0.0875		0.1070

Table 3 (1 of 4) Calibration of kw for east side of Study Area.

Inflow/Quadrant Number	Sample Site Number	Node Number in SynerGEE (July 2011 Model)	Average Chlorine Concentration (After Adjustment) on July 28, 2011 (mg/L)	Kw = 0		Kw = 0.01		Kw = 0.012		Kw = 0.014		Kw = 0.015		Kw = 0.0155		Kw = 0.0156	
				Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual
Inflow 1	1	1	1.62	1.62	0.0000	1.62	0.0000	1.62	0.0000	1.62	0.0000	1.62	0.0000	1.62	0.0000	1.62	0.0000
Inflow 2	2	2	1.36	1.36	0.0000	1.36	0.0000	1.36	0.0000	1.36	0.0000	1.36	0.0000	1.36	0.0000	1.36	0.0000
Inflow 3	3	3	1.62	1.62	0.0000	1.62	0.0000	1.62	0.0000	1.62	0.0000	1.62	0.0000	1.62	0.0000	1.62	0.0000
Quadrant 4 (West Side)	4	4	1.29	1.37	0.0061	1.36	0.0045	1.36	0.0042	1.35	0.0040	1.35	0.0039	1.35	0.0038	1.35	0.0038
	5	5	1.61	1.62	0.0002	1.61	0.0001	1.61	0.0000	1.61	0.0000	1.61	0.0000	1.61	0.0000	1.61	0.0000
	6	6	1.52	1.61	0.0085	1.57	0.0026	1.56	0.0019	1.55	0.0014	1.55	0.0011	1.55	0.0010	1.55	0.0010
	8	8	1.42	1.61	0.0362	1.57	0.0237	1.57	0.0217	1.56	0.0198	1.56	0.0188	1.55	0.0184	1.55	0.0183
	9	9	1.34	1.47	0.0162	1.42	0.0069	1.42	0.0057	1.41	0.0046	1.40	0.0041	1.40	0.0038	1.40	0.0038
	10	10	1.20	1.49	0.0848	1.33	0.0164	1.30	0.0113	1.29	0.0075	1.28	0.0060	1.27	0.0053	1.27	0.0052
Quadrant 1 (West Side)	11	11	1.06	1.46	0.1534	1.35	0.0820	1.33	0.0721	1.32	0.0633	1.31	0.0593	1.30	0.0573	1.30	0.0569
	12	12	1.19	1.49	0.0920	1.37	0.0322	1.35	0.0255	1.33	0.0199	1.32	0.0174	1.31	0.0163	1.31	0.0161
	13	13	0.90	1.49	0.3439	1.37	0.2199	1.35	0.2012	1.33	0.1840	1.32	0.1760	1.32	0.1721	1.32	0.1713
	14	14	0.99	1.40	0.1726	1.28	0.0866	1.26	0.0746	1.24	0.0639	1.23	0.0590	1.23	0.0566	1.23	0.0562
	15	15	0.94	1.41	0.2199	1.23	0.0878	1.20	0.0713	1.18	0.0572	1.16	0.0510	1.16	0.0480	1.16	0.0475
Quadrant 3 (East Side)	19	19	1.44	1.58	0.0198	1.46	0.0002	1.43	0.0001	1.41	0.0009	1.40	0.0017	1.40	0.0021	1.40	0.0022
	20	20	1.27	1.56	0.0839	1.37	0.0101	1.35	0.0052	1.32	0.0021	1.31	0.0011	1.30	0.0008	1.30	0.0007
	21	21	1.30	1.58	0.0815	1.46	0.0260	1.44	0.0194	1.42	0.0139	1.41	0.0116	1.40	0.0105	1.40	0.0103
Quadrant 2 (East Side)	22	22	1.43	1.59	0.0252	1.46	0.0008	1.43	0.0000	1.41	0.0002	1.40	0.0007	1.40	0.0010	1.39	0.0011
	24	24	1.46	1.59	0.0173	1.47	0.0003	1.45	0.0000	1.43	0.0005	1.43	0.0010	1.42	0.0013	1.42	0.0013
			SSR (East Side Only)		0.2276		0.0373		0.0247		0.0177		0.0160		0.0156		0.0156

Table 3 (2 of 4) Calibration of kw for east side of Study Area.

Inflow/Quadrant Number	Sample Site Number	Node Number in SynerGEE (July 2011 Model)	Average Chlorine Concentration (After Adjustment) on July 28, 2011 (mg/L)	Kw = 0.0157		Kw = 0.0158		Kw = 0.0159		Kw = 0.016		Kw = 0.0161		Kw = 0.0162		Kw = 0.0165	
				Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual
Inflow 1	1	1	1.62	1.62	0.0000	1.62	0.0000	1.62	0.0000	1.62	0.0000	1.62	0.0000	1.62	0.0000	1.62	0.0000
Inflow 2	2	2	1.36	1.36	0.0000	1.36	0.0000	1.36	0.0000	1.36	0.0000	1.36	0.0000	1.36	0.0000	1.36	0.0000
Inflow 3	3	3	1.62	1.62	0.0000	1.62	0.0000	1.62	0.0000	1.62	0.0000	1.62	0.0000	1.62	0.0000	1.62	0.0000
Quadrant 4 (West Side)	4	4	1.29	1.35	0.0038	1.35	0.0038	1.35	0.0038	1.35	0.0038	1.35	0.0038	1.35	0.0037	1.35	0.0037
	5	5	1.61	1.61	0.0000	1.61	0.0000	1.61	0.0000	1.61	0.0000	1.61	0.0000	1.61	0.0000	1.61	0.0000
	6	6	1.52	1.55	0.0010	1.55	0.0010	1.55	0.0009	1.55	0.0009	1.55	0.0009	1.55	0.0009	1.54	0.0008
	8	8	1.42	1.55	0.0182	1.55	0.0181	1.55	0.0180	1.55	0.0179	1.55	0.0179	1.55	0.0178	1.55	0.0175
	9	9	1.34	1.40	0.0037	1.40	0.0037	1.40	0.0036	1.40	0.0036	1.40	0.0036	1.40	0.0035	1.40	0.0034
	10	10	1.20	1.27	0.0051	1.27	0.0049	1.27	0.0048	1.27	0.0047	1.27	0.0046	1.27	0.0045	1.26	0.0041
Quadrant 1 (West Side)	11	11	1.06	1.30	0.0566	1.30	0.0562	1.30	0.0558	1.30	0.0554	1.30	0.0551	1.30	0.0547	1.30	0.0536
	12	12	1.19	1.31	0.0158	1.31	0.0156	1.31	0.0154	1.31	0.0152	1.31	0.0150	1.31	0.0148	1.31	0.0142
	13	13	0.90	1.32	0.1705	1.32	0.1697	1.31	0.1690	1.31	0.1682	1.31	0.1675	1.31	0.1667	1.31	0.1645
	14	14	0.99	1.22	0.0557	1.22	0.0553	1.22	0.0548	1.22	0.0544	1.22	0.0539	1.22	0.0535	1.22	0.0521
	15	15	0.94	1.15	0.0469	1.15	0.0463	1.15	0.0458	1.15	0.0452	1.15	0.0447	1.15	0.0441	1.14	0.0425
Quadrant 3 (East Side)	19	19	1.44	1.40	0.0023	1.40	0.0024	1.39	0.0025	1.39	0.0026	1.39	0.0027	1.39	0.0028	1.39	0.0031
	20	20	1.27	1.30	0.0006	1.30	0.0006	1.30	0.0005	1.30	0.0005	1.29	0.0004	1.29	0.0004	1.29	0.0003
	21	21	1.30	1.40	0.0101	1.40	0.0099	1.40	0.0097	1.40	0.0095	1.39	0.0093	1.39	0.0091	1.39	0.0085
Quadrant 2 (East Side)	22	22	1.43	1.39	0.0011	1.39	0.0012	1.39	0.0013	1.39	0.0014	1.39	0.0014	1.39	0.0015	1.39	0.0018
	24	24	1.46	1.42	0.0014	1.42	0.0015	1.42	0.0016	1.42	0.0016	1.42	0.0017	1.41	0.0018	1.41	0.0020
			SSR (East Side Only)		0.0156		0.0155404		0.0155290		0.0155282		0.0155381		0.0156		0.0157

Table 3 (3 of 4) Calibration of kw for east side of Study Area.

Inflow/Quadrant Number	Sample Site Number	Node Number in SynerGEE (July 2011 Model)	Average Chlorine Concentration (After Adjustment) on July 28, 2011 (mg/L)	Kw = 0.017		Kw = 0.02		Kw = 0.021		Kw = 0.025		Kw = 0.028		Kw = 0.0285		Kw = 0.029	
				Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual
Inflow 1	1	1	1.62	1.62	0.0000	1.62	0.0000	1.62	0.0000	1.62	0.0000	1.62	0.0000	1.62	0.0000	1.62	0.0000
Inflow 2	2	2	1.36	1.36	0.0000	1.36	0.0000	1.36	0.0000	1.36	0.0000	1.36	0.0000	1.36	0.0000	1.36	0.0000
Inflow 3	3	3	1.62	1.62	0.0000	1.62	0.0000	1.62	0.0000	1.62	0.0000	1.62	0.0000	1.62	0.0000	1.62	0.0000
Quadrant 4 (West Side)	4	4	1.29	1.35	0.0037	1.35	0.0034	1.35	0.0033	1.34	0.0029	1.34	0.0026	1.34	0.0026	1.34	0.0026
	5	5	1.61	1.61	0.0000	1.61	0.0000	1.61	0.0000	1.61	0.0000	1.60	0.0000	1.60	0.0000	1.60	0.0000
	6	6	1.52	1.54	0.0007	1.53	0.0003	1.53	0.0002	1.52	0.0000	1.51	0.0000	1.51	0.0001	1.51	0.0001
	8	8	1.42	1.55	0.0171	1.54	0.0147	1.54	0.0139	1.53	0.0112	1.52	0.0094	1.51	0.0091	1.51	0.0089
	9	9	1.34	1.40	0.0032	1.39	0.0021	1.38	0.0017	1.37	0.0008	1.36	0.0003	1.36	0.0003	1.35	0.0002
	10	10	1.20	1.26	0.0036	1.23	0.0013	1.23	0.0008	1.20	0.0000	1.18	0.0004	1.18	0.0005	1.17	0.0006
Quadrant 1 (West Side)	11	11	1.06	1.29	0.0518	1.27	0.0420	1.26	0.0391	1.23	0.0289	1.21	0.0227	1.21	0.0217	1.21	0.0208
	12	12	1.19	1.30	0.0132	1.28	0.0082	1.27	0.0068	1.24	0.0028	1.22	0.0010	1.22	0.0008	1.21	0.0007
	13	13	0.90	1.30	0.1608	1.28	0.1403	1.27	0.1340	1.24	0.1112	1.21	0.0963	1.21	0.0940	1.21	0.0917
	14	14	0.99	1.21	0.0500	1.18	0.0384	1.18	0.0350	1.14	0.0234	1.12	0.0167	1.11	0.0157	1.11	0.0147
	15	15	0.94	1.14	0.0399	1.10	0.0266	1.09	0.0229	1.04	0.0114	1.01	0.0058	1.01	0.0050	1.00	0.0044
Quadrant 3 (East Side)	19	19	1.44	1.38	0.0037	1.35	0.0080	1.35	0.0097	1.31	0.0177	1.29	0.0248	1.28	0.0261	1.28	0.0274
	20	20	1.27	1.28	0.0001	1.25	0.0005	1.24	0.0011	1.20	0.0051	1.18	0.0096	1.17	0.0104	1.17	0.0113
	21	21	1.30	1.39	0.0076	1.36	0.0034	1.35	0.0024	1.31	0.0002	1.29	0.0001	1.28	0.0002	1.28	0.0004
Quadrant 2 (East Side)	22	22	1.43	1.38	0.0022	1.35	0.0059	1.34	0.0074	1.30	0.0151	1.28	0.0221	1.27	0.0234	1.27	0.0247
	24	24	1.46	1.41	0.0024	1.38	0.0058	1.37	0.0071	1.34	0.0138	1.32	0.0198	1.31	0.0209	1.31	0.0220
			SSR (East Side Only)		0.0161		0.0235		0.0277		0.0519		0.0765		0.0811		0.0858

Table 3 (4 of 4) Calibration of kw for east side of Study Area.

Inflow/Quadrant Number	Sample Site Number	Node Number in SynerGEE (July 2011 Model)	Average Chlorine Concentration (After Adjustment) on July 28, 2011 (mg/L)	Kw = 0.03		Kw = 0.031		Kw = 0.032		Kw = 0.035		Kw = 0.04		Kw = 0.05	
				Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual
Inflow 1	1	1	1.62	1.62	0.0000	1.62	0.0000	1.62	0.0000	1.62	0.0000	1.62	0.0000	1.62	0.0000
Inflow 2	2	2	1.36	1.36	0.0000	1.36	0.0000	1.36	0.0000	1.36	0.0000	1.36	0.0000	1.36	0.0000
Inflow 3	3	3	1.62	1.62	0.0000	1.62	0.0000	1.62	0.0000	1.62	0.0000	1.62	0.0000	1.62	0.0000
Quadrant 4 (West Side)	4	4	1.29	1.34	0.0025	1.34	0.0024	1.34	0.0023	1.34	0.0021	1.33	0.0018	1.33	0.0012
	5	5	1.61	1.60	0.0000	1.60	0.0000	1.60	0.0000	1.60	0.0000	1.60	0.0000	1.60	0.0001
	6	6	1.52	1.50	0.0002	1.50	0.0002	1.50	0.0003	1.49	0.0007	1.48	0.0016	1.45	0.0041
	8	8	1.42	1.51	0.0083	1.51	0.0078	1.50	0.0073	1.50	0.0060	1.48	0.0041	1.46	0.0015
	9	9	1.34	1.35	0.0001	1.35	0.0001	1.34	0.0000	1.34	0.0000	1.32	0.0004	1.29	0.0022
	10	10	1.20	1.17	0.0010	1.16	0.0014	1.16	0.0018	1.14	0.0035	1.11	0.0071	1.07	0.0167
Quadrant 1 (West Side)	11	11	1.06	1.20	0.0191	1.20	0.0174	1.19	0.0159	1.17	0.0118	1.15	0.0066	1.10	0.0010
	12	12	1.19	1.21	0.0004	1.20	0.0002	1.19	0.0000	1.17	0.0001	1.15	0.0016	1.10	0.0083
	13	13	0.90	1.20	0.0873	1.19	0.0831	1.18	0.0791	1.16	0.0679	1.13	0.0520	1.07	0.0288
	14	14	0.99	1.10	0.0129	1.09	0.0113	1.09	0.0098	1.07	0.0060	1.03	0.0019	0.97	0.0003
	15	15	0.94	0.99	0.0032	0.98	0.0022	0.97	0.0014	0.95	0.0001	0.91	0.0010	0.83	0.0108
Quadrant 3 (East Side)	19	19	1.44	1.27	0.0300	1.26	0.0327	1.26	0.0355	1.23	0.0441	1.20	0.0596	1.14	0.0929
	20	20	1.27	1.16	0.0131	1.15	0.0150	1.14	0.0170	1.12	0.0235	1.09	0.0353	1.02	0.0619
	21	21	1.30	1.27	0.0008	1.26	0.0013	1.25	0.0019	1.23	0.0043	1.20	0.0102	1.13	0.0271
Quadrant 2 (East Side)	22	22	1.43	1.26	0.0273	1.25	0.0301	1.25	0.0329	1.22	0.0419	1.19	0.0582	1.12	0.0944
	24	24	1.46	1.30	0.0243	1.29	0.0267	1.29	0.0291	1.26	0.0368	1.23	0.0509	1.17	0.0823
			SSR (East Side Only)		0.0955		0.1058		0.1164		0.1506		0.2143		0.3587

Table 4 (1 of 3) Calibration of global kw for no bulk decay.

Inflow/Quadrant Number	Sample Site Number	Node Number in SynerGEE (July 2011 Model)	Average Chlorine Concentration (After Adjustment) on July 28, 2011 (mg/L)	Kw = 0		Kw = 0.01		Kw = 0.02		Kw = 0.025		Kw = 0.027		Kw = 0.03		Kw = 0.032	
				Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual
Inflow 1	1	1	1.62	1.62	0.0000	1.62	0.0000	1.62	0.0000	1.62	0.0000	1.62	0.0000	1.62	0.0000	1.62	0.0000
Inflow 2	2	2	1.36	1.36	0.0000	1.36	0.0000	1.36	0.0000	1.36	0.0000	1.36	0.0000	1.36	0.0000	1.36	0.0000
Inflow 3	3	3	1.62	1.62	0.0000	1.62	0.0000	1.62	0.0000	1.62	0.0000	1.62	0.0000	1.62	0.0000	1.62	0.0000
Quadrant 4 (West Side)	4	4	1.29	1.37	0.0066	1.36	0.0049	1.35	0.0037	1.35	0.0032	1.35	0.0030	1.34	0.0028	1.34	0.0026
	5	5	1.61	1.62	0.0002	1.62	0.0001	1.61	0.0000	1.61	0.0000	1.61	0.0000	1.61	0.0000	1.61	0.0000
	6	6	1.52	1.62	0.0109	1.58	0.0040	1.54	0.0008	1.53	0.0002	1.52	0.0001	1.51	0.0000	1.51	0.0000
	8	8	1.42	1.62	0.0403	1.58	0.0270	1.55	0.0172	1.54	0.0134	1.53	0.0121	1.52	0.0102	1.51	0.0091
	9	9	1.34	1.48	0.0197	1.44	0.0092	1.40	0.0033	1.38	0.0016	1.37	0.0011	1.36	0.0005	1.36	0.0003
	10	10	1.20	1.51	0.0995	1.35	0.0222	1.25	0.0031	1.22	0.0004	1.20	0.0000	1.19	0.0002	1.17	0.0006
Quadrant 1 (West Side)	11	11	1.06	1.48	0.1735	1.37	0.0956	1.29	0.0513	1.26	0.0364	1.24	0.0315	1.22	0.0251	1.21	0.0213
	12	12	1.19	1.51	0.1072	1.39	0.0405	1.30	0.0122	1.26	0.0053	1.24	0.0034	1.22	0.0015	1.21	0.0006
	13	13	0.90	1.51	0.3729	1.39	0.2409	1.30	0.1558	1.26	0.1246	1.24	0.1137	1.22	0.0988	1.20	0.0899
	14	14	0.99	1.43	0.1972	1.31	0.1027	1.21	0.0484	1.16	0.0310	1.15	0.0255	1.12	0.0185	1.11	0.0146
	15	15	0.94	1.45	0.2609	1.27	0.1107	1.13	0.0382	1.08	0.0190	1.05	0.0135	1.02	0.0073	1.00	0.0044
Quadrant 3 (East Side)	19	19	1.44	1.62	0.0309	1.49	0.0020	1.39	0.0035	1.34	0.0108	1.32	0.0146	1.30	0.0210	1.28	0.0257
	20	20	1.27	1.62	0.1201	1.42	0.0225	1.30	0.0005	1.25	0.0008	1.23	0.0022	1.20	0.0053	1.18	0.0080
	21	21	1.30	1.62	0.1036	1.49	0.0379	1.39	0.0081	1.34	0.0019	1.32	0.0007	1.30	0.0000	1.28	0.0002
Quadrant 2 (East Side)	22	22	1.43	1.62	0.0372	1.49	0.0035	1.38	0.0024	1.33	0.0092	1.31	0.0129	1.29	0.0194	1.27	0.0243
	24	24	1.46	1.62	0.0266	1.50	0.0022	1.41	0.0024	1.37	0.0084	1.35	0.0116	1.33	0.0171	1.31	0.0213
			SSR (All Sites)		1.6075		0.7259		0.3509		0.2661		0.2458		0.2277		0.2229

Table 4 (2 of 3) Calibration of global kw for no bulk decay.

Inflow/Quadrant Number	Sample Site Number	Node Number in SynerGEE (July 2011 Model)	Average Chlorine Concentration (After Adjustment) on July 28, 2011 (mg/L)	Kw = 0.0325		Kw = 0.0326		Kw = 0.0327		Kw = 0.0328		Kw = 0.0329		Kw = 0.033		Kw = 0.0331	
				Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual
Inflow 1	1	1	1.62	1.62	0.0000	1.62	0.0000	1.62	0.0000	1.62	0.0000	1.62	0.0000	1.62	0.0000	1.62	0.0000
Inflow 2	2	2	1.36	1.36	0.0000	1.36	0.0000	1.36	0.0000	1.36	0.0000	1.36	0.0000	1.36	0.0000	1.36	0.0000
Inflow 3	3	3	1.62	1.62	0.0000	1.62	0.0000	1.62	0.0000	1.62	0.0000	1.62	0.0000	1.62	0.0000	1.62	0.0000
Quadrant 4 (West Side)	4	4	1.29	1.34	0.0026	1.34	0.0026	1.34	0.0026	1.34	0.0026	1.34	0.0025	1.34	0.0025	1.34	0.0025
	5	5	1.61	1.60	0.0000	1.60	0.0000	1.60	0.0000	1.60	0.0000	1.60	0.0000	1.60	0.0000	1.60	0.0000
	6	6	1.52	1.51	0.0001	1.51	0.0001	1.51	0.0001	1.51	0.0001	1.51	0.0001	1.51	0.0001	1.51	0.0001
	8	8	1.42	1.51	0.0088	1.51	0.0088	1.51	0.0087	1.51	0.0087	1.51	0.0086	1.51	0.0086	1.51	0.0085
	9	9	1.34	1.36	0.0002	1.35	0.0002	1.35	0.0002	1.35	0.0002	1.35	0.0002	1.35	0.0002	1.35	0.0002
	10	10	1.20	1.17	0.0007	1.17	0.0008	1.17	0.0008	1.17	0.0008	1.17	0.0009	1.17	0.0009	1.17	0.0009
Quadrant 1 (West Side)	11	11	1.06	1.21	0.0205	1.21	0.0203	1.21	0.0201	1.21	0.0199	1.20	0.0198	1.20	0.0196	1.20	0.0194
	12	12	1.19	1.21	0.0005	1.21	0.0005	1.21	0.0004	1.21	0.0004	1.21	0.0004	1.21	0.0004	1.20	0.0003
	13	13	0.90	1.20	0.0878	1.20	0.0873	1.20	0.0869	1.20	0.0865	1.20	0.0861	1.20	0.0857	1.20	0.0853
	14	14	0.99	1.11	0.0137	1.10	0.0135	1.10	0.0133	1.10	0.0132	1.10	0.0130	1.10	0.0128	1.10	0.0127
	15	15	0.94	1.00	0.0038	1.00	0.0037	1.00	0.0035	1.00	0.0034	1.00	0.0033	0.99	0.0032	0.99	0.0031
Quadrant 3 (East Side)	19	19	1.44	1.28	0.0270	1.28	0.0272	1.28	0.0275	1.28	0.0277	1.28	0.0280	1.28	0.0282	1.28	0.0285
	20	20	1.27	1.18	0.0087	1.18	0.0089	1.18	0.0090	1.18	0.0092	1.18	0.0093	1.18	0.0095	1.18	0.0096
	21	21	1.30	1.28	0.0003	1.28	0.0004	1.28	0.0004	1.28	0.0004	1.28	0.0005	1.28	0.0005	1.28	0.0005
Quadrant 2 (East Side)	22	22	1.43	1.27	0.0256	1.27	0.0258	1.27	0.0261	1.26	0.0263	1.26	0.0266	1.26	0.0269	1.26	0.0271
	24	24	1.46	1.31	0.0224	1.31	0.0226	1.31	0.0228	1.30	0.0230	1.30	0.0232	1.30	0.0235	1.30	0.0237
			SSR (All Sites)		0.2226		0.2225328		0.2225091		0.2224970		0.2224980		0.2225115		0.2225365

Table 4 (3 of 3) Calibration of global kw for no bulk decay.

Inflow/Quadrant Number	Sample Site Number	Node Number in SynerGEE (July 2011 Model)	Average Chlorine Concentration (After Adjustment) on July 28, 2011 (mg/L)	Kw = 0.0332		Kw = 0.0335		Kw = 0.034		Kw = 0.035		Kw = 0.037		Kw = 0.04		Kw = 0.05	
				Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual	Simulated Chlorine Concentration (mg/L)	Squared Residual
Inflow 1	1	1	1.62	1.62	0.0000	1.62	0.0000	1.62	0.0000	1.62	0.0000	1.62	0.0000	1.62	0.0000	1.62	0.0000
Inflow 2	2	2	1.36	1.36	0.0000	1.36	0.0000	1.36	0.0000	1.36	0.0000	1.36	0.0000	1.36	0.0000	1.36	0.0000
Inflow 3	3	3	1.62	1.62	0.0000	1.62	0.0000	1.62	0.0000	1.62	0.0000	1.62	0.0000	1.62	0.0000	1.62	0.0000
Quadrant 4 (West Side)	4	4	1.29	1.34	0.0025	1.34	0.0025	1.34	0.0025	1.34	0.0024	1.34	0.0022	1.34	0.0020	1.33	0.0014
	5	5	1.61	1.60	0.0000	1.60	0.0000	1.60	0.0000	1.60	0.0000	1.60	0.0000	1.60	0.0000	1.60	0.0001
	6	6	1.52	1.51	0.0001	1.50	0.0001	1.50	0.0002	1.50	0.0002	1.50	0.0004	1.49	0.0008	1.46	0.0028
	8	8	1.42	1.51	0.0085	1.51	0.0083	1.51	0.0081	1.51	0.0076	1.50	0.0066	1.49	0.0054	1.47	0.0023
	9	9	1.34	1.35	0.0002	1.35	0.0001	1.35	0.0001	1.35	0.0001	1.34	0.0000	1.33	0.0001	1.30	0.0013
	10	10	1.20	1.17	0.0010	1.17	0.0011	1.16	0.0013	1.16	0.0017	1.15	0.0027	1.13	0.0045	1.09	0.0127
Quadrant 1 (West Side)	11	11	1.06	1.20	0.0193	1.20	0.0188	1.20	0.0180	1.19	0.0165	1.18	0.0137	1.16	0.0101	1.11	0.0026
	12	12	1.19	1.20	0.0003	1.20	0.0003	1.20	0.0002	1.19	0.0000	1.18	0.0000	1.16	0.0005	1.11	0.0055
	13	13	0.90	1.19	0.0849	1.19	0.0836	1.19	0.0816	1.18	0.0777	1.17	0.0704	1.15	0.0604	1.09	0.0347
	14	14	0.99	1.10	0.0125	1.10	0.0120	1.09	0.0112	1.09	0.0098	1.07	0.0072	1.05	0.0041	0.99	0.0000
	15	15	0.94	0.99	0.0030	0.99	0.0027	0.98	0.0023	0.98	0.0015	0.96	0.0004	0.93	0.0000	0.86	0.0063
Quadrant 3 (East Side)	19	19	1.44	1.27	0.0287	1.27	0.0295	1.27	0.0308	1.26	0.0334	1.25	0.0388	1.23	0.0473	1.16	0.0782
	20	20	1.27	1.17	0.0098	1.17	0.0102	1.17	0.0110	1.16	0.0127	1.15	0.0163	1.12	0.0222	1.06	0.0449
	21	21	1.30	1.27	0.0006	1.27	0.0007	1.27	0.0009	1.26	0.0014	1.25	0.0027	1.22	0.0054	1.16	0.0192
Quadrant 2 (East Side)	22	22	1.43	1.26	0.0274	1.26	0.0282	1.26	0.0295	1.25	0.0323	1.23	0.0380	1.21	0.0472	1.14	0.0811
	24	24	1.46	1.30	0.0239	1.30	0.0246	1.30	0.0257	1.29	0.0281	1.27	0.0330	1.25	0.0408	1.19	0.0701
			SSR (All Sites)		0.2226		0.2228		0.2233		0.2253		0.2325		0.2508		0.3630