EVALUATION OF THE APPLICATION UNIFORMITY OF SUBSURFACE DRIP DISTRIBUTION SYSTEMS

A Thesis

by

VANCE LEO WEYNAND

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

May 2004

Major Subject: Biological and Agricultural Engineering

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Approved as to style and content by:

Bruce J. Lesikar (Chair of Committee)	Sam E. Feagley (Member)
Ann L. Kenimer (Member)	Gerald L. Riskowski (Head of Department)

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ABSTRACT

Evaluation of Application Uniformity of Subsurface Drip

Distribution Systems. (May 2004)

Vance Leo Weynand, B.S, Texas A&M University

Chair of Advisory Committee: Dr. Bruce J. Lesikar

The goal of this research was to evaluate the application uniformity of subsurface drip distribution systems and the recovery of emitter flow rates. Emission volume in the field, and laboratory measured flow rates were determined for emitters from three locations. Additionally, the effects of lateral orientation with respect to slope on emitter plugging was evaluated.

Two different emitters were tested to evaluate slope effects on emitter plugging (type Y and Z). The emitters were alternately spliced together and installed in an up and down orientation on slopes of 0, 1, 2 and 4% and along the contour on slopes of 1 and 2%. The emitters were covered with soil and underwent a simulated year of dosing cycles, and then flushed with a flushing velocity of 0.6 m/s. Initial flow rates for the two emitter types were 2.38 L/hr with a C.V. of 0.07. There was no significant difference in flow rates among slopes for type Y emitters, but there was a significant difference between the 1% and 2 % contour slopes for type Z emitters.

Application uniformity of three different laterals at each site was evaluated. Sections of the lateral from the beginning, middle and end were excavated and emission volumes were recorded for each emitter. Application uniformity of laterals ranged from 48.69 to 9.49%, 83.55 to 72.60%, and 44.41 to 0% for sites A, B, and C, respectively.

Mean emitter flow rate was 2.21, 2.24, and 2.56 L/hr for sites A, B, and C, respectively under laboratory conditions. Application uniformity under laboratory conditions ranged from 70.97 to 14.91%, 86.67 to 79.99%, and 85.04 to 0.00% for sites A, B, and C, respectively.

A flushing velocity of 0.15 m/s with no chlorination, shock chlorination of 3400 mg/L and flushing velocity of 0.15 m/s, and shock chlorination of 3400 mg/L and flushing velocity of 0.6 m/s treatment regiments were applied to all laterals collected to assess emitter flow rate recovery to the nominal flow rate published by the manufacturer. All laterals showed an increase in the number of emitters within 10% of the published nominal flow rate.

DEDICATION

I would like to dedicate this thesis to the people in my life that mean the most to me: first and foremost my wife, Alaina, for her unconditional love and support of me to pursue this degree and her drive when I needed some encouraging. To Logan and Victoria, you are the light in my eyes and my pride and joy. Thank you to my parents, Joseph and Mary Weynand, for their guidance and support throughout my life in good times and bad. Also, I recognize and thank Robert and Rita Hudson for their support. Finally, I dedicate this thesis to God, for without him none of this could be possible.

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I wish to acknowledge the assistance and support of everybody involved with this opportunity. The person that deserves the most thanks in my pursuit of this degree is my committee chair, Bruce Lesikar. Throughout the years of working with Bruce he has always treated me with respect and demanded the best of my abilities even when I did not give them to him the first time. He is not just my advisor and boss. He has become a good friend. I would like to thank Ann Kenimer for her guidance throughout my undergraduate and graduate degrees. Sam Feagley, my external committee member, deserves my thanks for his support throughout this process. A special thanks is needed for Russell Persyn for his help in running the statistical analysis and for encouraging me to pursue this degree and my success with my undergraduate degree.

I wish to acknowledge David Carney for teaching me many valuable skills in the shop that I will carry with me forever. Dave has talents that I did not know existed when it comes to fabrication; I have great respect for his abilities. In addition, I would like to thank the efforts of the student workers that assisted me in completing my thesis: Bart Carter, Justin Mechell, and Jim Welch. I would especially like to thank Josh Friddell for his “above and beyond the call of duty” hard work when push came to shove; Josh was there to finish the job. Then there is Barry Goodrich, a fellow graduate student, who when no one else could go help me sample, volunteered to help.

TABLE OF CONTENTS

Page

Page

LIST OF FIGURES

Page

LIST OF TABLES

INTRODUCTION

Onsite wastewater treatment system performance is a growing national concern. Onsite wastewater treatment systems are often a significant contributor of pathogens and nutrients to the environment (EPA, 2000). In the 1998 states listing of waters not meeting their designated uses, 5,281 water bodies had high concentrations of pathogens and 4,773 water bodies had high nutrient concentrations. Onsite wastewater treatment systems serve approximately 25% of the US population and approximately 37% of new development (EPA, 1997). Traditional drain fields have continued to be used for wastewater dispersal, but two-thirds of the United State's soils are unsuitable for traditional drain fields (Perkins 1989). Some areas have high rainfall, high groundwater and/or heavy clay soils requiring alternative methods of wastewater distribution. The alternative wastewater distribution methods rely on uniform application of wastewater for final treatment and dispersal before wastewater reaches surface water or groundwater. In other areas of the US where water is scarce, the ability to reuse treated wastewater may have a positive economic and environmental impact. The ability to reuse treated wastewater for landscape and other non-potable uses would reduce the strain on drinking water sources.

Subsurface drip distribution has the potential for uniform application of wastewater over the entire dispersal area. In marginal soils, uniform distribution is

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This thesis is written to conform to the style of *Transactions of the ASAE*.

essential for proper treatment of wastewater. Subsurface drip distribution systems can be used in these areas, but the effects of different site conditions and drip emitter plugging on the drip distribution system performance are not fully understood. Slope of the site and orientation of the laterals in respect to the slope are site conditions affecting the performance. Plugging factors affecting the performance of the distribution system include physical, biological and chemical properties of the wastewater and soil where the drip laterals are installed.

As the population increases and development spreads out into areas with marginal soils or complex site conditions more research is needed to further develop alternative technologies and design practice of wastewater treatment and dispersal systems. The development of these technologies and operation and maintenance of the systems is necessary to ensure proper treatment of wastewater in order to protect the public health and environment.

Subsurface drip dispersal is becoming one of those technologies used in marginal soils and or complex site conditions. Drip dispersal systems have the ability to provide small uniform doses of water, organic material, nutrients and pathogens to the soil allowing marginal soils to treat the wastewater before it reaches another water body. Therefore, concerns about emitter plugging and site conditions affecting application uniformity need to be addressed.

OBJECTIVES

Subsurface drip dispersal systems are functioning all across the United States with different operation and maintenance procedures and site configurations. The goal of this research is to evaluate the uniformity of water application along drip laterals. This goal will be reached by evaluating the performance of a lab experiment in which subsurface drip laterals are placed on different slope and contour configurations, and evaluating drip laterals operated at three different subsurface drip dispersal systems under similar operation and maintenance procedures. Since uniformity of wastewater application is essential to treatment, this research concentrated on the following objectives:

1. Evaluate emitter flow rate data from a lab experiment evaluating two different emitter types operated on different slopes and contours;
2. Evaluate the application uniformity of drip laterals operating as a part of a subsurface drip distribution system;
3. Determine the flow rate for emitters that have been in operation for several years; and
4. Evaluate the effectiveness of specific field flushing and chlorination methods for recovering emitter flow rates.

LITERATURE REVIEW

This literature review focuses on the evaluation of subsurface drip distribution systems for the application of wastewater to the soil. Drip emitters, orientation and operation of drip fields, different emitter plugging factors, techniques to maintain and recover emitter flow rates, and methods for evaluating application uniformity will be reviewed.

Drip System

A subsurface drip distribution system distributes wastewater utilizing a network of tubing installed below the ground surface. A drip distribution system consists of a pump tank, controller, filtration system and drip laterals configured into one or more zones.

Drip Distribution System Components

The components of the drip distribution system include, supply lines, zone control valves, supply and return manifolds, drip laterals, drip emitters, return lines, check valves and air relief valves/vacuum breakers. Figure 1 illustrates the different components of a drip distribution system. Supply lines provide wastewater to the supply manifolds of the system after passing through the zone control valve in systems with more than one zone. The supply manifold distributes wastewater to the individual drip laterals within the zone. The drip emitters located on the lateral provide a specific discharge point for the wastewater to enter the soil. The laterals then connect to a return manifold. Along the supply and return manifold, air relief/vacuum breakers are installed at the highest point of the manifolds to allow air to enter the system during depressurization (Netafim, 2002). The return manifold is used during system flushing to collect wastewater from the laterals and carry it to the return line which returns to the pretreatment device. Prior to connecting the return manifold to the return line a check valve is installed to prevent wastewater from entering the zone during the operation of other zones.

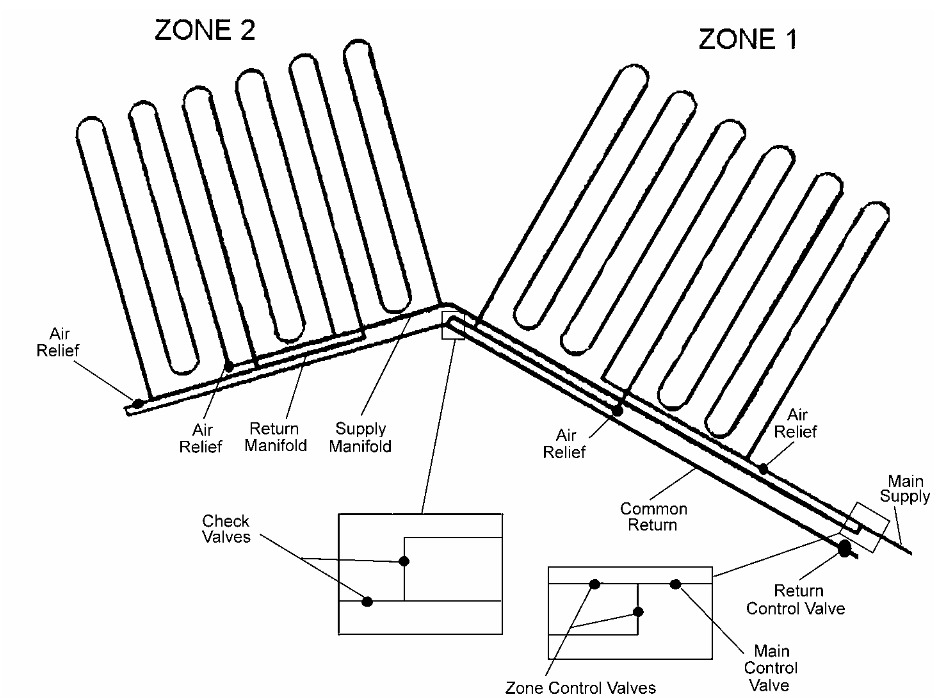

Figure 1. Components of a multiple zone drip distribution system.

Drip Emitters

A drip emitter is a device that is designed to dissipate pressure and to discharge a small amount of water into the soil. Emitters are usually classified by the method in which they dissipate pressure or discharge characteristics (Keller and Bliesner, 1990). For example, there are long path, vortex, orifice, flushing, continuous flushing and multi-outlet emitters. Any of these emitters can be either pressure compensating or non-pressure compensating. Drip tubing products used for wastewater application rely on several of these different types of emitters. Other characteristics of emitters used in wastewater application include filters incorporated into each emitter, impregnating chemicals to either prevent biological slime build-up or root intrusion and self cleaning features (Geoflow, 2000; Netafim, 2002).

Netafim's Bioline 2.27 L/hr (0.60 gph) (type Y) pressure compensating emitter has a nominal discharge rate of 2.34 L/hr (0.62 gph) with an inlet pressure between 34 – 482 kPa (5 – 70 psi) (Netafim, 2002). Additionally, when pressures range between 34 – 379 kPa, the flow rate of an individual emitter may not vary more than 10% from the nominal discharge rate. The manufactures coefficient of variation is 3% or lower (Netafim, 2002). Geoflow's Wasteflow PC 2.00 L/hr (0.53 gph) (type Z) emitter has a discharge rate of 2.00 L/hr (0.53 gph) with an inlet pressure between 48 – 414 kPa (7 – 60 psi) and the flow rate should not vary more than 5% of the nominal discharge rate of the emitter (Geoflow, 2000).

System Orientation

The orientation of a system refers to the orientation of the laterals in reference to the topography of a site. Netafim (2002) and Geoflow (2000) recommend the installation of drip laterals along the contour of the slope of a site.

Stages of Dosing Cycle

Every dosing cycle of a drip distribution system consists of four different stages; 1) pressurization flow, 2) pressurized flow, 3) depressurization flow and 4) resting. Pressurization flow is the flow entering the system from the point of initiating the dosing event until the system reaches the desired operation pressure. From that point the system operates under pressurized flow. When the pump is turned off until the system stops emitting water, the system undergoes depressurization flow. Finally, the system is in the resting stage until the initiation of the next dosing cycle. This resting period is important to allow water distribution into the soil for final treatment and subsequent dispersal..

Drip systems are designed to uniformly distribute water. The designer strives to minimize the relative volume of water distributed during the pressurization and depressurization flow periods and maximize the water volume during the pressurized flow. The pressurized flow stage is the only period when the system is uniformly distributing water.

Plugging Factors

Initially, one needs to understand the different factors that cause emitters to plug. The plugging of emitter orifices in trickle irrigation systems has caused many early users to abandon their systems. Water containing high concentrations of suspended inorganic and organic particulate material, microbes that cause a slime development, involved in biochemical accumulation of heavy metals, sulfides, and dissolved chemical constituents that cause scaling do pose a large problem in plugging emitters (Gillbert et al., 1979). Emitter plugging factors are categorized into physical, biological, and chemical plugging factors. The different plugging factor constituents associated with emitter plugging and the concentrations associated with different severities of plugging potential are given in table 1. Frequently, plugging of emitters is caused by a combination of the different factors.

Physical

Physical factors that cause emitter plugging can be associated with suspended and colloidal solids in the water. Suspended solids have both organic and inorganic components. ASAE (2001a) standards recommend filtration of 150 to 75 microns (100 to 200 mesh). By using this recommendation, only coarse to fine sands are removed leaving very fine sands, silts, and clays to pass through the filter. Soil particles passing through the filter are normally too small to plug emitters individually, but can flocculate together forming particles large enough to cause plugging of emitters (Pitts et al., 1993). Keller and Bliesner (1990) recommend the removal of particles larger than one-tenth the diameter of the orifice, and to plan for the worst case conditions because a constant water quality is important to the operation of the system. Particles that do pass through the filtration system can also settle and accumulate in low spots and distal ends due to reduced flow rates, and overtime this accumulation of particles can cause plugging (Lancaster, 1999, Netafim, 2002).

Table 1. Plugging potential of water (Bucks et al., 1979).

Plugging Factor	Little	Some	Severe
Physical[a]			
Suspended solids (maximum ppm)	<50	50-100	>100
Chemical[a]			
pH	<7.0	7.0-8.0	>8.0
Dissolved solids (maximum ppm)	<500	500-2000	>2000
Manganese (maximum ppm)	<0.1	0.1-1.5	>1.5
Iron (maximum ppm)	<0.1	0.1-1.5	>1.5
Hydrogen sulfide (maximum ppm)	<0.5	0.5-2.0	>2.0
Biological[b]			
Bacteria population (maximum number/mL)	<10,000	10,000-50,000	>50,000

[a]Maximum measured concentration from a representative number of water samples using standard procedures for analysis.
[b]Maximum number of bacteria per milliliter can be obtained from portable field samples and laboratory analysis. Bacterial populations do reflect increased algae and microbial nutrients.

Soil particles can also be ingested into the emitters from the soil surrounding the laterals. After the system is turned off, water remaining in the laterals drains to the lower end of the distribution field. Without a vacuum breaker, saturated soil around the emitter prevents air entering into the lateral causing a vacuum which can siphon soil into the emitter during depressurization (Lancaster, 1999). This process can cause severe clogging after one cycle. Vacuum breakers should be installed at the highest point of the supply and return manifold (Geoflow, 2000; Netafim, 2002). Particles can also enter the system through open pipes during installation or repair (Evans, 2001).

Since drip laterals are placed into the root zone of the cover crop, a potential exists for roots to intrude into the emitters causing plugging. Plugging of emitters due to root intrusion can be caused by stress in the cover grass of the subsurface drip dispersal field. When the cover grass becomes stressed, the roots will move toward emitters in search of water. In a study of a vegetable crop, areas of excess water showed weeds growing vigorously while in areas that had root intrusion, visual indications of stress were present (Irrigation Training and Research Center, 1996).

Biological

Subsurface drip distribution systems provide a favorable environment for bacterial growth. Additionally, wastewater is biologically active and contains organic material and nutrients which increases growth and build up of algae and bacterial slime. The inside surface of the components used to construct a subsurface drip distribution system provides a place for microbial growth. Supply lines, supply manifold, connections to the manifolds, drip tubing, looped ends, return manifold and return line can have a build-up of biological material. Wastewater remains in the components or at least the residue of wastewater remains in the components during the resting period between dosing events. Also, a fresh dose of wastewater brings additional nutrients to the biological film that can develop on the inside surface of the components.

Biological growth can be moved within the drip distribution system during a dosing event. When the pump turns on, a rapid flow of water moves through the supply line and supply manifold as water enters the drip laterals. As the system pressurizes, the water velocity slows to the normal flow rate allowing suspended particles to settle in the system.

Algae found in surface waters or formed during wastewater treatment have the potential of passing through the filtration system and into the drip laterals.

Keller and Bliesner (1990) discuss that slime composed of microorganisms produced by bacteria form "glue" that traps particulate matter that passes through filtration can easily plug emitters. The bacterial slime attaches to the sides of the tubing and combines with particles that have passed through filtration forming particles large enough to plug emitters. The attachment of inorganic particles to biological slime is a significant source of emitter plugging (Pitts et al., 1990).

Sievers and Miles (2000) observed a biological slime in the internal entrance of emitters contributing to plugging, and after shock chlorination and flushing, large amounts of a brown biomass were removed from the lines.

Chemical

Chemical plugging of emitters is the result of precipitation of calcium, magnesium, iron or manganese from solution. Water with a base concentration of bicarbonates greater than 2 mg/L and a pH greater than 7.5 is likely to produce calcium precipitates (Keller and Bliesner 1990). To determine if the wastewater has the potential to form a calcium carbonate scale, the Langelier saturation index or Ryzner index is used to determine the concentration of calcium carbonate in the water (Metcalf and Eddy, 2003). Changes in pH, temperature, pressure, dissolved oxygen, chlorination, or chemical injections can cause minerals in solution to precipitate. Precipitates may form a scale on the inside of the drip tubing. Scale builds reducing the cross sectional area and increases the roughness of the line (Pitts et al., 1993). The combination of the two reduces the velocity of the water causing particles to settle. If scale builds up excessively, then plugging can occur in the emitters.

Maintenance

The maintenance of any system is essential to the prevention of any foreseen problem with the system. The prevention of plugging in drip emitters can be categorized into managing the wastewater and managing the drip distribution system. These different techniques for managing both the wastewater and drip distribution system include filtration and chemical treatments. To further manage the drip distribution system, flushing of the laterals is necessary.

Filtration

Increasing the quality of the wastewater entering the drip distribution system considerably reduces plugging potential. Adequate filtration is needed to reduce the particulate material suspended in the effluent. The level of filtration needed depends on the initial quality of the effluent entering the system. Filtration systems must be able to handle peak loads of suspended particles (Nakayama et al., 1978). Keller and Bliesner (1990) indicate that most manufacturers recommend the removal of particles larger than 0.075 mm or 0.15 mm (75 to 150 microns) which is about one-tenth the size of the orifice. Geoflow Inc (2000) recommends a 104 micron (150 mesh) vortex filter for there systems while Netafim Irrigation Inc. (2002) recommends the use of 100-130 micron filter (140 or 120 mesh) filter for there systems. Common filter sizes in microns and mesh sizes is shown in table 2.

Trooien et al. (1998) recommend the filter should be checked regularly and cleaned when the differential pressure across the filter increases by 21- 34 kPa (3-5 psi). ASAE (2001a) recommends that filter capacity be large enough to permit the designed flow rate without requiring frequent cleaning, and if hand cleaning is necessary should not be required more than daily. Additionally, maximum pressure head needs to be less than 70 kPa (10 psi) across the filter.

Table 2. Common filter sizes.

Mesh No.	Micron Rating
100	152
120	130
140	100
150	104
180	84
200	74
300	46

The pump tank of an onsite wastewater treatment system adds a settling chamber that allows separation of the larger particles still remaining in the wastewater. When a pretreatment system is upset or hydraulically overloaded, there is a potential for suspended solids to enter the distribution system if proper filtration is not used.

Chemical Treatment

Information presented for chemical treatment of laterals pertains to agricultural practices for irrigating crops. Chemical treatment is often required to prevent emitter plugging due to biological slime and chemical precipitation (Pitts et al., 1990). To reduce emitter plugging associated with an accumulation of bacterial slime, chlorine injection is the most common method used because it is a very effective and cost efficient biocide (Evans, 2001). Evans (2001) recommends a free chlorine residual of 1 mg/l (1 ppm) for at least 30 minutes at the distal ends of the laterals. Netafim (2000b) recommends a continuous chlorination maintaining a chlorine residual of 0.5 mg/l (0.5 ppm) or an intermittent chlorination with a residual of 2-3 mg/l (2-3 ppm) at the distal end of the laterals. ASAE (2001a) recommends either a continuous or intermittent use of chlorine or other bactericides with a residual of 0.1 mg/L (0.1 ppm) or 1.0 mg/L (1.0 ppm), respectively. Alam et al. (1999) recommend a continuous residual of 1 to 2 mg/L (1-2 ppm) if the biological load of the water is high and shock chlorination of 10 to 30 mg/L (10 to 30 ppm) residual if the biological load is not as high.

If sodium or calcium hypochlorite is used as the disinfection method, caution should be used with effluent containing more than 0.4 mg/L (0.4 ppm) dissolved iron, since it can cause precipitation of iron (ASAE, 2001a). Chlorine added to wastewater will also react to other water constituents reducing the effectiveness of the chlorine. Enough chlorine must be used to meet the required reactions of the water and still have residual at the distal end of the laterals. The use of calcium hypochlorite can lead to the precipitation of calcium from solution. The efficiency of chlorine decreases at a pH above 7.5 (Pitts et al., 1993). The efficiency of chlorine increases exponentially as the pH of the water decreases being optimal at 5.5 - 6.0 (Evans, 2001). In order to reduce the pH, chlorine injection can be coupled with an acid injection to increase effectiveness. The chlorine and acid should be injected from different sources to reduce the potential of generating lethal chlorine gas (ASAE, 2001a). When chlorine is added to the system, a test kit should be used to ensure that the amount of chlorine added is sufficient. A color test kit that measures free chlorine residual should be used (Pitts et al., 1990).

Acid is also used in drip irrigation to dissolve and decompose carbonate, phosphate, and hydroxide scales, and is not effective on organic matter, sand or silt. The amount of acid used depends on the quality and buffering capacity of the water being used and the intent of the treatment. If acid is injected to prevent scale from building up, the pH should be a little below 7.0, and if the intent is to remove existing scale, the pH needs to be lower (Pitts et al. 1993). As mentioned before, the Langelier saturation index or Ryzner is used to determine the likelihood of calcium bicarbonate to precipitate and form a scale. Recommended concentrations for continuous acid injection are shown in table 3. The total acid concentrations of the water are designed to reach a pH between 4.5 and 5. Prior to an acid or chlorine treatment, it is recommended that the laterals be flushed to remove any solids (Netafim, 2000a).

Table 3. Recommended acid concentration to treat water (Netafim, 2000a).

Acid percentage	Recommended concentrations in treated water
Hydrochloric acid 33%	0.6%
Phosphoric acid 85%	0.6%
Nitric acid 60%	0.6%
Sulfuric acid 65%	0.6%

Sievers and Miles (2000) conducted an on-site wastewater treatment demonstration project using septic tank effluent from an individual residence for distribution through a drip system. During the observation time, the design flow through the system decreased from 18.9 to 7.6 L/min (5 to 2 gpm). To try and recover the flow rate, the system was shock chlorinated several times using concentrations of 500, 250, and 500 mg/L (500, 250, and 500 ppm) of lithium hypochlorite with 45 minutes of contact time followed by flushing of the system for 10 minutes. The flow rates increased from 7.6 to 10.6 L/min (2 to 2.8 gpm) in zone 1 and from 7.6 to 8.3 L/min (2 to 2.2 gpm) in zone 2. After one week, the flow rates were tested again showing a flow rate of 10.06 L/min (2.8 gpm) in zone one and 11.4 L/min (3.0 gpm) in zone 2. The system was then dosed with a 10 % solution of copper sulfate followed by flushing for three consecutive days and then repeated a week later with no change in flow rates. The system was then treated with a 50% solution of a commercial material for unclogging drains. After a two hour contact time and 20 minute flushing, the flow rate of the system increased to 15.2 L/min (4 gpm) (80% of the design flow rate) in both zones.

Plugging of emitters due to root intrusion is minimized due to physical barriers designed into the emitters. Treflan herbicide is also used to prevent roots from growing into the emitters. Treflan is either impregnated into the emitters directly during manufacturing or disk filters impregnated with the herbicide are used (Gushiken, 1993).

Flushing

The practice of routine flushing of mains, submains and lateral lines is recommended to control the buildup of sediment in lower parts and the distal end of laterals (Gilbert, et al., 1979; Pitts et al., 1993). Evans (2001) explains that the flushing velocity needs to be large enough to carry heavy particles from the laterals. The standard for field flushing in the irrigation industry is 0.3 m/s (1 ft/s) (ASAE, 2001a). Sanjines (1999) recommends a Reynolds number of 4000 to ensure turbulent flow in the lateral, which corresponds to 0.3 m/s (1 ft/s) through a 0.52 inch diameter drip lateral. The use of the 0.3 m/s (1 ft/s) flushing velocity does not consider the bacterial slime that adheres to the walls of the drip laterals. Netafim (2002) recommends the flushing of laterals with velocities of 0.3- 0.6 m/s (1-2 ft/s) several times a year, but may be as frequent as every day depending on the site conditions. These conditions include effluent quality and characteristics, filtration efficiency, length of tubing in each zone, and local regulations for maintenance. Ruskin (2001) states that the use of the ASAE standard of 0.3 m/s (1 ft/s) is more than adequate for flushing of laterals. Ravina et al. (1997) states that longer supply lines with velocities of less than 0.5 m/s (1.64 ft/s) increases emitter clogging due to biological growth accumulating on the pipe walls until it is sheared and carried on to the end of laterals.

The exact method of treatment that provides the best results depends on the site conditions of interest. Methods of combining acid and chlorine treatments need to be explored to efficiently treat bacterial slime.

Currently, the maintenance and treatment techniques of subsurface drip laterals used in onsite wastewater treatment rely on past research done on micro irrigation. Some of these techniques are still valid for the onsite industry, but the characteristics of the water being applied can be considerably different and additional maintenance and treatment maybe needed when water quality is different.

Application Uniformity

The potential for uniform distribution of wastewater is one of the main advantages of subsurface drip distribution. ASAE (1999) discussed statistical uniformity represented in the following equation:

$$U_S = 100(1 - V_q) \qquad (1)$$

where

U_S = statistical uniformity coefficient,%, and

V_q = manufacturing coefficient of variation.

The coefficient of variation in this calculation refers to the depth of water applied. This statistical uniformity coefficient describes the uniformity of wastewater distribution assuming a normal distribution of flow rates from the emitters. In the case of emitters being plugged, ASAE (1999) standards calls for the calculation of the emitter discharge coefficient of variation, including emitter plugging as:

$$V_{qp} = \left[\frac{1}{(1-C)}\left(V_{qs}^{\ 2} + 1\right) - 1\right]^{1/2} \qquad (2)$$

where

V_{qp} = emitter discharge coefficient of variation including emitter plugging,

C = proportion of emitters (decimal) completely plugged, and

V_{qs} = site conditions coefficient of variation.

Therefore, the statistical uniformity of the field considering plugging can be calculated by using V_{qp} in place of V_q in equation 1. For given site conditions, V_{qs} can be used in Equation 1 for V_q to determine the uniformity of a system. Application uniformity of a system is affected by hydraulic design, topography, operating pressure, pipe size, emitter spacing, and emitter discharge variability. Discharge variability is due to manufacturer's coefficient of variation, emitter wear, and emitter plugging ASAE (1999). Table 4 illustrates the acceptability depending on the range of statistical uniformity.

Table 4. Methods of comparison of statistical uniformity (ASAE, 1999).

Method Acceptability	Statistical Uniformity, U_s (%)
Excellent	100-95
Good	90-85
Fair	80-75
Poor	70-65
Unacceptable	<60

ASAE (1983) also represents flow variation through the Christiansen Uniformity Coefficient:

$$C_u = 1 - \frac{\overline{\Delta q}}{\bar{q}} \tag{3}$$

where

C_u = the uniformity coefficient,

$\bar{q}$ = the mean emitter flow, and

$\overline{\Delta q}$ = the mean absolute deviation from the mean emitter flow.

Smajstrla et al. (1997) demonstrates a field technique for evaluating the application uniformity of a drip distribution system. This method used the top 1/6 and bottom 1/6 emitter flow volumes, flow rate, or time to fill a container. The sum of the top and bottom 1/6 of the emitters are plotted on figure 2 to calculate the application uniformity.

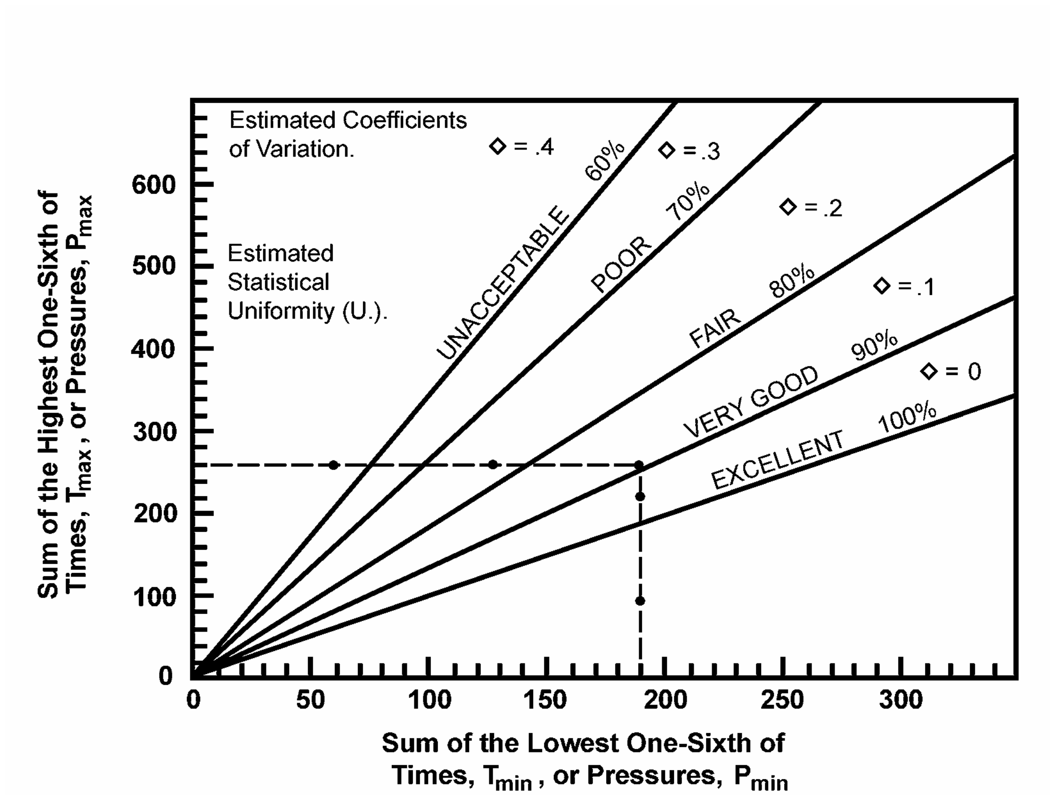

Figure 2. Statistical uniformity nomograph (Smajstrla et al., 1997).

An additional method of evaluating the application uniformity of a system is described in Burt et al. (1997). This method uses a distribution uniformity using the average depth of application of the lower quartile over the average depth of application (equation 4). This method has been used by USDA and NRCS since the 1940s.

$$DUlq = \frac{avg.\_low - quarter\_depth}{avg.depth\_of\_water\_accumulated\_in\_allelements} \quad (4)$$

Lamm et al. (2002) utilizes this method in calculating the distribution uniformity of drip laterals applying wastewater from a beef lagoon. Distribution uniformities ranged from 54.3% to 97.9% for the tubing evaluated.

Only a small percentage of emitter plugging can reduce the application uniformity (Nakayama and Bucks, 1981). Talozi and Hills (2001) have modeled the effects of emitter and lateral clogging on the discharge of water through all laterals. Results show that the discharge from laterals that were simulated to be clogged decreased while laterals that were not clogged increased. In addition to decreases in discharge for emitters that were clogged, the model showed an increase of pressure at the manifold inlet. Due to the increased inlet pressure, a lower discharge rate by the pump was observed. Berkowitz (2001) observed reductions in emitter irrigation flow ranging from 7 to 23% at five sites observed. Reductions in scouring velocities were also observed from the designed 0.6 m/s (2ft/s) to 0.3 m/s (1ft/s). Lines also developed some slime build-up, as reflected by the reduction in scouring velocities, but this occurred to a less degree with higher quality effluent.

METHODS AND PROCEDURES

The focus of this research was to evaluate flow rates from drip emitters used for wastewater application. Flow rates were determined for both emitters collected from laboratory experiments and from operational septic units in the field. The purpose for measuring emitter flow rates was to determine the potential for emitter plugging and the subsequent effect on uniformity of water distribution. This section describes methods used to measure the flow rate in the laboratory and at field sites, and as well as the methods used to evaluate drip emitter recovery methods.

Emitter Flow Rate Testing Apparatus

The emitter flow rate testing apparatus used in this research to determine emitter flow rates and to apply treatments to the emitters in the laboratory was described by Persyn (2000). In general, the testing approach can determine flow rate in ten 3.04 m (10 ft) segments of drip tubing. Laterals are isolated using ball valves located before each lateral and a check valve at the end of each lateral. Water is supplied to the laterals from a 120 liter plastic tank with a 373-watt (1/2 hp) high head pump. Water discharged from individual emitters was collected in plastic containers located on a movable catch basin. During the slope effect on emitter plugging experiment, no modifications to the emitter flow rate test apparatus were performed. However, prior to determining flow rates from the drip emitters collected in the field, some modifications were performed to the apparatus. A 74 micron (200 mesh) screen filter was installed before the drip laterals in order to follow ANSI/ASAE Standard S553 Collapsible Emitter Hose (Drip Tape)

Specifications and Performance Testing (ASAE, 2001b). An additional pressure gauge was installed approximately 15.24 cm (6 in) below the drip tubing elevation. This additional pressure gauge allowed calculations to account for pressure loss due to elevation change assuming 6.89 kPa (1 psi) for every 70.40 cm (2.31 ft) of elevation change. These calculations indicated that pressure gauge be set at 139.38 kPa (20.21 psi). To enhance the accuracy of measuring the operating pressure a test gauge with a 0.5% accuracy was used, and the pressure readings were taken from both ends of the manifolds with the same gauge, 6.35 mm (1/4 in) tubing was connected to a pressure manifold with ball valves for selecting whether the supply or return manifold pressure was being determined.

Slope Effects Experiment

The effect of slope on emitter plugging was evaluated by constructing a metal frame designed to support drip laterals on different slopes. The system was set-up to simulate placement of drip laterals on four different slopes and two different contour configurations. Drip laterals consisting of three runs were configured to run up and down slopes of 0, 1, 2, and 4% and were also oriented on contours of 1 and 2%. The test system was constructed of 2.54 cm (1 in) square tubing frame 2.74 m long by 66 cm wide (9 ft by 26 in) with adjustable 2.54 cm (1 in) square tubing supports at both ends of the frame. The frame was allowed to pivot on a 1.27 cm (1/2 in) bolt located in the center of the length. The system used to test drip laterals placed along a contour consisted of a 2.54 cm (1 in) square tubing frame 3.35 m long by 66 cm wide (11ft by 26 in), and adjustable 2.54 cm (1 in) square tubing supports located in the middle of the frame. The frame was allowed to pivot on a 1.27 cm (1/2 in) bolt located in the center of the width. The replicate frames for the different slope and contour configurations were stacked vertically to minimize space requirements. Three 3.04 m long by 15.24 cm (10 ft by 6 in) plastic channels were affixed to the top of each frame to hold the drip tubing and soil.

To maximize the number of emitters evaluated, each run of tubing was constructed by connecting 12 segments of new tubing, 20.32 cm (8 in) long, containing one emitter located in the center of the segment. Two different pressure compensating emitters, Netafim 2.34 L/hr (0.62 gph) and Geoflow 1.98 L/hr (0.51 gph), type Y and Z, respectively, were alternately spliced together using barbed connectors. Each run of tubing, 3.04 m (10 ft) in length, contained 12 emitters; 6 type Y and 6 type Z emitters. The first emitter of each run was a type Y emitter followed by a type Z emitter. This alternating sequence was maintained throughout the entire length of the run. After the runs were constructed, the emitters were numbered and placed on the flow rate testing apparatus to measure the flow rate from each individual emitter using the flow rate test protocol developed by Persyn (2000).

Once the emitters flow rates were determined, three individual runs were placed in each channel of the slope testing apparatus to form one lateral with three runs. The runs of the tubing were arranged to allow a lateral to have emitters with consecutive numbers along the length. All three runs of the laterals used to determine the effects of slope orientations were placed in a single channel. For laterals with runs placed on the contour, each run was placed in a separate channel stair-stepped down the slope.

The runs were looped together in numerical order in the manner that water would flow through the laterals. The configuration of the runs in the channels for the up and down the slope and contour configurations is illustrated in figure 3. After all of the runs were placed in the channels, soil was added to cover the tubing. Gravel was placed at the ends of the channels to allow water to drain from the channels and prevent soil from washing out. In the event that soil did wash out of the channels, additional soil was added throughout the experiment to maintain soil covering.

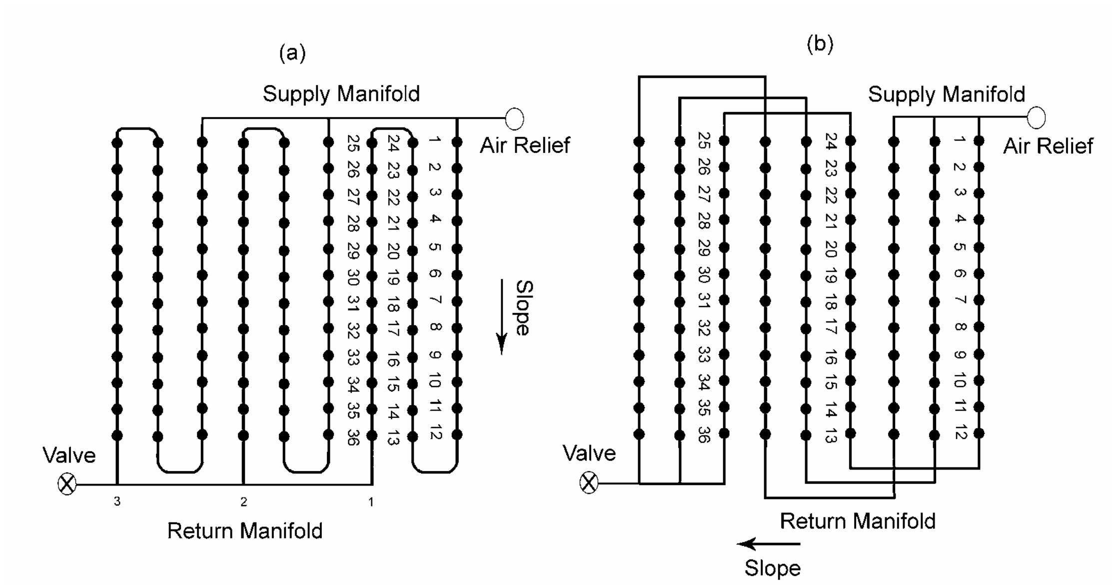

Figure 3. Configuration of lateral layout for up and down the slope (a) and along the contour of a slope (b).

Supply and return manifolds were constructed of 1.9 cm (3/4 in) SCH 40 PVC pipe for each configuration. These manifolds supplied water to the first run of each lateral. An air relief valve was installed with each supply manifold. Two 1.9 cm (3/4 in) SCH 40 PVC elbows were connected together to form the looped ends connecting runs.

Return manifolds were constructed of 1.9 cm (3/4 in) SCH 40 PVC pipe connected to the last run of each lateral. These return manifolds functioned as a closed end of the lateral.

The slope test system configuration allowed for three repetitions of each slope and contour. In the slope testing system, a total of 18 laterals containing 648 pressure compensating emitters 324 type Y and 324 type Z were used. Later 8 type Z emitters were removed from the evaluation due to wrong emitter type. Each of the slope and contour configurations used 3 laterals and 54 each type Y and type Z emitters.

Tap water was supplied to the laterals from a 4542 L (1200 gal) supply tank using a 373-watt (1/2 hp), high head pump. Tap water was used in the experiment to reduce the effects of biological growth or variances in water quality. Each slope and contour configuration was supplied water through the supply manifold. A counter was used to record the number of dosing cycles delivered to the system. Additionally, a flow meter was installed to record the total volume of water supplied to the system. The pressure in the laterals was regulated by a 138 kPa (20 psi) 75.7 L/min (20 gpm) regulator installed after the pump. A pressure gauge was installed on the supply manifold to allow a periodic check of the operating pressure. A repeat cycle timer was used to dose the system for 30 seconds every 70 minutes. This dosing time allowed the drip laterals to pass through the pressurization period and then operate in a fully pressurized mode for 10 seconds. After the pump cycle terminated, the emitter passed through the depressurizing and resting segments of the dosing cycle.

The slope effect experiment was designed to evaluate the impact of drip distribution system orientation on the plugging of drip emitters due to suction of soil back into the emitters. The system was pressurized to 138 kPa (20 psi), operated at full pressure for 10 seconds and then turned off. The dosing cycle was repeated for a simulated year of operation for an onsite subsurface drip distribution system estimated at 1460 cycles which corresponds to four cycles a day for a year. Throughout the experiment, flow meter and operating pressure readings were taken weekly. Pressure readings were checked to ensure the system maintained pressurization of 138 kPa (20 psi) before the pump was turned off.

After the simulated year, emitter flow rates were determined using the same testing protocol and flow rate testing apparatus. Once emitter flow rates were determined the laterals were flushed using a flushing velocity of 0.6 m/s (2 ft/s). The flow rate of the emitters was again determined using the same testing protocol.

Field Drip Lateral Uniformity Experiment

Three different sites located in central Texas were evaluated in the study to determine the emission volume from emitters in a drip lateral during a ten minute dose event. Each of the sites evaluated used a mechanical filtration system prior to distribution to 2.34 L/hr (0.62 gph) Netafim Bioline drip tubing. Emitter spacing along the tubing was 60.96 cm (2 ft) and laterals were spaced every 60.96 cm (2 ft). Average climatically conditions for central Texas are; annual temperature 20.27 degrees Celsius (68.5 degrees Fahrenheit), annual precipitation 85.59 cm (33.7 in), and annual evapotranspiration 159.23 cm (62.69 in)

Site Conditions

Site A served an intermediate/middle school with a design flow of 45,424 liters per day (12,000 gpd) operating for 3-5 years. Secondary treated effluent is dosed to the drip field. The treatment process is accomplished by primary treatment using a septic tank and advanced treatment using a recirculating media filter. Before effluent is dosed to the drip field, it passes through a mechanical filtration system consisting of a bank of 4, 100 micron (140 mesh) disk filters. The drip field is set up with a total of 12 zones that are dual zone dosed. Zones 9 and 10 were examined in this study. Lines are flushed after 32 doses for zone 9 and 34 doses for zone 10 (figure 4). Laterals were randomly selected; lateral 1 was located at the end of zone 9, laterals 2 and 3 were located in the middle portion of zones 9 and 10, respectively. Each lateral consisted of two runs 50.3 meters (165 feet) in length looped together at the down slope end of the field for a total lateral length of 100.6 meters (330 feet). The laterals were installed 20 to 25 cm (8-10 in) deep in a sandy loam soil with a clay pan directly below the laterals. Both supply and return manifolds were located at the upslope end of the field. Slopes along the runs were 1.33 %, 1.72 %, and 0.99% for laterals 1, 2, and 3, respectively. The slope of the soil surface along manifolds was 1%, and the slope along the looped ends was 0.003%. Vacuum breakers were located on the supply and return manifold for each zone.

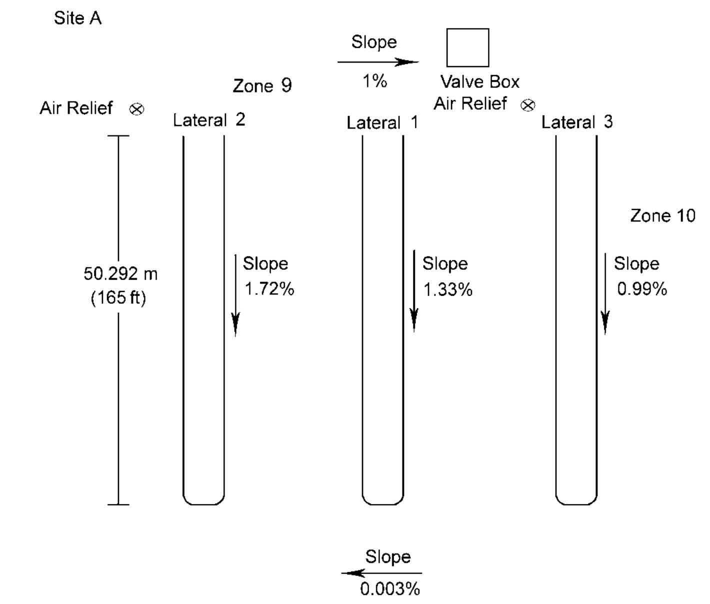

Figure 4. Orientation of drip laterals at site A.

Site B served an elementary school with a design flow of 37,854 liters per day (10,000 gpd) operating for 7 years. Primary treated effluent was dosed to the drip field. Primary treatment is accomplished using a septic tank. Secondary treatment is accomplished by the addition of Nibbler pods within the second compartment of the septic tank. Nibbler pods are a fixed film aerobic treatment unit utilizing plastic balls contained in a basket with air being supplied to the middle of the basket. Before effluent is dosed to the drip distribution field it passes through a mechanical filtration system consisting of a bank of two 130 micron (120 mesh) disk filters. The drip field is set up with zones that are dual zone dosed. Laterals were excavated from zone 4 for this experiment and were randomly selected. Laterals are flushed after 55 doses for zone 4. Randomly selected laterals used in this experiment were located at the beginning of zone

4 and were spaced eight feet from each other (figure 5). Each lateral consisted of two runs 73.1 meters (240 feet) in length looped together at the down slope end of the field for a total lateral length of 146.2 meters (480 feet). The laterals were installed 25 cm to 30.5 cm (10 to 12 in) deep in a sandy loam soil. Both supply and return manifolds are located at the upslope end of the field. The laterals of the system are placed along the contour of the slope at the site. The slopes of the laterals were 0.44%, 0.51%, and 0.64% for laterals 1, 2, and 3, respectively. The slope of the soil surface along the supply and return manifold was 3.8%, and the slope along the looped ends was 2.05%. Vacuum breakers were located on the supply and return manifold for each zone.

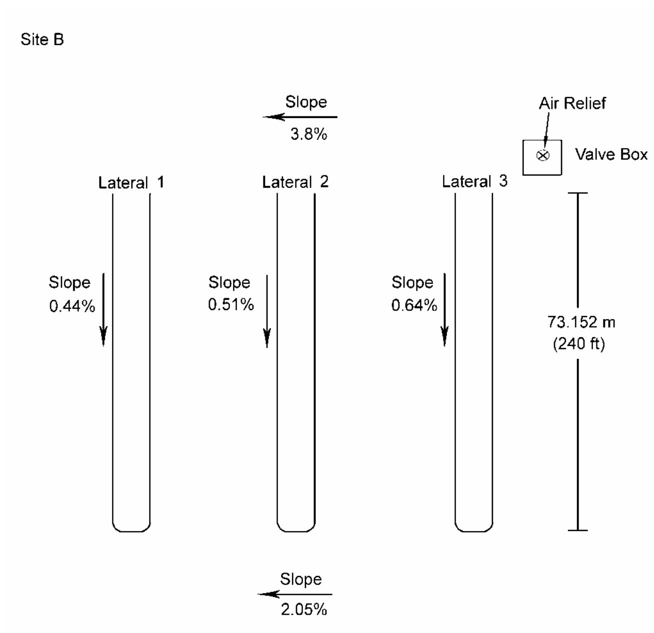

Figure 5. Orientation of drip laterals at site B.

Site C served a middle school with a design flow of 56,781 liters per day (15,000 gpd) operating for 3-5 years. Primary treated effluent is dosed to the drip field. Primary treatment is accomplished using a septic tank. As at Site B wastewater at Site C is treated with Nibbler pods located in the second compartment of the septic tank. Before effluent is dosed to the drip field, it passes through a mechanical filtration system using a bank of three 130 micron (120 mesh) disk filters. The drip field is set up with zones that are dual zone dosed. Laterals were excavated from zones 6 and 7 for this experiment. Laterals are flushed after 60 doses for zone 6 and 65 doses for zone 7. Laterals were randomly selected for this experiment with laterals 1 and 2 from zone 7 and lateral 3 from zone 6 (figure 6). Laterals evaluated were spaced eight feet from each other. Laterals 1 and 2 were located at the down slope end of zone seven, while lateral 3 was located at the upslope end of zone 6. Laterals consisted of one run 120.7 meters (396 feet) in length. The laterals were installed 20 to 30.5 cm (8 to 12 in) deep in a clay loam soil. The supply manifold was installed at the down slope end of the field and the return manifold was installed at the upslope end of the field. The manifolds were constructed with the supply line entering the middle of the manifold. The laterals of the system are placed along the contour of the slope at the site. The slopes of the laterals were 0.40%, 0.43%, and 0.41% for laterals 1, 2, and 3, respectively. The slope of the ground surface along the supply manifold was 0.75%, and the slope of the ground surface along the return manifold was 2.12%. Before the drip lateral connected to the return manifold, the lateral raised up in elevation 22.86 cm (9 in) within a length of 30.5 cm creating a hump before the return manifold. Vacuum breakers were located on the supply and return manifold for each zone.

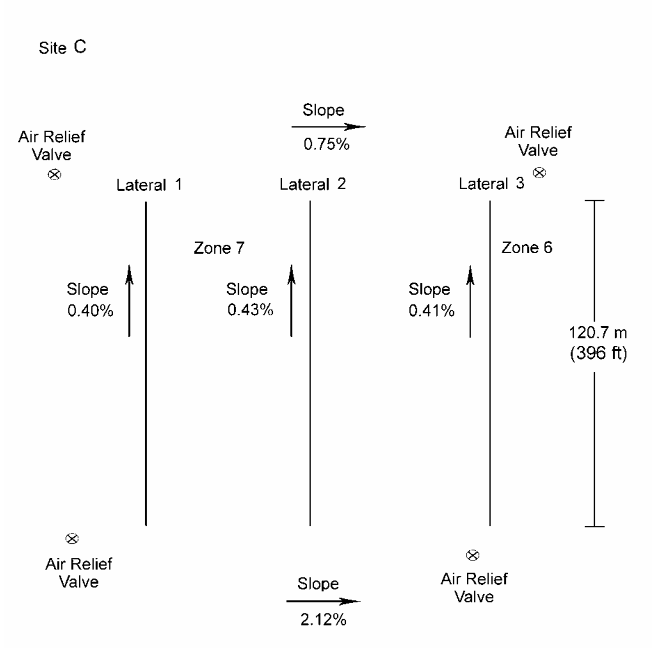

Figure 6. Orientation of drip laterals at site C.

Field Test Protocol

Three sections of tubing were excavated along a drip lateral. The first section was at the beginning of the lateral; this included the first 12 emitters of the lateral. The second section was the middle of the lateral; this included the middle 12 emitters of the lateral. If the middle of the lateral was located at a looped end, this included the last six of the run and the first six emitters of the next run. The last section excavated included the last 12 emitters of the lateral. The tubing was excavated and left in the soil to evaluate the application uniformity in the field. Additional emitters were excavated at the end of the section to ensure a total of 12 emitters for evaluation from each section sampled during the test. If an emitter was damaged during excavation it was removed from the line and the line was repaired. If tubing damage during excavation did not result in a damaged emitter, the damaged section was removed and replaced using new tubing and barbed couplings. The location of the emitters and groups of emitters are illustrated in figure 7.

Under each emitter, soil was excavated allowing the placement of a 1.4 L (3 pint) plastic collection container. Pressure gauges were placed in the tubing at each of the different lateral sections to record operating pressure during each trial.

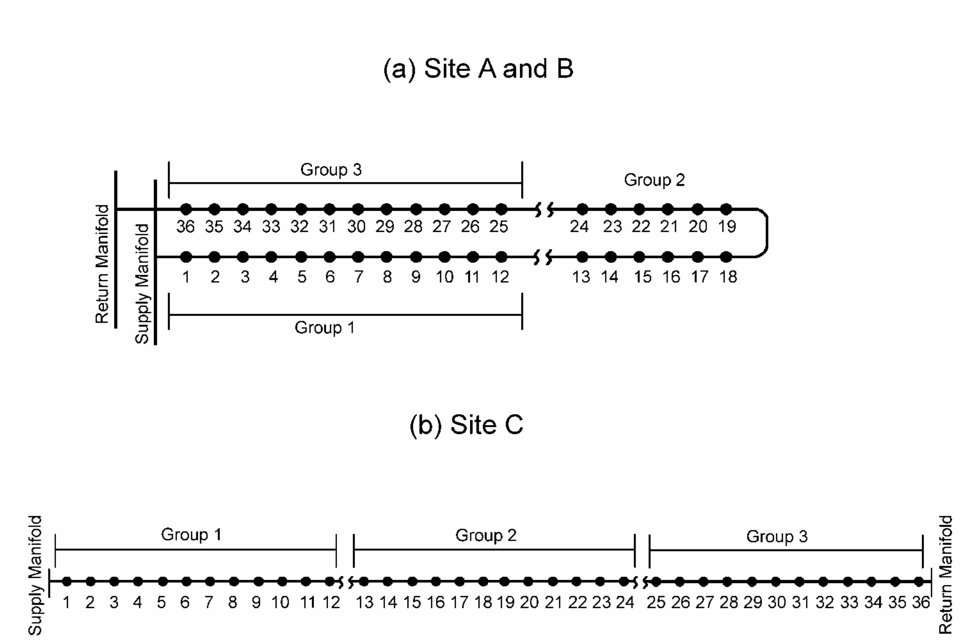

Figure 7. Location of emitters and groups for laterals collected from the field; (a) sites A and B, (b) site C.

A dosing cycle consisted of a total pump run time of 10 minutes. The volume of water exiting the emitters was collected in the 1.4 L (3 pint) plastic containers. In several locations along the tubing, water exiting the emitters flowed along the tubing. To prevent water from flowing along the tubing, 2.54 cm (1 in) sections of tubing were cut, wrapped around the tubing, and placed by an emitter. Once the pump turned off, the system was allowed to depressurize and drain before the containers were removed. When emitters stopped dripping for more than 30 seconds, the containers were removed and weighed to determine the volume of water discharged. Throughout the experiment the density of water was assumed to be 1 g/cm^3. The weight of the water plus container as well as the empty container was recorded following the dosing event. Recording the final container weight was necessary due to mud being stuck to some of the containers. The dosing event was repeated three times for each lateral.

After the field emitter flow volumes were recorded the tubing was collected. The location of the tubing was noted with a permanent marker. The tubing was placed into black plastic bags containing a small amount of water to maintain moisture during transport to the laboratory. This environment was maintained until the tubing was tested in the laboratory. All tubing was evaluated within 14 days of being returned to the laboratory.

Drip tubing collected from the different sites was taken to the laboratory to determine the emitter flow rate. The emitters were evaluated at a pressure of 138 kPa and without a flushing velocity passing by the emitters. Water was collected from individual emitters in 1 liter plastic containers. The containers were weighed and the volume was determined using an assumed density of water of 1 g/cm^3. The water collection period was set at five minutes to minimize error associated with the starting and stopping of the individual runs and residual water in containers. Run times generated a volume of approximately 200 ml in each container. The water was collected from approximately 6 emitters per line. After removing the container from under the emitters, the containers were weighed to determine the volume emitted. Before returning the container to the collection rack, containers were shaken to remove excess water. Emission volumes from the individual emitters were collected three separate times and these individual volumes were averaged to obtain the emitter flow rate for each emitter.

A sampling event was conducted by connecting all 36 emitters from each field set to the testing apparatus. The tubing was cut into six, 3.05 meter (10 ft) lengths containing 6 emitters per line. An additional line of new tubing was located in the seventh section of the testing apparatus to allow pressures and flushing velocities to be set before application to the field tubing. Sections of tubing 2.54 cm (1 in) in length were cut open and wrapped around the tubing and the support wire to more closely simulate a level line. Additional pieces of tubing were placed close to emitters to prevent lateral movement of water along the tubing. Prior to sampling, the new line of tubing was used to set the operating pressure in the tubing. Once the pump was turned on and the valve to the line being evaluated was opened, the emitters were allowed to run for approximately 2 to 5 minutes to allow air to escape the line and the emitters allowed to reach equilibrium. Sampling was conducted only if no air was exiting the emitter. In the few instances that air did escape during sampling, the test was abandoned and rerun. Once the system was pressurized, the pump ran for the duration of the testing event. Fresh water was added to the pump tank between testing events, when different treatments were applied, and between different sampling runs. The laboratory provided a temperature-controlled environment between 20 and 30 degrees Celsius.

Emitter Flow Rate Recovery Experiment

A treatment regiment was applied to each line after determining the initial emitter flow rate. The first regiment applied to the lines was a flushing velocity of 0.15 m/s (0.5 ft/s) with no chlorination. The flushing velocity was set by measuring the flow volume passing through the section of new tubing placed on the test apparatus. A gate valve on the return line was used to adjust the flow rate. A flow meter was used to verify the flushing velocity. The flushing velocity was maintained for five minutes for each line individually. The tubing was allowed to reach an equilibrium pressure before starting the five minute treatment. The second regiment applied to the tubing was a shock chlorination of 3400 mg/L (3400 ppm). Liquid chlorine bleach containing 6% sodium hypochlorite by weight was used to obtain the desired bleach concentration. The chlorine solution was dosed for five minutes to all lines on the test apparatus. The chlorine solution was allowed to react in the lines for two hours before the lines were flushed with a flushing velocity of 0.15 m/s (0.5 ft/s). The third regiment applied to the lines was a second chlorine shock of 3400 mg/L (3400 ppm). The same procedure was used to administer the first chlorine shock treatment. However, the flushing velocity for the third regiment was 0.6 m/s (2 ft/s).

Between each treatment regiment the emitter flow rate was determined using procedures described earlier. Each treatment regiment was performed sequentially on each set of tubing collected from the field study. In other words, the initial flow rate was determined followed by a 0.15 m/s (0.5 ft/s) flushing velocity, shock chlorine treatment of 3400 mg/L (3400 ppm) and a 0.15 m/s (0.5 ft/s) flushing velocity and finally an additional 3400 mg/L (3400 ppm) shock chlorine treatment and a 0.6 m/s (2 ft/s) flushing velocity with emitter flow rates determined between each regiment.

Emitter Range Evaluation

The emitter flow rate range was evaluated to determine the percentage of emitters within 10% of the published nominal flow rate of the emitters. The emitters evaluated from the slope effects evaluation were tested to determine if the flow rate of the individual emitters was within 10% of the mean flow rate of the emitters evaluated for both emitter types. Emitters evaluated from the field and the emitter recovery experiment was tested to determine if the flow rate of the individual emitters was within 10% of the nominal emitter flow rate published by the manufacturer.

Statistical Evaluation

A statistical evaluation was performed on the data collected from the different experiments. Datum from the slope experiment was tested for 95% significance between the different slopes and the mean flow rate for the slopes. Additionally, a significance test was conducted for all emitters for 95% significance between sets of emitter flow rate data collected initially, after conducting the slope effect experiment, and following line flushing. Data from the field experiment were tested for 95% significance between groups within the field for each lateral. Initial flow rate data were evaluated following a similar procedure to the field data in order to compare between field and lab. Emitter recovery data were evaluated for 95% significance between treatment means.

Application Uniformity

Three different methods were utilized to evaluate the uniformity of the drip distribution systems. The first method, presented by ASAE (1999) is calculated as a function of coefficient of variation of the sample. This ASAE standard has since been removed from publication in 2001. The second method, calculated statistical uniformity based on the coefficient of variation and the percentage of emitters completely plugged (equation 2). A new coefficient of variation was calculated considering the emitter plugging. This method was also removed from ASAE standards in 2001. The final method used to evaluate uniformity of the drip lateral used the mean lower quartile of the sample as presented in Burt et al. (1997). This method calculates the distribution uniformity using the mean of the lower quartile over the mean of the entire sample. All three methods of calculating the uniformity were applied to the field experiment data and the initial flow rate of the tubing collected from the field.

RESULTS AND DISCUSSION

Slope Effects Experiment

The slope effect experiment was designed to evaluate the physical plugging potential resulting from the suction of soil into the emitters during depressurization. Two different emitter types were evaluated separately. Emitter flow rates were determined before any testing, after a simulated year of operation, and after flushing the lateral (Appendix A and B). Emitters were tested to see if any correlation existed between the orientation and slope at which the emitters were operated and the likeliness of emitter plugging. Drip laterals were operated in orientations of up and down the slope with slopes of 4%, 2%, 1%, and 0% as well as an orientation along the contour with 2% and 1% slopes.

The initial flow rate for emitter type Y was 2.38 L/hr (0.63 gph) with a coefficient of variation of 0.07, which is higher than the manufactures reported coefficient of variation of 0.04 for new tubing (table 5). For type Y emitters, there was no significant difference in emitter flow rates across the different slope configurations after the simulated year of operation ended, but the standard deviation and coefficient of variation increased. Emitters did, however, show changes in flow rate after the simulated year of operation. The number of emitters within 10% of the mean evaluated flow rate dropped from 88 to 27%. The number of emitters whose flow rate was above 10% of the mean evaluated flow rate increased from 5 to 48% and emitters below 10% of the mean evaluated flow rate increased from 8 to 25%. It is believed that soil particles were sucked back into the emitters and became stuck in the emitter's diaphragm. Lamm et al. (2002) came to the same conclusion when evaluating emitters with high flow rates.

Table 5. Evaluation of type Y emitter flow rates as affected by slope and slope orientation.

		Emitter Flow Rates					Range %		
Slope %	n	Mean (L/hr)	S. D.	C.V.	Max (L/hr)	Min (L/hr)	Above	Within	Below
Initial									
4	54	2.35	0.18	0.08	2.74	1.77	6	85	9
2	54	2.41	0.18	0.07	2.85	2.01	9	83	7
1	54	2.39	0.14	0.06	2.89	2.09	4	93	4
0	54	2.39	0.15	0.06	2.90	2.08	4	87	9
C 2[a]	54	2.37	0.17	0.07	2.77	1.98	6	85	9
C 1	54	2.34	0.14	0.06	2.60	1.94	0	93	7
Total	324	2.38b*	0.16	0.07	2.90	1.77	5	88	8
After Simulated Year									
4	54	2.17	1.40	0.65	4.97	0.00	39	35	26
2	54	2.81	1.31	0.47	6.12	0.01	52	31	17
1	54	2.21	1.25	0.57	4.26	0.00	37	37	26
0	54	2.35	1.20	0.51	5.12	0.00	48	30	22
C 2	54	2.41	1.48	0.61	5.58	0.00	48	17	35
C 1	54	2.45	1.42	0.58	5.60	0.00	61	13	26
Total	324	2.41b	1.33	0.55	6.12	0.00	48	27	25
After Flush									
4	54	2.76	1.24	0.45	5.66	0.00	52	31	17
2	54	3.15	1.17	0.37	7.38	2.07	50	48	2
1	54	2.91	0.70	0.24	5.36	2.01	56	43	2
0	54	2.86	0.73	0.26	6.19	2.28	46	54	0
C 2	54	2.91	1.09	0.37	5.56	0.55	48	44	7
C 1	54	3.19	1.41	0.44	8.77	0.56	50	46	4
Total	324	2.97a	1.09	0.37	8.77	0.00	50	44	5

*Means with different letter designations are significantly different ($p < 0.05$).
[a] C indicates laterals placed on contour slope configurations.

After the flushing velocity treatment the percentage of emitters within 10% of the initial population mean flow rate increased to 44%. The percentage of emitters that were above the range increased to 50%, but the number of emitters that were below the range decreased to 5%. When averaging all emitters for each slope orientation for each stage of the experiment, there was a statistically significant difference between the initial mean flow rate compared to the flow rate after flushing. The mean emitter flow rate generally increased with each stage of the experiment.

The mean initial flow rate of the type Z emitters was 2.38 L/hr (0.63 gph) with a coefficient of variation of 0.07 (table 6). After the simulated year of operation there was a significant difference in the mean flow rate between emitters located on contour 1% and contour 2%. All other slope orientations showed no significant difference in means. After the simulated year of operation the percentage of emitters above 10% of the population mean increased to 32%. The percentage of emitters within 10% of the population mean flow rate also decreased to 42%, while the number of emitters below 10% of the population mean flow rate increased to 25%. After flushing the laterals the percentage of emitters within 10% of the population mean flow rate increased to 57%, the percentage below decreased to 7% and the percentage above increased to 35%. A percentage (1.27%) of emitters below the range remained completely clogged and the flow rate of others emitters increased in flow rate more than after the simulated year. Mean flow rates of emitter type Z were not compared due to interactions between treatments and orientation of laterals. The mean flow rate decreased after the simulated year and then increased after the laterals were flushed.

Table 6. Evaluation of type Z emitter flow rates as affected by slope and slope orientations.

		Emitter Flow Rates					Range %		
Slope %	**N**	**Mean (L/hr)**	**S.D**	**C.V.**	**Max (L/hr)**	**Min (L/hr)**	**Above**	**Within**	**Below**
Initial									
4	54	2.36	0.16	0.07	2.62	1.94	2	85	13
2	47	2.39	0.13	0.05	2.69	2.10	9	85	6
1	54	2.40	0.15	0.06	2.79	2.11	9	85	6
0	53	2.40	0.16	0.07	2.82	2.05	8	87	6
C 1[a]	54	2.36	0.17	0.07	2.93	1.89	11	80	7
C 2	54	2.38	0.19	0.08	2.75	1.87	6	83	9
Total	316	2.38	0.16	0.07	2.93	1.87	7	84	8
After Simulated Year									
4	54	2.13	1.18	0.55	3.55	0.00	19	65	17
2	47	2.15	1.28	0.60	5.08	0.02	34	40	26
1	54	2.29	1.14	0.50	4.74	0.00	43	35	22
0	53	2.22	1.04	0.47	4.81	0.00	26	49	25
C 1	54	2.55a*	1.16	0.45	4.34	0.00	31	22	44
C 2	54	1.84b	1.37	0.74	5.10	0.00	41	43	15
Total	316	2.21	1.16	0.52	5.10	0.00	32	42	25
After Flush									
4	54	2.47	0.86	0.35	4.32	0.00	30	57	13
2	47	3.11	1.46	0.47	7.04	0.00	38	53	9
1	54	2.91	0.83	0.29	6.47	2.26	50	50	0
0	53	2.75	0.64	0.23	5.33	2.13	36	62	2
C 1	54	2.77	1.22	0.44	5.32	0.00	33	50	15
C 2	54	2.54	0.98	0.39	7.46	0.00	24	69	6
Total	316	2.75	1.04	0.38	7.46	0.00	35	57	7

*Means with different letter designations are significantly different ($p < 0.05$).
[a] C indicates laterals placed on contour slope configurations.

Field Drip Lateral Uniformity Experiment

Discharge volumes were collected from emitters located at the beginning, middle and end of drip laterals to evaluate distribution uniformity. Drip laterals from three different sites were excavated and the volume of water emitted from individual emitters during a 10 minute dosing cycle was recorded (Appendix C, D, and E). The drip distribution systems were allowed to complete a pump dosing cycle that included pressurization, pressurized flow, and depressurization. Once the data was collected emission volumes were used to evaluate the application uniformity of the different laterals by group in the field.

Groups within laterals at site A showed a range of excellent to unacceptable statistical uniformity as shown in table 4. Results of the different methods used to evaluate the application uniformity of the laterals at site A, and the significance between groups within the laterals are shown in table 7. Application uniformity at the site varied by group and lateral with each method used to evaluate uniformity. The two methods used to calculate statistical uniformity only differ when emitters are completely plugged. Within laterals, group 1 showed the greatest statistical uniformity and distribution uniformity followed by group 2 then group 3. Lower uniformities within group 3 were attributed to the greater percentage of emitters that were completely plugged. In the instances where the uniformity was not acceptable (N.A.) corresponds to the coefficient of variation with and without considering emitter plugging becoming greater than one, therefore, the uniformity was negative. The application uniformity for all laterals would be considered unacceptable using ASAE criteria for statistical uniformity. Distribution uniformity of the laterals ranged from 35.96 to 0.

A statistical evaluation was performed on the mean flow from each different group within a lateral. Each group within lateral A1 was significantly different from each other, with group 2, located at the down slope of the system, received significantly more water than the other groups, and group three received the least amount of water. Lateral A2 showed the most complete plugging of emitters and the highest standard deviation resulting in no significant difference in means. On lateral A3, groups 1 and 2 were statistically the same, while groups 1 and 3 were also statistically the same. Emitters located within group 2 discharged the greatest mean volume for all three laterals evaluated. This greater discharge was due to water movement toward the lower portion of the field during depressurization. During collection of emission volumes group 2 was the last group to be recorded because of the time required for emitters to stop discharging water. The mean volume emitted from group 2 in lateral A2 was not much greater than group 1 but 16.66% of the emitters within group 2 were completely plugged compared to no emitters completely plugged within group 1.

Groups within laterals at site B showed a range of good to poor statistical uniformity (table 4). Results of the different methods used to evaluate application uniformity of the laterals at site B, and the significance between groups within the laterals is shown in table 8. The statistical and distribution uniformity groups and lateral for site B did not vary as much as those at the other two sites. No emitters were completely plugged so the two methods used to calculate statistical uniformity were the same. For each lateral, group 3 showed the lowest statistical and distribution uniformity. Group 1 had the highest statistical uniformity for laterals B1 and B3, but group 2 had the highest distribution uniformity in laterals B2 and B3. The overall statistical uniformity for lateral B1 was 79.98 and a distribution uniformity of 72.60. Lateral B2 had a statistical uniformity of 79.06 and distribution uniformity of 73.59. Lateral B3 had 83.55 and 76.57 statistical and distribution uniformities, respectively.

Table 7. Evaluation of emission volumes collected from three laterals at site A.

	Emission Volume							
Group	**Mean (ml)**	**S.D.**	**C.V.**	**Emitters Plugged (%)**	**C.V. with Emitter Plugging**	**Statistical[a] Uniformity**	**Statistical[b] Uniformity with Emitter Plugging**	**DUlq[c]**
lateral A1								
1	412.61b*	16.81	0.04	0.00	0.04	95.93	95.93	94.74
2	605.36a	61.27	0.10	0.00	0.10	89.88	89.88	85.68
3	151.05c	133.88	0.89	16.66	1.07	11.37	N.A.	0.15
Lateral	389.68	206.29	0.53	5.55	0.60	47.06	40.38	26.77
lateral A2								
1	366.52a	38.77	0.11	0.00	0.11	89.42	89.42	87.36
2	369.83a	285.64	0.77	16.66	0.96	22.76	4.31	0.26
3	203.32a	155.10	0.76	25.00	1.05	23.72	N.A.	0.00
Lateral	313.23	199.73	0.64	13.88	0.80	36.24	20.42	9.49
lateral A3								
1	423.40a,b	97.82	0.23	0.00	0.23	76.90	76.90	68.20
2	596.52a	239.07	0.40	0.00	0.40	59.92	59.92	43.99
3	269.24b	171.64	0.64	8.33	0.73	36.25	26.91	3.36
Lateral	429.73	220.48	0.51	2.77	0.55	48.69	45.30	35.96
Site	377.54	212.67	0.56	7.40	0.65	43.67	34.99	24.88

*Means with different letter designations are significantly different ($p < 0.05$).
[a] Statistical Uniformity was calculated using equation 1 and V_{qs}
[b]Statistical Uniformity was calculated using equation 1 and 2
[c]DUlq was calculated using equation 4.

Statistical evaluation between group means within lateral B1 showed significant difference between group 2 and 3. Significant differences were determined between each of the groups of lateral B2. Lateral B3 showed significant differences between group 1 and 3 and between group 2 and 3. Group 2 discharged the greatest mean emission volume of the three groups for each lateral. Amoozegar et al. (1994) reported similar findings in laboratory experiments with lateral placed on a continuous slope.

Table 8. Evaluation of emission volumes collected from three laterals at site B.

Group	Emission Volume Mean (ml)	S.D.	C.V.	Emitters Plugged (%)	C.V. with Emitter Plugging	Statistical[a] Uniformity	Statistical[b] Uniformity with Emitter Plugging	DUlq[c]
lateral B1								
1	409.34a,b*	55.98	0.14	0.00	0.14	86.32	86.32	82.76
2	444.54a	63.52	0.14	0.00	0.14	85.71	85.71	80.62
3	362.90b	100.78	0.28	0.00	0.28	72.23	72.23	70.92
Lateral	405.60	81.21	0.20	0.00	0.20	79.98	79.98	72.60
lateral B2								
1	390.56b	38.93	0.10	0.00	0.10	90.03	90.03	86.37
2	459.47a	41.32	0.09	0.00	0.09	91.01	91.01	86.67
3	320.72c	86.69	0.27	0.00	0.27	72.97	72.97	62.34
Lateral	390.25	81.70	0.21	0.00	0.21	79.06	79.06	73.59
lateral B3								
1	414.72a	31.63	0.08	0.00	0.08	92.37	92.37	89.89
2	424.35a	32.77	0.08	0.00	0.08	92.28	92.28	91.74
3	335.26b	76.80	0.23	0.00	0.23	77.09	77.09	69.35
Lateral	391.45	64.38	0.16	0.00	0.16	83.55	83.55	76.57
Site	395.76	75.80	0.19	0.00	0.19	80.85	80.85	74.03

* Means with different letter designations are significantly different ($p < 0.05$).
[a] Statistical Uniformity was calculated using equation 1 and V_{qs}
[b]Statistical Uniformity was calculated using equation 1 and 2
[c]DUlq was calculated using equation 4.

The laterals at site C showed a range of poor to unacceptable statistical uniformity according to table 4. The different methods used to evaluate the application uniformity of site C, and the significance between the groups within the laterals is shown in table 9. The application uniformity of site C was the poorest of the three sites evaluated. Within laterals C1 and C2, application uniformity for groups 2 and 2 was N.A. or 0.00 depending on the method used. When the uniformity was N.A. the coefficient of variation was greater than one which resulted in negative application uniformity. Group 1 of laterals C1 and C2 had application uniformity ranging between 65.75 to 53.22 and 25.85 to 0.08, respectively. Lateral C3 had the best uniformity with values ranging from 57.58 to 40.68 for group 1, 55.41 to 47.54 for group 2, and 34.27 to 24.21 for group 3. The overall application uniformity of laterals C1 and C2 were either N.A. or 0.00 while lateral C3 was 44.41 to 23.72. Laterals C1 and C2 showed a statistically greater volume of water for group 1 compared to groups 2 and 3. Groups 2 and 3 of lateral C1 and C2 had a large percentage of completely plugged emitters. Hills and Brenes (2001) observed emitters at the distal ends of laterals in the laboratory partially or fully clogged due to accumulation of silts and bacterial slimes. Groups 1 and 2 on lateral three were statistically the same while group 3 was statistically different.

The operating pressure of the different sites was also recorded during field evaluation and is shown in table 10. Netafim recommends an operating pressure of 172 to 276 kPa (25 to 40 psi) (Netafim, 2002). The operation pressure of sites A and C are below the recommended operation pressure. Conversely at site B the operating pressure for groups 1 and 2 are greater than recommended while, pressures for group 3 is within the recommended range. The operating pressure of the different systems correlates well with application uniformity and emitter plugging of the different sites. Sites A and C, which were operated below the recommended pressure, showed the lowest application uniformity and the most emitter plugging. Both sites A and C had a large pressure loss from the pump house to the field. Site B had the highest operating pressure in the field, best application uniformity and no complete emitter plugging in the field. Talozi and Hill's (2001) model of drip distribution systems showed similar results. They reported increases in inlet pressures with increased emitter plugging.

Table 9. Evaluation of emission volumes collected from three laterals at site C.

	Emission Volume							
Group	**Mean (ml)**	**S.D.**	**C.V.**	**Emitters Plugged (%)**	**C.V. with Emitter Plugging**	**Statistical[a] Uniformity**	**Statistical[b] Uniformity with Emitter Plugging**	**DUlq[c]**
lateral C1								
1	622.23a*	213.13	0.34	8.33	0.47	65.75	53.22	59.15
2	32.76b	69.55	2.12	66.66	3.94	N.A.	N.A.	0.00
3	15.61b	44.11	2.83	83.33	7.27	N.A	N.A.	0.00
Lateral	223.54	313.39	1.40	52.77	2.30	N.A.	N.A.	0.00
lateral C2								
1	465.17a	344.93	0.74	8.33	0.83	25.85	16.89	0.08
2	106.01b	177.05	1.67	66.66	3.22	N.A.	N.A.	0.00
3	31.15b	65.38	2.10	58.33	3.46	N.A.	N.A.	0.00
Lateral	200.78	292.41	1.46	47.22	2.22	N.A.	N.A.	0.00
lateral C3								
1	322.13a	136.66	0.42	0.00	0.42	57.58	57.58	40.68
2	306.47a	136.65	0.45	0.00	0.45	55.41	55.41	47.54
3	152.16b	100.02	0.66	0.00	0.66	34.27	34.27	24.21
Lateral	260.26	144.69	0.56	0.00	0.56	44.41	44.41	23.72
Site	228.19	259.89	1.14	33.33	1.56	N.A.	N.A.	0.00

* Means with different letter designations are significantly different ($p < 0.05$).

[a] Statistical Uniformity was calculated using equation 1 and V_{qs}

[b]Statistical Uniformity was calculated using equation 1 and 2
[c]DUlq was calculated using equation 4.

Table 10. Average operation pressure for sites A, B, and C.

	Pressure kPa (psi)			
Lateral	**Pump House**	**Group 1**	**Group 2**	**Group 3**
Site A	372 (54)			
1		***[a]	***	***
2		56 (8.0)	54 (7.8)	40 (5.8)
3		79 (11.4)	63 (9.1)	57 (8.3)
Site B	***			
1		344 (50.0)	282 (40.9)	263 (38.2)
2		346 (50.3)	283 (41.1)	264 (38.3)
3		346 (50.3)	284 (41.2)	256 (37.1)
Site C	391 (56.6)			
1		92 (13.3)	78 (11.3)	79 (11.5)
2		93 (13.5)	82 (11.9)	78 (11.4)
3		88 (12.8)	***	32 (4.6)

[a] Indicates missing data points.

Field Flow Rates

Drip laterals from three different sites in operation were collected and returned to the lab to determine the flow rate from each emitter under pressurized flow (Appendix F, G, and H). Analysis was done on the flow rates from the different sites to compare the statistical and distribution uniformity of the emitters under pressurized flow verses the flow under field conditions. In addition, laterals were tested to determine whether the flow rate of individual emitters is within 10% of the nominal flow rate published by the manufacture for type Y emitters (tables 11-13).

The flow range for any one emitter could vary from 2.106 to 2.574 L/hr (0.56 to 0.68 gph). Site A had 36% of the emitters evaluated to be within range, 22% to be considered below and 43% to be considered above. Site B had 71%, 10%, and 19% to be considered within, below, and above range, respectively. Site C had 30%, 69%, and 1% emitters to be considered within, below, and above range, respectively.

Differences in application uniformity between field and lab conditions come from the different site conditions that affect uniformity. Site conditions affecting the statistical uniformity include site topography causing drainage to lower portions of the field, hydraulic properties of the system, length of runs, and operating pressure. Emitter variations due to plugging, manufacture's coefficient of variation, or wear also affect uniformity. Evaluating the emitter flow rate in the lab eliminated site conditions affecting the emitter; therefore, statistical and distribution uniformity of the emitter flow rate was determined by emitter variations. Since the manufacturer's coefficient of variation is defined and published, emitter variations are narrowed down to emitter plugging and wear.

Site A showed an increase in the application uniformity of the laterals in the laboratory compared to field conditions. Lateral A1's overall application uniformity increased as well as the uniformity within group 3, but uniformity within groups 1 and 2 decreased slightly. The overall uniformity of lateral A2 increased. This increase was attributed to the percentage of completely plugged emitters going from 13.88% to 0.00%. There were, however, several emitters with low flow rates indicated with the minimum flow rate. Lateral A3 showed an increase in application uniformity in each group as well as the entire lateral. Statistical uniformity for laterals at site A range from unacceptable to good according to ASAE criteria. The mean flow rate from each group was statistically similar for all laterals. Variation in volumes collected from emitters in the field could be due to site slope, drainage of the laterals to the lower portions of the field, and the hydraulic condition at the site.

Site B showed very little change in application uniformity between the lab and the field. However, there was an increase in the uniformity in group 3 for laterals B1 and B3. All laterals showed unacceptable to good statistical uniformity according to ASAE criteria.

Site C showed a varied change in application uniformity from the field to the lab. Lateral C1 had a decrease in uniformity for group 1 while groups 2 and 3 stayed the same. Lateral C2 had an increase in uniformity for group 1 while groups 2 and 3 stayed the same. Groups 2 and 3 experienced severe plugging within groups. Lateral C3 had an increase in uniformity for each group within the lateral and for the entire lateral. The increase in uniformity of lateral C3 could be attributed to an increase in operation pressure during the lab test compared to operation pressure observed in the field. As previously discussed, the measured field operation pressure was below the pressure compensating range of the emitters for group 3.

Table 11. Evaluation of emitter flow rates collected from three laterals at site A.

		Emitter Flow Rate					Range %							
Group	**n**	**Mean (L/hr)**	**Max (L/hr)**	**Min (L/hr)**	**S.D.**	**C.V.**	**Above**	**Within**	**Below**	**Emitters Plugged (%)**	**C.V. with Emitter Plugging**	**Statistical[a] Uniformity**	**Statistical[b] Uniformity with Emitter Plugging**	**DUlq[c]**
lateral A1														
1	12	2.39a*	2.60	2.17	0.15	0.06	8	92	0	0.00	0.06	93.72	93.72	92.37
2	12	2.24a	2.76	1.56	0.33	0.15	8	58	33	0.00	0.15	85.27	85.27	80.79
3	11	2.00a	4.09	0.00	1.59	0.80	64	0	36	16.66	0.98	20.50	2.11	1.21
Total	35	2.21	4.09	0.00	0.90	0.41	26	51	23	5.55	0.48	59.38	51.68	49.53
lateral A2														
1	12	2.50a	3.71	2.01	0.43	0.17	33	58	8	0.00	0.17	82.80	82.80	86.60
2	12	2.21a	3.35	0.02	1.34	0.61	50	25	25	0.00	0.61	39.37	39.37	2.76
3	13	2.02a	4.86	0.02	1.68	0.83	38	23	38	0.00	0.83	16.83	16.83	1.87
Total	37	2.24	4.86	0.02	1.26	0.56	41	35	24	0.00	0.56	43.92	43.92	14.91
lateral A3														
1	12	2.70a	3.36	1.87	0.43	0.16	67	25	8	0.00	0.16	84.07	84.07	80.16
2	12	2.56a	3.43	1.12	0.72	0.28	58	17	25	0.00	0.28	71.88	71.88	61.02
3	12	2.43a	3.69	0.06	1.00	0.41	58	25	17	0.00	0.41	58.85	58.85	46.41
Total	36	2.56	3.69	0.06	0.74	0.29	61	22	17	0.00	0.29	70.97	70.97	62.01
Site	108	2.34	4.86	0.00	1.00	0.43	43	36	22	1.85	0.46	57.00	54.48	42.74

* Means with different letter designations are significantly different ($p < 0.05$).

[a] Statistical Uniformity was calculated using equation 1 and V_{qs}

[b] Statistical Uniformity was calculated using equation 1 and 2

[c] DUlq was calculated using equation 4.

Table 12. Evaluation of emitter flow rates collected from three laterals at site B.

		Emitter Flow Rate					Range %							
Group	n	Mean (L/hr)	Max (L/hr)	Min (L/hr)	S.D.	C.V.	Above	Within	Below	Emitters Plugged (%)	C.V. with Emitter Plugging	Statistical[a] Uniformity	Statistical[b] Uniformity with Emitter Plugging	DUlq[c]
lateral B1														
1	12	2.62a*	4.58	2.15	0.67	0.26	25	75	0	0.00	0.26	74.43	74.43	84.92
2	12	2.31a	2.67	1.94	0.21	0.09	8	67	25	0.00	0.09	90.91	90.91	88.47
3	12	2.51a	2.87	2.18	0.19	0.08	42	58	0	0.00	0.08	92.43	92.43	91.02
Total	36	2.48	4.58	1.94	0.43	0.17	25	67	8	0.00	0..17	82.87	82.87	86.92
lateral B2														
1	12	2.24a	2.62	1.92	0.21	0.09	8	67	25	0.00	0.09	90.63	90.63	88.14
2	12	2.31a	2.57	1.74	0.21	0.09	0	92	8	0.00	0.09	90.91	90.91	88.38
3	12	2.16a	2.66	0.02	0.70	0.32	8	75	17	0.00	0.32	67.59	67.59	63.63
Total	36	2.24	2.66	0.02	0.43	0.19	6	78	17	0.00	0.19	80.70	80.70	79.99
lateral B3														
1	12	2.42b	2.70	2.11	0.18	0.07	17	83	0	0.00	0.07	92.56	92.56	90.57
2	12	2.28b	2.50	1.98	0.14	0.06	0	92	8	0.00	0.06	93.86	93.86	92.01
3	12	2.73a	3.36	2.10	0.42	0.15	58	33	8	0.00	0.15	84.62	84.62	79.55
Total	36	2.48	3.36	1.98	0.33	0.13	25	69	6	0.00	0.13	86.67	86.67	86.41
Site	108	2.40	4.58	0.02	0.41	0.17	19	71	10	0.00	0.17	83.00	83.00	84.17

* Means with different letter designations are significantly different ($p < 0.05$).

[a] Statistical Uniformity was calculated using equation 1 and V_{qs}

[b] Statistical Uniformity was calculated using equation 1 and 2

[c] DUlq was calculated using equation 4.

Table 13. Evaluation of emitter flow rates collected for three laterals from site C.

		Emitter Flow Rate					Range %							
Group	**n**	**Mean (L/hr)**	**Max (L/hr)**	**Min (L/hr)**	**S.D.**	**C.V.**	**Above**	**Within**	**Below**	**Emitters Plugged (%)**	**C.V. with Emitter Plugging**	**Statistical[a] Uniformity**	**Statistical[b] Uniformity with Emitter Plugging**	**DUlq[c]**
lateral 1														
1	12	1.43a*	2.38	0.00	0.94	0.66	0	33	67	8.33	0.75	34.27	25.02	8.27
2	12	0.30b	2.26	0.00	0.68	2.27	0	8	92	75.00	4.85	N.A.	N.A.	0.00
3	12	0.39b	1.98	0.00	0.61	1.56	0	0	100	50.00	2.43	N.A.	N.A.	0.00
Total	36	0.71	2.38	0.00	0.90	1.27	0	14	86	44.44	1.93	N.A.	N.A.	0.00
lateral 2														
1	12	1.81a	2.30	0.00	0.66	0.36	0	42	58	8.33	0.49	63.54	51.43	48.59
2	12	0.82b	2.35	0.00	0.92	1.12	0	8	92	75.00	2.83	N.A.	N.A.	0.00
3	12	0.46b	2.25	0.00	0.85	1.85	0	8	92	50.00	2.80	N.A.	N.A.	0.00
Total	36	1.03	2.35	0.00	0.98	0.96	0	19	81	44.44	1.56	4.36	N.A.	0.00
lateral 3														
1	12	2.05a	2.47	0.86	0.44	0.21	0	58	42	0.00	0.21	78.54	78.54	71.45
2	12	2.14a	2.52	1.74	0.23	0.11	0	50	50	0.00	0.11	89.25	89.25	87.16
3	12	2.22a	2.62	1.79	0.25	0.11	8	58	33	0.00	0.11	88.74	88.74	85.19
Total	36	2.14	2.62	0.86	0.32	0.15	3	53	42	0.00	0.15	85.04	85.04	80.86
Site	108	1.89	2.62	0.00	1.00	0.77	1	30	69	29.62	1.12	23.00	N.A.	0.00

* Means with different letter designations are significantly different ($p < 0.05$).

[a] Statistical Uniformity was calculated using equation 1 and V_{qs}

[b] Statistical Uniformity was calculated using equation 1 and 2

[c] DUlq was calculated using equation 4.

Emitter Flow Rate Recovery Experiment

All tubing collected during field evaluation was subjected to the emitter flow rate recovery experiment. This study used various combinations of flushing and chlorination as the treatments. All tubing was subjected to the same three treatments: flushing velocity of 0.15 m/s (0.5 ft/s) with no chlorination, a shock chlorination of 3400 mg/L (3400 ppm) over a contact time of two hours and an additional flushing velocity of 0.15 m/s (0.5 ft/s), and a shock chlorination of 3400 mg/L (3400 ppm) and a flushing velocity of 0.6 m/s (2 ft/s). Treatment options will be referred to as treatments flhalf, clhalf, and cltwo, respectively.

The treatment options chosen for this experiment address physical and biological emitter plugging factors. Flushing events are used to remove sediment and other particles from the tubing either by carrying sediment back to the pretreatment device or by forcing the material through the emitters. Shock chlorination treatments are used to break-up and kill biological material in the tubing.

Average emitter flow rate from site A showed no significant difference between treatment options within groups 1 and 2. Group 3, however, showed a significant difference between treatments cltwo and flhalf. Although there were no differences between treatments, some of the individual emitters were recovered to within 10% of the published nominal flow rate, while others moved out of the interval. The percentage of emitters within, above, and below 10% of the nominal flow rate is shown in table 14.

Table 14. Comparison of emitter flow rates measured after treatment regiments on drip laterals collected from site A.

	Flow Rate						Range %		
Treatment	**Mean (L/hr)**	**S.D.**	**C.V.**	**Max (L/hr)**	**Min (L/hr)**	**Emitters Plugged %**	**Above**	**Within**	**Below**
lateral A1									
initial	2.21	0.90	0.41	4.09	0.00	5.71	26	51	26
flhalf	2.08	0.80	0.38	2.71	0.02	0.00	11	69	23
clhalf	2.22	0.59	0.26	2.72	0.04	0.00	3	83	17
cltwo	2.54	0.52	0.21	5.09	2.03	0.00	19	75	6
lateral A2									
initial	2.24	1.26	0.56	4.86	0.02	0.00	41	35	24
flhalf	2.00	0.98	0.49	3.46	0.02	0.00	16	59	24
clhalf	2.33	0.58	0.25	3.49	0.42	0.00	22	70	8
cltwo	2.48	0.31	0.12	3.90	1.87	0.00	22	76	3
lateral A3									
initial	2.56	0.74	0.29	3.69	0.06	0.00	61	22	17
flhalf	2.37	0.57	0.24	3.50	0.06	0.00	19	69	11
clhalf	2.41	0.73	0.30	4.79	0.02	0.00	25	64	11
cltwo	2.53	0.56	0.22	4.13	0.36	0.00	25	72	3
All Emitters									
initial	2.34a,b	1.00	0.43	4.86	0.00	1.85	43	36	22
flhalf	2.15b	0.81	0.38	3.50	0.02	0.00	16	66	19
clhalf	2.32a,b	0.63	0.27	4.79	0.02	0.00	17	72	12
cltwo	2.52a	0.47	0.19	5.09	0.36	0.00	22	75	4

* Means with different letter designations are significantly different ($p < 0.05$).

Average emitter flow rates from site B showed no significant difference between any of the lateral treatments. However, flow rates of individual emitters varied thus changing the percent of emitters being above, within or below 10% of the nominal published flow rate (Table 15). Typically, the percent of emitters within 10% of the nominal flow rate increased following the treatment regiments.

Table 15. Comparison of emitter flow rates measured after treatment regiments on drip laterals collected from site B.

Treatment	Flow Rate Mean (L/hr)	S.D.	C.V.	Max (L/hr)	Min (L/hr)	Emitters Plugged %	Range % Above	Within	Below
lateral B1									
initial	2.48	0.43	0.17	4.58	1.94	0.00	25	67	8
flhalf	2.42	0.39	0.16	4.48	2.10	0.00	14	83	3
clhalf	2.44	0.76	0.31	6.86	2.07	0.00	3	94	3
cltwo	2.48	0.91	0.36	7.71	2.06	0.00	6	92	3
lateral B2									
initial	2.24	0.43	0.19	2.66	0.02	0.00	6	78	17
flhalf	2.30	0.17	0.07	2.78	1.92	0.00	6	83	11
clhalf	2.32	0.13	0.06	2.73	2.06	0.00	6	92	3
cltwo	2.32	0.09	0.04	2.53	2.16	0.00	0	100	0
lateral B3									
initial	2.48	0.33	0.13	3.36	1.98	0.00	25	69	6
flhalf	2.34	0.17	0.07	2.75	2.06	0.00	11	83	6
clhalf	2.30	0.11	0.05	2.74	2.11	0.00	3	97	0
cltwo	2.31	0.15	0.06	2.91	1.99	0.00	3	94	3
Total									
initial	2.40a	0.41	0.17	4.58	0.02	0.00	19	71	10
flhalf	2.36a	0.27	0.11	4.48	1.92	0.00	10	83	6
clhalf	2.35a	0.45	0.19	6.86	2.06	0.00	4	94	2
cltwo	2.37a	0.53	0.23	7.71	1.99	0.00	3	95	2

* Means with different letter designations are significantly different ($p < 0.05$).

Averaged over all emitters from different laterals, emitters from site C showed a significant difference between treatment cltwo and both the initial flow rate and the flow rate after treatment flhalf. Treatments flhalf and the initial flow rate showed no significant difference. Neither did treatment flhalf from clhalf or treatment clhalf from cltwo. When comparing different treatments within groups, all groups showed a significant difference between the initial flow rate and the flow rate after treatment cltwo. Treatments flhalf and clhalf showed no significant difference from either the initial flow rate or the flow rate of treatment cltwo. As with the other sites the percent of emitters with flow rates within 10 % of the nominal flow increased (Table 16).

Table 16. Comparison of emitter flow rates measured after treatment regiments on drip laterals collected from site C.

	Flow Rate						Range %		
Treatment	Mean (L/hr)	S.D.	C.V.	Max (L/hr)	Min (L/hr)	Emitters Plugged %	Above	Within	Below
lateral C1									
initial	0.71	0.90	1.27	2.38	0.00	44.44	0	14	86
flhalf	0.99	0.96	0.97	2.37	0.00	36.11	0	22	78
clhalf	1.32	0.90	0.68	2.29	0.00	16.66	0	33	67
cltwo	1.73	0.74	0.43	2.49	0.00	8.33	0	42	58
lateral C2									
initial	1.03	0.98	0.96	2.35	0.00	44.44	0	19	81
flhalf	1.17	1.04	0.89	2.56	0.00	38.88	0	36	64
clhalf	1.34	1.05	0.79	2.56	0.00	30.55	0	44	56
cltwo	1.65	0.86	0.52	2.66	0.00	13.88	3	47	50
lateral C3									
initial	2.14	0.32	0.15	2.62	0.86	0.00	3	56	42
flhalf	2.21	0.20	0.09	2.55	1.49	0.00	0	75	25
clhalf	2.19	0.25	0.11	2.55	1.09	0.00	0	75	25
cltwo	2.30	0.09	0.04	2.53	2.09	0.00	0	97	3
Total									
initial	1.29c	1.00	0.77	2.62	0.00	29.62	1	30	69
flhalf	1.46b,c	0.98	0.67	2.56	0.00	25.00	0	44	56
clhalf	1.62a,b	0.90	0.56	2.56	0.00	15.74	0	51	49
cltwo	1.89a	0.71	0.38	2.66	0.00	7.40	1	62	37

* Means with different letter designations are significantly different ($p < 0.05$).

SUMMARY AND CONCLUSIONS

An evaluation of drip distribution systems was conducted to better understand factors affecting emitter plugging and the effect of emitter plugging on application uniformity.

The first experiment evaluated the effects of slope and contour orientation of laterals during the dosing cycle on the potential of emitter plugging due to suctioning of soil into the emitters during depressurization. Results of the experiment showed that there was no significant difference ($p > 0.05$) in mean flow rate for type Y and type Z drip emitters installed up and down the slope, but there was a significant difference for type Z emitters oriented on the contour between a 1% and 2% slope and no difference for type Y emitters. Averaged over all emitters no significant difference was found between initial flow rate and flow rate after a year of simulated use. However, there were significant differences for type Y emitters between initial flow rate and those following a simulated year of use to the flow rate after the laterals were flushed.

Field application uniformity tests of three sites under similar operation and maintenance programs were evaluated. Using ASAE criteria the application uniformity of the laterals evaluated ranged from fair to unacceptable. While application uniformity in different groups within the laterals ranged from excellent to unacceptable using ASAE criteria. This variation in application uniformity between groups emphasizes that all portions of the distribution system need to be evaluated when assessing application uniformity. There was also a correlation between application uniformity of the systems and operating pressure. For the systems evaluated, application uniformity was better for the system with the highest operation pressure compared to systems with lower operating pressures. The system with the highest operating pressure also had no complete plugging of emitters while the other systems had complete plugging of several emitters.

Other site conditions also affected the volume of water collected from different groups within the laterals. Emitters located at the down slope ends of the laterals typically emitted a greater volume of water than emitters located in other portions of the laterals, and emitters located at the end of the lateral emitted less water than emitters in other portions of the lateral.

Emitters were collected and taken to the laboratory to evaluate flow rate of emitters that had been in operation for several years. Emitters evaluated had flow rates both greater and lesser than 10% of the nominal flow rate published by the manufacturer. The average flow rate from seven of the nine laterals evaluated was within 10% of the nominal flow rate for the emitter. The percentage of emitters within 10% of the nominal flow rate ranged from 78% to 14% for the nine laterals tested while within groups variation was 92% to 0% within 10% of the nominal flow rate. The percentage of emitters that discharged greater than 10% of the nominal flow rate ranged from 61% to 0% and 67% to 0% within laterals and groups, respectively, and the percentage that discharged less than 10% of the nominal flow rate ranged from 86% to 6% and 100% to 0% within laterals and groups, respectively.

In addition to the flow rate measurements for the individual emitters the application uniformity of the laterals was evaluated to compare between the field application uniformity. Evaluating application uniformity using emitter flow rates determined in the laboratory eliminates the effect of site conditions. Site A application uniformity increased in the lab compared to that observed in the field showing that field conditions affect the application uniformity. Site B showed little difference in application uniformity between the laboratory and field. Laterals that did change showed an increase in application uniformity. Site C showed both a decrease and an increase in application uniformity between laboratory and field evaluations. Lateral C1 showed a decrease in application uniformity for group 1 but laterals 2 and 3 showed increases in application uniformity in the laboratory compared to the field.

Emitters were subjected to a regiment of treatments to recover the emitter flow rates to the published flow rate. After each treatment regiment the flow rate of the emitters was collected and evaluated. For site A averaged over all emitters, there was only a significant difference between the second chlorine shock treatment and the first flush treatment. Within groups 1 and 2, there was no significant difference between treatments, but for group 3 there was a significant difference between the first flush and the second chlorine treatment. For site B, there was no significant difference between treatments for all the emitters or within groups. For site C, there was significant difference between the initial flow rate and the chlorine treatments and between the first flush treatment and the second chlorine treatment when comparing all emitters. When comparing groups, there was a significant difference in the flow rate between the initial flow rate and the second chlorine treatment, but the average flow rate for the site was still below 10% of the nominal flow rate of the emitters.

These results are limited to the systems evaluated with similar operation and maintenance procedures and site conditions. Under different operation and maintenance procedures, or site conditions results could vary from those presented here depending on the differences in operation and maintenance and design of the systems. To properly evaluate the application uniformity of a subsurface drip distribution system the volume of water applied by emitters within all lateral groups must be evaluated for a normal dosing cycle of the system.

FUTURE WORK

Although this research provided new information concerning drip distribution, data was limited to one type of tubing and management program. Therefore, the following questions still need to be addressed;

- Evaluation of emitters by different manufactures,
- Evaluation of design approaches in reference to operation pressure, and
- Evaluation of and maintenance procedures.

The addition of this information would strengthen this data set, and provide new insight to the proper design and maintenance of this technology.

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APPENDIX A

FLOW RATES FOR NETAFIM PRESSURE COMPENSATING EMITTERS FOR SLOPE TEST

Flow rate measurements were conducted on 324 Netafim Bioline 2.34 L/hr pressure compensating emitters from the manufacturer, after a simulated year, and after flushing. This appendix lists all the emitters used in this research by location and reporting the average flow rate for each emitter in liters per hour (L/hr) and gallons per hour (gph).

						Initial		After Test		After Flush	
Emitter	Lateral Position	Line Position	Slope	Lateral	Line	Average Flow Rate (L/hr)	Average Flow Rate (gph)	Average Flow Rate (L/hr)	Average Flow Rate (gph)	Average Flow Rate (L/hr)	Average Flow Rate (gph)
1	1	1	4	1	1	2.61	0.69	0.10	0.03	2.59	0.69
3	3	3	4	1	1	2.51	0.66	3.04	0.80	3.45	0.91
5	5	5	4	1	1	2.27	0.60	3.61	0.95	4.06	1.07
7	7	7	4	1	1	2.46	0.65	3.05	0.81	5.66	1.50
9	9	9	4	1	1	2.35	0.62	3.15	0.83	4.82	1.27
11	11	11	4	1	1	2.29	0.61	4.37	1.15	3.60	0.95
13	13	1	4	1	2	2.43	0.64	2.20	0.58	2.31	0.61
15	15	3	4	1	2	2.74	0.73	2.52	0.67	2.54	0.67
17	17	5	4	1	2	2.60	0.69	2.26	0.60	2.28	0.60
19	19	7	4	1	2	2.17	0.57	2.37	0.63	2.46	0.65
21	21	9	4	1	2	2.21	0.58	2.24	0.59	2.17	0.57
23	23	11	4	1	2	2.22	0.59	0.04	0.01	0.03	0.01
25	25	1	4	1	3	2.30	0.61	2.63	0.70	5.39	1.42
27	27	3	4	1	3	2.33	0.62	2.57	0.68	3.04	0.80
29	29	5	4	1	3	2.35	0.62	0.03	0.01	0.16	0.04
31	31	7	4	1	3	2.38	0.63	2.77	0.73	2.70	0.71
33	33	9	4	1	3	2.37	0.63	0.00	0.00	0.00	0.00
35	35	11	4	1	3	2.25	0.59	0.06	0.02	3.36	0.89
37	1	1	4	2	4	2.33	0.61	0.04	0.01	2.45	0.65
39	3	3	4	2	4	2.46	0.65	2.52	0.67	3.04	0.80
41	5	5	4	2	4	2.54	0.67	2.40	0.63	2.73	0.72

Emitter	Lateral Position	Line Position	Slope	Lateral	Line	Initial Average Flow Rate (L/hr)	Initial Average Flow Rate (gph)	After Test Average Flow Rate (L/hr)	After Test Average Flow Rate (gph)	After Flush Average Flow Rate (L/hr)	After Flush Average Flow Rate (gph)
43	7	7	4	2	4	2.28	0.60	2.33	0.62	2.48	0.66
45	9	9	4	2	4	2.38	0.63	2.79	0.74	2.43	0.64
47	11	11	4	2	4	2.39	0.63	2.58	0.68	3.02	0.80
49	13	1	4	2	5	2.38	0.63	2.84	0.75	2.11	0.56
51	15	3	4	2	5	2.73	0.72	2.44	0.64	2.25	0.60
53	17	5	4	2	5	2.58	0.68	2.17	0.57	2.26	0.60
55	19	7	4	2	5	2.43	0.64	2.52	0.67	2.61	0.69
57	21	9	4	2	5	2.24	0.59	2.06	0.54	2.10	0.56
59	23	11	4	2	5	2.22	0.59	2.29	0.61	2.34	0.62
61	25	1	4	2	6	2.42	0.64	2.77	0.73	3.16	0.83
63	27	3	4	2	6	2.38	0.63	2.78	0.73	3.23	0.85
65	29	5	4	2	6	2.39	0.63	3.09	0.82	5.20	1.37
67	31	7	4	2	6	2.21	0.58	1.91	0.50	2.27	0.60
69	33	9	4	2	6	2.22	0.59	2.79	0.74	3.21	0.85
71	35	11	4	2	6	2.11	0.56	0.05	0.01	3.98	1.05
73	1	1	4	3	7	2.15	0.57	3.39	0.89	3.58	0.95
75	3	3	4	3	7	1.94	0.51	2.63	0.69	3.21	0.85
77	5	5	4	3	7	2.38	0.63	2.88	0.76	2.86	0.76
79	7	7	4	3	7	2.27	0.60	3.27	0.86	2.88	0.76
81	9	9	4	3	7	2.02	0.53	2.60	0.69	2.57	0.68
83	11	11	4	3	7	2.44	0.64	2.60	0.69	2.95	0.78

						Initial		After Test		After Flush	
Emitter	Lateral Position	Line Position	Slope	Lateral	Line	Average Flow Rate (L/hr)	Average Flow Rate (gph)	Average Flow Rate (L/hr)	Average Flow Rate (gph)	Average Flow Rate (L/hr)	Average Flow Rate (gph)
85	13	1	4	3	8	2.52	0.67	2.35	0.62	2.11	0.56
87	15	3	4	3	8	2.49	0.66	2.29	0.61	2.36	0.62
89	17	5	4	3	8	2.23	0.59	2.38	0.63	2.36	0.62
91	19	7	4	3	8	2.11	0.56	0.08	0.02	0.10	0.03
93	21	9	4	3	8	2.36	0.62	0.08	0.02	0.10	0.03
95	23	11	4	3	8	1.77	0.47	0.20	0.05	0.69	0.18
97	25	1	4	3	9	2.63	0.70	3.05	0.81	3.61	0.95
99	27	3	4	3	9	2.47	0.65	4.97	1.31	3.14	0.83
101	29	5	4	3	9	2.21	0.58	4.71	1.24	4.38	1.16
103	31	7	4	3	9	2.47	0.65	4.06	1.07	4.07	1.08
105	33	9	4	3	9	2.51	0.66	0.33	0.09	2.92	0.77
107	35	11	4	3	9	2.36	0.62	0.40	0.11	3.71	0.98
109	1	1	2	4	10	2.43	0.64	2.94	0.78	2.56	0.68
111	3	3	2	4	10	2.68	0.71	3.91	1.03	3.13	0.83
113	5	5	2	4	10	2.54	0.67	3.02	0.80	3.15	0.83
115	7	7	2	4	10	2.42	0.64	3.33	0.88	3.06	0.81
117	9	9	2	4	10	2.34	0.62	2.33	0.61	2.98	0.79
119	11	11	2	4	10	2.76	0.73	5.10	1.35	5.06	1.34
121	13	1	2	4	11	2.31	0.61	2.28	0.60	2.46	0.65
123	15	3	2	4	11	2.58	0.68	2.42	0.64	2.51	0.66
125	17	5	2	4	11	2.85	0.75	2.20	0.58	2.49	0.66

						Initial		After Test		After Flush	
Emitter	**Lateral Position**	**Line Position**	**Slope**	**Lateral**	**Line**	**Average Flow Rate (L/hr)**	**Average Flow Rate (gph)**	**Average Flow Rate (L/hr)**	**Average Flow Rate (gph)**	**Average Flow Rate (L/hr)**	**Average Flow Rate (gph)**
127	19	7	2	4	11	2.48	0.65	2.62	0.69	2.47	0.65
129	21	9	2	4	11	2.06	0.55	2.20	0.58	2.20	0.58
131	23	11	2	4	11	2.09	0.55	2.46	0.65	2.46	0.65
133	25	1	2	4	12	2.44	0.64	2.98	0.79	2.77	0.73
135	27	3	2	4	12	2.40	0.63	2.54	0.67	3.40	0.90
137	29	5	2	4	12	2.30	0.61	3.91	1.03	3.85	1.02
139	31	7	2	4	12	2.47	0.65	3.29	0.87	2.64	0.70
141	33	9	2	4	12	2.18	0.58	0.01	0.00	3.19	0.84
143	35	11	2	4	12	2.35	0.62	2.27	0.60	2.73	0.72
145	1	1	2	5	13	2.36	0.62	2.43	0.64	2.44	0.64
147	3	3	2	5	13	2.28	0.60	2.29	0.60	2.47	0.65
149	5	5	2	5	13	2.24	0.59	4.81	1.27	4.53	1.20
151	7	7	2	5	13	2.44	0.64	2.92	0.77	2.81	0.74
153	9	9	2	5	13	2.26	0.60	3.78	1.00	3.37	0.89
155	11	11	2	5	13	2.26	0.60	3.87	1.02	5.81	1.54
157	13	1	2	5	14	2.39	0.63	2.58	0.68	2.38	0.63
159	15	3	2	5	14	2.60	0.69	2.04	0.54	2.28	0.60
161	17	5	2	5	14	2.56	0.68	2.78	0.73	2.49	0.66
163	19	7	2	5	14	2.22	0.59	4.36	1.15	4.21	1.11
165	21	9	2	5	14	2.01	0.53	4.27	1.13	4.13	1.09
167	23	11	2	5	14	2.20	0.58	0.38	0.10	2.07	0.55

Emitter	Lateral Position	Line Position	Slope	Lateral	Line	Initial Average Flow Rate (L/hr)	Initial Average Flow Rate (gph)	After Test Average Flow Rate (L/hr)	After Test Average Flow Rate (gph)	After Flush Average Flow Rate (L/hr)	After Flush Average Flow Rate (gph)
169	25	1	2	5	15	2.38	0.63	3.03	0.80	3.25	0.86
171	27	3	2	5	15	2.39	0.63	3.54	0.93	3.24	0.85
173	29	5	2	5	15	2.29	0.60	5.16	1.36	2.46	0.65
175	31	7	2	5	15	2.29	0.61	4.15	1.10	2.72	0.72
177	33	9	2	5	15	2.49	0.66	0.12	0.03	2.77	0.73
179	35	11	2	5	15	2.32	0.61	4.41	1.16	2.35	0.62
181	1	1	2	6	16	2.43	0.64	3.26	0.86	4.37	1.15
183	3	3	2	6	16	2.53	0.67	2.57	0.68	3.30	0.87
185	5	5	2	6	16	2.53	0.67	3.95	1.04	5.21	1.38
187	7	7	2	6	16	2.42	0.64	6.12	1.62	7.08	1.87
189	9	9	2	6	16	2.42	0.64	2.25	0.59	7.38	1.95
191	11	11	2	6	16	2.27	0.60	3.12	0.83	4.77	1.26
193	13	1	2	6	17	2.58	0.68	2.64	0.70	2.54	0.67
195	15	3	2	6	17	2.72	0.72	2.04	0.54	2.37	0.63
197	17	5	2	6	17	2.60	0.69	2.59	0.68	2.52	0.67
199	19	7	2	6	17	2.38	0.63	2.32	0.61	2.34	0.62
201	21	9	2	6	17	2.47	0.65	2.35	0.62	2.39	0.63
203	23	11	2	6	17	2.09	0.55	2.60	0.69	2.48	0.66
205	25	1	2	6	18	2.85	0.75	3.43	0.91	2.44	0.65
207	27	3	2	6	18	2.51	0.66	2.10	0.55	2.60	0.69
209	29	5	2	6	18	2.40	0.63	3.58	0.95	2.52	0.66

Emitter	Lateral Position	Line Position	Slope	Lateral	Line	Initial Average Flow Rate (L/hr)	Initial Average Flow Rate (gph)	After Test Average Flow Rate (L/hr)	After Test Average Flow Rate (gph)	After Flush Average Flow Rate (L/hr)	After Flush Average Flow Rate (gph)
211	31	7	2	6	18	2.47	0.65	0.17	0.04	2.43	0.64
213	33	9	2	6	18	2.37	0.63	0.06	0.01	2.34	0.62
215	35	11	2	6	18	2.52	0.67	0.02	0.01	2.30	0.61
217	1	1	1	7	19	2.48	0.65	0.61	0.16	2.68	0.71
219	3	3	1	7	19	2.50	0.66	2.52	0.67	3.13	0.83
221	5	5	1	7	19	2.46	0.65	3.68	0.97	4.54	1.20
223	7	7	1	7	19	2.32	0.61	4.26	1.12	3.55	0.94
225	9	9	1	7	19	2.38	0.63	3.01	0.80	5.36	1.42
227	11	11	1	7	19	2.44	0.64	2.37	0.63	3.50	0.92
229	13	1	1	7	20	2.42	0.64	2.29	0.61	2.23	0.59
231	15	3	1	7	20	2.60	0.69	2.15	0.57	2.36	0.62
233	17	5	1	7	20	2.89	0.76	2.58	0.68	2.77	0.73
235	19	7	1	7	20	2.42	0.64	2.40	0.63	2.47	0.65
237	21	9	1	7	20	2.36	0.62	3.05	0.81	2.48	0.66
239	23	11	1	7	20	2.30	0.61	2.52	0.66	2.50	0.66
241	25	1	1	7	21	2.47	0.65	3.65	0.96	2.73	0.72
243	27	3	1	7	21	2.25	0.60	3.53	0.93	2.65	0.70
245	29	5	1	7	21	2.43	0.64	0.04	0.01	2.67	0.70
247	31	7	1	7	21	2.27	0.60	0.08	0.02	2.51	0.66
249	33	9	1	7	21	2.44	0.65	0.00	0.00	2.47	0.65
251	35	11	1	7	21	2.45	0.65	0.02	0.01	2.86	0.76

						Initial		After Test		After Flush	
Emitter	**Lateral Position**	**Line Position**	**Slope**	**Lateral**	**Line**	**Average Flow Rate (L/hr)**	**Average Flow Rate (gph)**	**Average Flow Rate (L/hr)**	**Average Flow Rate (gph)**	**Average Flow Rate (L/hr)**	**Average Flow Rate (gph)**
253	1	1	1	8	22	2.31	0.61	3.39	0.89	2.67	0.70
255	3	3	1	8	22	2.44	0.64	2.75	0.73	3.78	1.00
257	5	5	1	8	22	2.30	0.61	3.40	0.90	3.29	0.87
259	7	7	1	8	22	2.37	0.63	3.21	0.85	4.09	1.08
261	9	9	1	8	22	2.40	0.63	4.25	1.12	4.73	1.25
263	11	11	1	8	22	2.30	0.61	3.03	0.80	4.24	1.12
265	13	1	1	8	23	2.39	0.63	2.43	0.64	2.33	0.62
267	15	3	1	8	23	2.64	0.70	0.11	0.03	2.37	0.63
269	17	5	1	8	23	2.59	0.69	2.52	0.66	2.45	0.65
271	19	7	1	8	23	2.21	0.58	2.68	0.71	2.48	0.66
273	21	9	1	8	23	2.24	0.59	2.37	0.62	2.26	0.60
275	23	11	1	8	23	2.09	0.55	2.35	0.62	2.28	0.60
277	25	1	1	8	24	2.25	0.59	3.75	0.99	3.40	0.90
279	27	3	1	8	24	2.44	0.64	3.00	0.79	2.52	0.67
281	29	5	1	8	24	2.33	0.62	3.25	0.86	3.26	0.86
283	31	7	1	8	24	2.38	0.63	0.08	0.02	2.90	0.77
285	33	9	1	8	24	2.36	0.62	3.26	0.86	2.76	0.73
287	35	11	1	8	24	2.27	0.60	0.03	0.01	2.49	0.66
289	1	1	1	9	25	2.40	0.63	2.37	0.63	3.83	1.01
291	3	3	1	9	25	2.34	0.62	2.51	0.66	3.01	0.79
293	5	5	1	9	25	2.32	0.61	2.51	0.66	2.98	0.79

Emitter	Lateral Position	Line Position	Slope	Lateral	Line	Initial Average Flow Rate (L/hr)	Initial Average Flow Rate (gph)	After Test Average Flow Rate (L/hr)	After Test Average Flow Rate (gph)	After Flush Average Flow Rate (L/hr)	After Flush Average Flow Rate (gph)
295	7	7	1	9	25	2.40	0.63	0.03	0.01	2.83	0.75
297	9	9	1	9	25	2.29	0.60	0.28	0.07	2.36	0.62
299	11	11	1	9	25	2.51	0.66	0.00	0.00	2.66	0.70
301	13	1	1	9	26	2.47	0.65	2.41	0.64	2.24	0.59
303	15	3	1	9	26	2.61	0.69	2.40	0.64	2.33	0.62
305	17	5	1	9	26	2.61	0.69	2.35	0.62	2.37	0.63
307	19	7	1	9	26	2.35	0.62	3.15	0.83	2.45	0.65
309	21	9	1	9	26	2.11	0.56	2.50	0.66	2.01	0.53
311	23	11	1	9	26	2.17	0.57	2.45	0.65	2.40	0.63
313	25	1	1	9	27	2.39	0.63	2.66	0.70	3.15	0.83
315	27	3	1	9	27	2.43	0.64	1.98	0.52	3.19	0.84
317	29	5	1	9	27	2.36	0.62	2.37	0.63	3.23	0.85
319	31	7	1	9	27	2.51	0.66	1.42	0.37	3.38	0.89
321	33	9	1	9	27	2.48	0.66	3.41	0.90	2.56	0.68
323	35	11	1	9	27	2.38	0.63	0.00	0.00	2.57	0.68
325	1	1	0	10	28	2.31	0.61	2.49	0.66	2.35	0.62
327	3	3	0	10	28	2.32	0.61	3.50	0.93	2.34	0.62
329	5	5	0	10	28	2.12	0.56	3.74	0.99	3.20	0.85
331	7	7	0	10	28	2.32	0.61	5.12	1.35	5.45	1.44
333	9	9	0	10	28	2.40	0.63	3.13	0.83	6.19	1.64
335	11	11	0	10	28	2.32	0.61	1.81	0.48	2.85	0.75

Emitter	Lateral Position	Line Position	Slope	Lateral	Line	Initial Average Flow Rate (L/hr)	Initial Average Flow Rate (gph)	After Test Average Flow Rate (L/hr)	After Test Average Flow Rate (gph)	After Flush Average Flow Rate (L/hr)	After Flush Average Flow Rate (gph)
337	13	1	0	10	29	2.51	0.66	2.34	0.62	2.46	0.65
339	15	3	0	10	29	2.49	0.66	3.03	0.80	2.28	0.60
341	17	5	0	10	29	2.45	0.65	4.30	1.14	4.31	1.14
343	19	7	0	10	29	2.34	0.62	2.17	0.57	2.43	0.64
345	21	9	0	10	29	2.13	0.56	2.68	0.71	2.72	0.72
347	23	11	0	10	29	2.08	0.55	2.47	0.65	2.43	0.64
349	25	1	0	10	30	2.41	0.64	3.41	0.90	2.57	0.68
351	27	3	0	10	30	2.43	0.64	3.31	0.87	2.39	0.63
353	29	5	0	10	30	2.54	0.67	0.31	0.08	3.42	0.90
355	31	7	0	10	30	2.46	0.65	0.20	0.05	2.55	0.67
357	33	9	0	10	30	2.48	0.65	0.03	0.01	2.41	0.64
359	35	11	0	10	30	2.42	0.64	0.02	0.01	2.43	0.64
361	1	1	0	11	31	2.32	0.61	2.35	0.62	2.38	0.63
363	3	3	0	11	31	2.38	0.63	2.35	0.62	2.56	0.68
365	5	5	0	11	31	2.26	0.60	2.58	0.68	2.30	0.61
367	7	7	0	11	31	2.36	0.62	3.35	0.89	3.30	0.87
369	9	9	0	11	31	2.22	0.59	2.47	0.65	2.71	0.72
371	11	11	0	11	31	2.53	0.67	2.74	0.72	3.23	0.85
373	13	1	0	11	32	2.59	0.68	2.72	0.72	2.78	0.73
375	15	3	0	11	32	2.66	0.70	2.99	0.79	2.52	0.67
377	17	5	0	11	32	2.90	0.77	3.18	0.84	2.60	0.69

						Initial		After Test		After Flush	
Emitter	Lateral Position	Line Position	Slope	Lateral	Line	Average Flow Rate (L/hr)	Average Flow Rate (gph)	Average Flow Rate (L/hr)	Average Flow Rate (gph)	Average Flow Rate (L/hr)	Average Flow Rate (gph)
379	19	7	0	11	32	2.40	0.63	3.13	0.83	2.52	0.67
381	21	9	0	11	32	2.10	0.55	3.04	0.80	2.56	0.68
383	23	11	0	11	32	2.10	0.56	2.45	0.65	2.62	0.69
385	25	1	0	11	33	2.46	0.65	0.55	0.15	2.99	0.79
387	27	3	0	11	33	2.41	0.64	4.09	1.08	2.46	0.65
389	29	5	0	11	33	2.41	0.64	0.01	0.00	2.58	0.68
391	31	7	0	11	33	2.45	0.65	0.00	0.00	2.56	0.68
393	33	9	0	11	33	2.39	0.63	0.00	0.00	2.88	0.76
395	35	11	0	11	33	2.53	0.67	0.00	0.00	2.53	0.67
397	1	1	0	12	34	2.50	0.66	3.40	0.90	3.85	1.02
399	3	3	0	12	34	2.42	0.64	2.37	0.62	2.44	0.65
401	5	5	0	12	34	2.45	0.65	2.70	0.71	2.58	0.68
403	7	7	2	14	36	2.37	0.63	2.66	0.70	3.39	0.90
405	9	9	4	16	38	2.41	0.64	3.00	0.79	3.32	0.88
407	11	11	6	18	40	2.47	0.65	2.62	0.69	3.10	0.82
409	13	13	8	20	42	2.35	0.62	2.27	0.60	2.66	0.70
411	15	15	10	22	44	2.48	0.65	2.23	0.59	2.49	0.66
413	17	17	12	24	46	2.57	0.68	2.34	0.62	2.28	0.60
415	19	19	14	26	48	2.34	0.62	2.71	0.72	2.65	0.70
417	21	21	16	28	50	2.23	0.59	2.39	0.63	2.68	0.71
419	23	23	18	30	52	2.25	0.60	2.50	0.66	2.62	0.69

Emitter	Lateral Position	Line Position	Slope	Lateral	Line	Initial Average Flow Rate (L/hr)	Initial Average Flow Rate (gph)	After Test Average Flow Rate (L/hr)	After Test Average Flow Rate (gph)	After Flush Average Flow Rate (L/hr)	After Flush Average Flow Rate (gph)
421	25	25	20	32	54	2.51	0.66	2.63	0.69	3.78	1.00
423	27	27	22	34	56	2.48	0.65	2.95	0.78	3.23	0.85
425	29	29	24	36	58	2.36	0.62	0.40	0.10	3.15	0.83
427	31	31	26	38	60	2.32	0.61	2.03	0.54	2.66	0.70
429	33	33	28	40	62	2.27	0.60	2.62	0.69	2.34	0.62
431	35	35	30	42	64	2.46	0.65	2.79	0.74	2.32	0.61
433	1	1	c2	13	37	2.60	0.69	2.72	0.72	2.51	0.66
435	3	3	c2	13	37	2.54	0.67	0.52	0.14	2.67	0.71
437	5	5	c2	13	37	2.40	0.63	3.30	0.87	4.16	1.10
439	7	7	c2	13	37	2.36	0.62	5.24	1.38	5.41	1.43
441	9	9	c2	13	37	2.45	0.65	4.81	1.27	4.62	1.22
443	11	11	c2	13	37	2.39	0.63	3.20	0.84	2.85	0.75
445	13	1	c2	13	38	2.45	0.65	0.00	0.00	2.46	0.65
447	15	3	c2	13	38	2.72	0.72	2.42	0.64	2.37	0.63
449	17	5	c2	13	38	2.60	0.69	2.22	0.59	2.21	0.58
451	19	7	c2	13	38	2.57	0.68	2.24	0.59	2.22	0.59
453	21	9	c2	13	38	2.20	0.58	2.70	0.71	2.86	0.76
455	23	11	c2	13	38	2.24	0.59	2.28	0.60	2.40	0.64
457	25	1	c2	13	39	2.42	0.64	2.85	0.75	3.02	0.80
459	27	3	c2	13	39	2.15	0.57	3.44	0.91	2.62	0.69
461	29	5	c2	13	39	2.48	0.65	2.71	0.72	2.46	0.65

Emitter	Lateral Position	Line Position	Slope	Lateral	Line	Initial Average Flow Rate (L/hr)	Initial Average Flow Rate (gph)	After Test Average Flow Rate (L/hr)	After Test Average Flow Rate (gph)	After Flush Average Flow Rate (L/hr)	After Flush Average Flow Rate (gph)
463	31	7	c2	13	39	2.31	0.61	0.00	0.00	2.54	0.67
465	33	9	c2	13	39	2.45	0.65	3.31	0.87	2.66	0.70
467	35	11	c2	13	39	2.48	0.66	0.00	0.00	2.92	0.77
469	1	1	c2	14	40	2.44	0.64	2.30	0.61	2.46	0.65
471	3	3	c2	14	40	2.46	0.65	5.58	1.47	4.83	1.28
473	5	5	c2	14	40	2.39	0.63	3.14	0.83	2.61	0.69
475	7	7	c2	14	40	2.44	0.65	2.13	0.56	5.55	1.47
477	9	9	c2	14	40	2.41	0.64	1.25	0.33	4.65	1.23
479	11	11	c2	14	40	2.40	0.64	3.36	0.89	2.65	0.70
481	13	1	c2	14	41	2.51	0.66	2.46	0.65	2.55	0.67
483	15	3	c2	14	41	2.56	0.68	0.19	0.05	2.36	0.62
485	17	5	c2	14	41	2.62	0.69	0.70	0.18	2.31	0.61
487	19	7	c2	14	41	2.39	0.63	2.72	0.72	2.52	0.67
489	21	9	c2	14	41	1.98	0.52	2.81	0.74	2.67	0.71
491	23	11	c2	14	41	2.04	0.54	2.51	0.66	2.63	0.69
493	25	1	c2	14	42	2.24	0.59	0.51	0.13	1.03	0.27
495	27	3	c2	14	42	2.30	0.61	0.55	0.14	1.17	0.31
497	29	5	c2	14	42	2.23	0.59	0.66	0.17	1.10	0.29
499	31	7	c2	14	42	2.34	0.62	4.62	1.22	3.11	0.82
501	33	9	c2	14	42	2.18	0.58	0.21	0.06	0.55	0.14
503	35	11	c2	14	42	2.25	0.59	2.87	0.76	2.56	0.68

Emitter	Lateral Position	Line Position	Slope	Lateral	Line	Initial Average Flow Rate (L/hr)	Initial Average Flow Rate (gph)	After Test Average Flow Rate (L/hr)	After Test Average Flow Rate (gph)	After Flush Average Flow Rate (L/hr)	After Flush Average Flow Rate (gph)
505	1	1	c2	15	43	2.45	0.65	2.41	0.64	2.47	0.65
507	3	3	c2	15	43	2.29	0.61	1.14	0.30	3.77	1.00
509	5	5	c2	15	43	2.47	0.65	4.64	1.22	5.56	1.47
511	7	7	c2	15	43	2.23	0.59	1.69	0.45	5.54	1.46
513	9	9	c2	15	43	2.38	0.63	4.93	1.30	4.09	1.08
515	11	11	c2	15	43	2.38	0.63	5.14	1.36	3.92	1.04
517	13	1	c2	15	44	2.77	0.73	2.38	0.63	2.64	0.70
519	15	3	c2	15	44	2.42	0.64	2.12	0.56	2.19	0.58
521	17	5	c2	15	44	2.56	0.68	2.90	0.77	2.45	0.65
523	19	7	c2	15	44	2.24	0.59	2.04	0.54	2.48	0.65
525	21	9	c2	15	44	2.02	0.53	2.79	0.74	2.34	0.62
527	23	11	c2	15	44	2.05	0.54	1.90	0.50	2.49	0.66
529	25	1	c2	15	45	2.37	0.63	2.78	0.74	3.77	1.00
531	27	3	c2	15	45	2.36	0.62	3.67	0.97	2.55	0.67
533	29	5	c2	15	45	2.43	0.64	0.07	0.02	2.68	0.71
535	31	7	c2	15	45	2.46	0.65	3.41	0.90	2.86	0.76
537	33	9	c2	15	45	2.22	0.59	3.72	0.98	2.44	0.65
539	35	11	c2	15	45	2.12	0.56	0.00	0.00	2.59	0.69
541	1	1	c1	16	46	2.34	0.62	2.57	0.68	2.52	0.66
543	3	3	c1	16	46	2.39	0.63	4.72	1.25	5.75	1.52
545	5	5	c1	16	46	2.44	0.64	0.53	0.14	0.56	0.15

Emitter	Lateral Position	Line Position	Slope	Lateral	Line	Initial Average Flow Rate (L/hr)	Initial Average Flow Rate (gph)	After Test Average Flow Rate (L/hr)	After Test Average Flow Rate (gph)	After Flush Average Flow Rate (L/hr)	After Flush Average Flow Rate (gph)
547	7	7	c1	16	46	2.38	0.63	3.78	1.00	4.05	1.07
549	9	9	c1	16	46	2.41	0.64	3.20	0.84	7.16	1.89
551	11	11	c1	16	46	2.32	0.61	4.86	1.28	4.10	1.08
553	13	1	c1	16	47	2.42	0.64	2.63	0.70	2.28	0.60
555	15	3	c1	16	47	2.48	0.65	2.54	0.67	2.27	0.60
557	17	5	c1	16	47	2.50	0.66	2.37	0.63	2.05	0.54
559	19	7	c1	16	47	2.31	0.61	2.47	0.65	2.46	0.65
561	21	9	c1	16	47	2.20	0.58	0.40	0.11	2.38	0.63
563	23	11	c1	16	47	2.29	0.60	0.46	0.12	2.34	0.62
565	25	1	c1	16	48	2.54	0.67	2.83	0.75	3.62	0.96
567	27	3	c1	16	48	2.23	0.59	3.31	0.87	2.55	0.67
569	29	5	c1	16	48	2.24	0.59	0.28	0.07	4.20	1.11
571	31	7	c1	16	48	2.40	0.63	0.96	0.25	4.11	1.09
573	33	9	c1	16	48	2.42	0.64	0.03	0.01	2.53	0.67
575	35	11	c1	16	48	2.21	0.58	0.15	0.04	2.88	0.76
577	1	1	c1	17	49	2.36	0.62	2.70	0.71	2.74	0.72
579	3	3	c1	17	49	2.51	0.66	3.89	1.03	7.06	1.87
581	5	5	c1	17	49	2.32	0.61	5.60	1.48	8.77	2.32
583	7	7	c1	17	49	2.16	0.57	3.59	0.95	2.75	0.73
585	9	9	c1	17	49	2.33	0.62	3.71	0.98	4.08	1.08
587	11	11	c1	17	49	2.08	0.55	0.35	0.09	3.52	0.93

						Initial		After Test		After Flush	
Emitter	Lateral Position	Line Position	Slope	Lateral	Line	Average Flow Rate (L/hr)	Average Flow Rate (gph)	Average Flow Rate (L/hr)	Average Flow Rate (gph)	Average Flow Rate (L/hr)	Average Flow Rate (gph)
589	13	1	c1	17	50	2.55	0.67	0.04	0.01	2.43	0.64
591	15	3	c1	17	50	2.50	0.66	0.17	0.04	2.20	0.58
593	17	5	c1	17	50	2.34	0.62	4.11	1.08	2.25	0.60
595	19	7	c1	17	50	2.22	0.59	2.83	0.75	2.29	0.61
597	21	9	c1	17	50	1.94	0.51	2.79	0.74	2.67	0.71
599	23	11	c1	17	50	2.09	0.55	2.75	0.73	2.55	0.67
601	25	1	c1	17	51	2.40	0.63	3.14	0.83	3.70	0.98
603	27	3	c1	17	51	2.56	0.68	2.28	0.60	2.59	0.68
605	29	5	c1	17	51	2.49	0.66	2.75	0.73	2.64	0.70
607	31	7	c1	17	51	2.46	0.65	2.71	0.71	2.84	0.75
609	33	9	c1	17	51	2.36	0.62	3.04	0.80	3.50	0.93
611	35	11	c1	17	51	2.34	0.62	2.72	0.72	2.40	0.63
613	1	1	c1	17	52	2.59	0.68	2.39	0.63	2.63	0.69
615	3	3	c1	18	52	2.24	0.59	0.94	0.25	3.05	0.81
617	5	5	c1	18	52	2.30	0.61	3.07	0.81	5.14	1.36
619	7	7	c1	18	52	2.31	0.61	3.46	0.91	3.48	0.92
621	9	9	c1	18	52	2.20	0.58	4.16	1.10	3.36	0.89
623	11	11	c1	18	52	2.33	0.62	3.89	1.03	5.31	1.40
625	13	1	c1	18	53	2.40	0.63	2.41	0.64	2.43	0.64
627	15	3	c1	18	53	2.60	0.69	0.18	0.05	2.55	0.67
629	17	5	c1	18	53	2.47	0.65	2.79	0.74	2.61	0.69

Emitter	Lateral Position	Line Position	Slope	Lateral	Line	Initial Average Flow Rate (L/hr)	Initial Average Flow Rate (gph)	After Test Average Flow Rate (L/hr)	After Test Average Flow Rate (gph)	After Flush Average Flow Rate (L/hr)	After Flush Average Flow Rate (gph)
631	19	7	c1	18	53	2.13	0.56	2.92	0.77	2.47	0.65
633	21	9	c1	18	53	2.19	0.58	2.70	0.71	2.44	0.65
635	23	11	c1	18	53	2.17	0.57	3.57	0.94	2.49	0.66
637	25	1	c1	18	54	2.58	0.68	2.69	0.71	2.97	0.78
639	27	3	c1	18	54	2.36	0.62	3.24	0.86	2.61	0.69
641	29	5	c1	18	54	2.23	0.59	0.34	0.09	2.40	0.63
643	31	7	c1	18	54	2.39	0.63	3.07	0.81	2.47	0.65
645	33	9	c1	18	54	2.27	0.60	0.00	0.00	2.44	0.64
647	35	11	c1	18	54	2.32	0.61	3.20	0.85	2.86	0.75

APPENDIX B

FLOW RATES FOR GEOFLOW PRESSURE COMPENSATING EMITTERS FOR SLOPE TEST

Flow rate measurements were conducted on 324 Geoflow 1.98 L/hr (0.51 gph) pressure compensating emitters from the manufacturer, after a simulated year, and after flushing. This appendix lists all the emitters used in this research by location and reporting the average flow rate for each emitter in liters per hour (L/hr) and gallons per hour (gph). Results for 316 emitters are displayed 8 emitters were eliminated due to wrong emitter type

Emitter	Lateral Position	Line Position	Slope	Lateral	Line	Initial Average Flow Rate (L/hr)	Initial Average Flow Rate (gph)	After Test Average Flow Rate (L/hr)	After Test Average Flow Rate (gph)	After Flush Average Flow Rate (L/hr)	After Flush Average Flow Rate (gph)
2	2	2	4	1	1	2.49	0.66	2.38	0.63	2.46	0.65
4	4	4	4	1	1	2.42	0.64	2.71	0.72	2.47	0.65
6	6	6	4	1	1	2.28	0.60	3.12	0.82	2.31	0.61
8	8	8	4	1	1	2.48	0.66	2.59	0.68	2.48	0.66
10	10	10	4	1	1	2.37	0.63	2.50	0.66	2.42	0.64
12	12	12	4	1	1	2.34	0.62	2.38	0.63	2.38	0.63
14	14	2	4	1	2	2.56	0.68	2.45	0.65	3.29	0.87
16	16	4	4	1	2	2.62	0.69	2.42	0.64	4.26	1.12
18	18	6	4	1	2	2.52	0.67	2.46	0.65	3.14	0.83
20	20	8	4	1	2	2.13	0.56	2.46	0.65	2.91	0.77
22	22	10	4	1	2	2.25	0.59	2.57	0.68	2.84	0.75
24	24	12	4	1	2	2.24	0.59	2.59	0.68	2.81	0.74
26	26	2	4	1	3	2.39	0.63	2.39	0.63	2.32	0.61
28	28	4	4	1	3	2.34	0.62	2.23	0.59	2.20	0.58
30	30	6	4	1	3	2.22	0.59	2.03	0.54	2.07	0.55
32	32	8	4	1	3	2.48	0.66	0.00	0.00	0.00	0.00
34	34	10	4	1	3	2.36	0.62	0.00	0.00	0.06	0.01
36	36	12	4	1	3	2.35	0.62	2.43	0.64	2.34	0.62
38	2	2	4	2	4	2.43	0.64	2.46	0.65	2.45	0.65
40	4	4	4	2	4	2.48	0.65	2.35	0.62	2.60	0.69
42	6	6	4	2	4	2.44	0.64	2.44	0.64	2.49	0.66
44	8	8	4	2	4	2.28	0.60	2.28	0.60	2.32	0.61

						Initial		After Test		After Flush	
Emitter	**Lateral Position**	**Line Position**	**Slope**	**Lateral**	**Line**	**Average Flow Rate (L/hr)**	**Average Flow Rate (gph)**	**Average Flow Rate (L/hr)**	**Average Flow Rate (gph)**	**Average Flow Rate (L/hr)**	**Average Flow Rate (gph)**
46	10	10	4	2	4	2.49	0.66	2.49	0.66	2.49	0.66
48	12	12	4	2	4	2.37	0.63	2.36	0.62	2.37	0.63
50	14	2	4	2	5	2.54	0.67	2.64	0.70	2.54	0.67
52	16	4	4	2	5	2.47	0.65	2.42	0.64	2.64	0.70
54	18	6	4	2	5	2.58	0.68	3.06	0.81	2.77	0.73
56	20	8	4	2	5	1.94	0.51	2.54	0.67	2.45	0.65
58	22	10	4	2	5	2.21	0.58	2.57	0.68	3.61	0.95
60	24	12	4	2	5	2.21	0.58	3.55	0.94	2.94	0.78
62	26	2	4	2	6	2.47	0.65	2.60	0.69	2.61	0.69
64	28	4	4	2	6	2.34	0.62	0.01	0.00	0.10	0.03
66	30	6	4	2	6	2.01	0.53	2.09	0.55	1.98	0.52
68	32	8	4	2	6	2.44	0.64	2.55	0.67	2.53	0.67
70	34	10	4	2	6	2.37	0.63	2.52	0.66	2.34	0.62
72	36	12	4	2	6	2.49	0.66	2.32	0.61	2.48	0.66
74	2	2	4	3	7	2.32	0.61	2.38	0.63	2.48	0.65
76	4	4	4	3	7	2.14	0.56	0.09	0.02	1.70	0.45
78	6	6	4	3	7	2.44	0.64	2.42	0.64	2.52	0.67
80	8	8	4	3	7	2.24	0.59	2.28	0.60	2.29	0.61
82	10	10	4	3	7	2.33	0.62	2.33	0.62	2.37	0.63
84	12	12	4	3	7	2.59	0.68	2.37	0.63	2.60	0.69
86	14	2	4	3	8	2.60	0.69	3.12	0.82	2.90	0.77
88	16	4	4	3	8	2.55	0.67	3.03	0.80	3.28	0.87

Emitter	Lateral Position	Line Position	Slope	Lateral	Line	Initial Average Flow Rate (L/hr)	Initial Average Flow Rate (gph)	After Test Average Flow Rate (L/hr)	After Test Average Flow Rate (gph)	After Flush Average Flow Rate (L/hr)	After Flush Average Flow Rate (gph)
90	18	6	4	3	8	2.41	0.64	2.83	0.75	4.32	1.14
92	20	8	4	3	8	2.05	0.54	2.86	0.75	3.20	0.85
94	22	10	4	3	8	2.05	0.54	2.87	0.76	3.26	0.86
96	24	12	4	3	8	2.07	0.55	0.80	0.21	4.13	1.09
98	26	2	4	3	9	2.31	0.61	0.01	0.00	0.02	0.01
100	28	4	4	3	9	2.47	0.65	0.14	0.04	2.16	0.57
102	30	6	4	3	9	2.38	0.63	2.39	0.63	2.36	0.62
104	32	8	4	3	9	2.40	0.63	2.41	0.64	2.48	0.65
106	34	10	4	3	9	2.35	0.62	2.38	0.63	2.46	0.65
108	36	12	4	3	9	2.40	0.64	2.41	0.64	2.32	0.61
110	2	2	2	4	10	2.38	0.63	2.33	0.62	2.39	0.63
112	4	4	2	4	10	2.36	0.62	2.31	0.61	2.36	0.62
114	6	6	2	4	10	2.63	0.69	2.41	0.64	2.46	0.65
116	8	8	2	4	10	2.36	0.62	2.46	0.65	2.44	0.64
118	10	10	2	4	10	2.53	0.67	2.52	0.67	2.52	0.67
120	12	12	2	4	10	2.36	0.62	2.73	0.72	2.38	0.63
122	14	2	2	4	11	2.65	0.70	5.08	1.34	4.41	1.16
124	16	4	2	4	11	2.42	0.64	0.07	0.02	4.82	1.27
126	18	6	2	4	11	2.61	0.69	3.05	0.81	4.23	1.12
128	20	8	2	4	11	2.10	0.55	3.01	0.80	3.90	1.03
130	22	10	2	4	11	2.30	0.61	0.32	0.09	7.04	1.86
132	24	12	2	4	11	2.37	0.63	3.57	0.94	5.59	1.48

Emitter	Lateral Position	Line Position	Slope	Lateral	Line	Initial Average Flow Rate (L/hr)	Initial Average Flow Rate (gph)	After Test Average Flow Rate (L/hr)	After Test Average Flow Rate (gph)	After Flush Average Flow Rate (L/hr)	After Flush Average Flow Rate (gph)
134	26	2	2	4	12	2.50	0.66	2.82	0.74	2.48	0.66
136	28	4	2	4	12	2.40	0.63	2.42	0.64	2.42	0.64
138	30	6	2	4	12	***	***	***	***	***	***
140	32	8	2	4	12	***	***	***	***	***	***
142	34	10	2	4	12	***	***	***	***	***	***
144	36	12	2	4	12	2.36	0.62	2.22	0.59	2.45	0.65
146	2	2	2	5	13	2.21	0.58	2.34	0.62	2.32	0.61
148	4	4	2	5	13	2.57	0.68	2.53	0.67	2.62	0.69
150	6	6	2	5	13	2.59	0.68	2.62	0.69	2.61	0.69
152	8	8	2	5	13	***	***	***	***	***	***
154	10	10	2	5	13	2.34	0.62	2.52	0.67	2.35	0.62
156	12	12	2	5	13	2.41	0.64	2.48	0.66	2.47	0.65
158	14	2	2	5	14	2.40	0.63	4.02	1.06	3.45	0.91
160	16	4	2	5	14	***	***	***	***	***	***
162	18	6	2	5	14	***	***	***	***	***	***
164	20	8	2	5	14	2.33	0.62	3.34	0.88	4.01	1.06
166	22	10	2	5	14	2.10	0.55	3.01	0.80	6.01	1.59
168	24	12	2	5	14	2.33	0.62	3.14	0.83	3.02	0.80
170	26	2	2	5	15	2.55	0.67	0.03	0.01	0.00	0.00
172	28	4	2	5	15	2.45	0.65	2.32	0.61	2.42	0.64
174	30	6	2	5	15	2.40	0.63	0.10	0.03	2.43	0.64
176	32	8	2	5	15	2.29	0.60	0.02	0.00	2.12	0.56

						Initial		After Test		After Flush	
Emitter	Lateral Position	Line Position	Slope	Lateral	Line	Average Flow Rate (L/hr)	Average Flow Rate (gph)	Average Flow Rate (L/hr)	Average Flow Rate (gph)	Average Flow Rate (L/hr)	Average Flow Rate (gph)
178	34	10	2	5	15	2.33	0.61	0.02	0.01	2.51	0.66
180	36	12	2	5	15	2.39	0.63	2.38	0.63	2.46	0.65
182	2	2	2	6	16	2.29	0.60	2.41	0.64	2.39	0.63
184	4	4	2	6	16	2.37	0.62	2.34	0.62	2.53	0.67
186	6	6	2	6	16	2.32	0.61	2.33	0.62	2.55	0.67
188	8	8	2	6	16	2.48	0.65	2.51	0.66	2.65	0.70
190	10	10	2	6	16	2.25	0.60	1.53	0.40	2.43	0.64
192	12	12	2	6	16	2.39	0.63	2.34	0.62	2.51	0.66
194	14	2	2	6	17	2.69	0.71	0.06	0.02	3.40	0.90
196	16	4	2	6	17	2.55	0.67	3.11	0.82	3.84	1.01
198	18	6	2	6	17	2.37	0.63	3.14	0.83	5.91	1.56
200	20	8	2	6	17	2.24	0.59	3.20	0.85	5.90	1.56
202	22	10	2	6	17	2.13	0.56	2.93	0.77	6.55	1.73
204	24	12	2	6	17	2.44	0.64	3.92	1.04	3.72	0.98
206	26	2	2	6	18	2.42	0.64	0.07	0.02	2.26	0.60
208	28	4	2	6	18	2.64	0.70	2.61	0.69	2.59	0.69
210	30	6	2	6	18	2.35	0.62	0.05	0.01	0.07	0.02
212	32	8	2	6	18	2.22	0.59	0.06	0.02	2.09	0.55
214	34	10	2	6	18	***	***	***	***	***	***
216	36	12	2	6	18	2.36	0.62	0.02	0.01	2.23	0.59
218	2	2	1	7	19	2.39	0.63	2.46	0.65	2.63	0.69
220	4	4	1	7	19	2.76	0.73	2.95	0.78	2.99	0.79

Emitter	Lateral Position	Line Position	Slope	Lateral	Line	Initial Average Flow Rate (L/hr)	Initial Average Flow Rate (gph)	After Test Average Flow Rate (L/hr)	After Test Average Flow Rate (gph)	After Flush Average Flow Rate (L/hr)	After Flush Average Flow Rate (gph)
222	6	6	1	7	19	2.50	0.66	2.40	0.63	3.52	0.93
224	8	8	1	7	19	2.38	0.63	2.34	0.62	2.56	0.68
226	10	10	1	7	19	2.42	0.64	0.07	0.02	2.69	0.71
228	12	12	1	7	19	2.64	0.70	2.70	0.71	2.76	0.73
230	14	2	1	7	20	2.69	0.71	4.36	1.15	2.71	0.72
232	16	4	1	7	20	2.79	0.74	1.59	0.42	2.76	0.73
234	18	6	1	7	20	2.60	0.69	3.36	0.89	4.74	1.25
236	20	8	1	7	20	2.51	0.66	2.80	0.74	3.30	0.87
238	22	10	1	7	20	2.23	0.59	2.93	0.77	3.98	1.05
240	24	12	1	7	20	2.11	0.56	2.96	0.78	3.19	0.84
242	26	2	1	7	21	2.35	0.62	2.45	0.65	2.66	0.70
244	28	4	1	7	21	2.38	0.63	3.12	0.82	3.23	0.85
246	30	6	1	7	21	2.52	0.67	2.96	0.78	2.68	0.71
248	32	8	1	7	21	2.31	0.61	0.00	0.00	2.26	0.60
250	34	10	1	7	21	2.41	0.64	0.00	0.00	2.45	0.65
252	36	12	1	7	21	2.31	0.61	2.45	0.65	2.44	0.64
254	2	2	1	8	22	2.35	0.62	2.33	0.62	2.43	0.64
256	4	4	1	8	22	2.54	0.67	2.37	0.62	2.70	0.71
258	6	6	1	8	22	2.40	0.63	2.37	0.63	2.45	0.65
260	8	8	1	8	22	2.28	0.60	2.46	0.65	2.29	0.61
262	10	10	1	8	22	2.40	0.63	2.37	0.63	2.43	0.64
264	12	12	1	8	22	2.46	0.65	2.69	0.71	2.48	0.66

						Initial		After Test		After Flush	
Emitter	**Lateral Position**	**Line Position**	**Slope**	**Lateral**	**Line**	**Average Flow Rate (L/hr)**	**Average Flow Rate (gph)**	**Average Flow Rate (L/hr)**	**Average Flow Rate (gph)**	**Average Flow Rate (L/hr)**	**Average Flow Rate (gph)**
266	14	2	1	8	23	2.39	0.63	2.94	0.78	2.93	0.77
268	16	4	1	8	23	2.41	0.64	3.65	0.96	5.63	1.49
270	18	6	1	8	23	2.44	0.65	0.58	0.15	4.26	1.13
272	20	8	1	8	23	2.20	0.58	3.59	0.95	3.50	0.93
274	22	10	1	8	23	2.14	0.57	3.50	0.93	2.92	0.77
276	24	12	1	8	23	2.22	0.59	4.74	1.25	3.19	0.84
278	26	2	1	8	24	2.38	0.63	2.52	0.67	2.39	0.63
280	28	4	1	8	24	2.38	0.63	2.81	0.74	2.50	0.66
282	30	6	1	8	24	2.39	0.63	2.58	0.68	2.51	0.66
284	32	8	1	8	24	2.55	0.67	2.59	0.68	2.52	0.66
286	34	10	1	8	24	2.50	0.66	2.69	0.71	2.54	0.67
288	36	12	1	8	24	2.39	0.63	2.36	0.62	2.46	0.65
290	2	2	1	9	25	2.27	0.60	2.23	0.59	2.65	0.70
292	4	4	1	9	25	2.28	0.60	2.24	0.59	2.35	0.62
294	6	6	1	9	25	2.35	0.62	0.02	0.01	2.42	0.64
296	8	8	1	9	25	2.47	0.65	0.09	0.02	2.42	0.64
298	10	10	1	9	25	2.40	0.64	2.28	0.60	2.42	0.64
300	12	12	1	9	25	2.38	0.63	2.72	0.72	2.35	0.62
302	14	2	1	9	26	2.64	0.70	3.10	0.82	2.43	0.64
304	16	4	1	9	26	2.26	0.60	0.03	0.01	3.63	0.96
306	18	6	1	9	26	2.51	0.66	0.41	0.11	3.87	1.02
308	20	8	1	9	26	2.14	0.57	3.21	0.85	3.13	0.83

Emitter	Lateral Position	Line Position	Slope	Lateral	Line	Initial Average Flow Rate (L/hr)	Initial Average Flow Rate (gph)	After Test Average Flow Rate (L/hr)	After Test Average Flow Rate (gph)	After Flush Average Flow Rate (L/hr)	After Flush Average Flow Rate (gph)
310	22	10	1	9	26	2.11	0.56	3.14	0.83	3.12	0.83
312	24	12	1	9	26	2.23	0.59	1.13	0.30	6.47	1.71
314	26	2	1	9	27	2.48	0.65	1.31	0.35	2.28	0.60
316	28	4	1	9	27	2.42	0.64	2.57	0.68	2.37	0.63
318	30	6	1	9	27	2.43	0.64	2.84	0.75	2.37	0.63
320	32	8	1	9	27	2.31	0.61	2.14	0.57	2.41	0.64
322	34	10	1	9	27	2.55	0.67	2.86	0.76	2.45	0.65
324	36	12	1	9	27	2.50	0.66	0.00	0.00	2.41	0.64
326	2	2	0	10	28	2.32	0.61	2.69	0.71	2.30	0.61
328	4	4	0	10	28	2.44	0.64	2.33	0.62	2.46	0.65
330	6	6	0	10	28	2.32	0.61	2.30	0.61	2.34	0.62
332	8	8	0	10	28	2.30	0.61	2.64	0.70	2.36	0.62
334	10	10	0	10	28	2.32	0.61	1.28	0.34	2.23	0.59
336	12	12	0	10	28	2.25	0.60	2.16	0.57	2.31	0.61
338	14	2	0	10	29	2.57	0.68	1.29	0.34	3.98	1.05
340	16	4	0	10	29	2.80	0.74	2.34	0.62	2.74	0.72
342	18	6	0	10	29	2.44	0.64	4.38	1.16	3.19	0.84
344	20	8	0	10	29	***	***	***	***	***	***
346	22	10	0	10	29	2.12	0.56	4.81	1.27	4.30	1.14
348	24	12	0	10	29	2.34	0.62	1.17	0.31	4.40	1.16
350	26	2	0	10	30	2.56	0.68	3.03	0.80	2.62	0.69
352	28	4	0	10	30	2.31	0.61	2.35	0.62	2.38	0.63

						Initial		After Test		After Flush	
Emitter	**Lateral Position**	**Line Position**	**Slope**	**Lateral**	**Line**	**Average Flow Rate (L/hr)**	**Average Flow Rate (gph)**	**Average Flow Rate (L/hr)**	**Average Flow Rate (gph)**	**Average Flow Rate (L/hr)**	**Average Flow Rate (gph)**
354	30	6	0	10	30	2.53	0.67	1.17	0.31	2.36	0.62
356	32	8	0	10	30	2.28	0.60	2.30	0.61	2.36	0.62
358	34	10	0	10	30	2.44	0.64	0.03	0.01	2.43	0.64
360	36	12	0	10	30	2.51	0.66	2.75	0.73	2.57	0.68
362	2	2	0	11	31	2.26	0.60	2.31	0.61	2.32	0.61
364	4	4	0	11	31	2.39	0.63	2.49	0.66	2.49	0.66
366	6	6	0	11	31	2.09	0.55	2.20	0.58	2.13	0.56
368	8	8	0	11	31	2.39	0.63	2.56	0.68	2.46	0.65
370	10	10	0	11	31	2.33	0.62	2.40	0.63	2.49	0.66
372	12	12	0	11	31	2.35	0.62	2.61	0.69	2.49	0.66
374	14	2	0	11	32	2.57	0.68	0.02	0.01	2.59	0.69
376	16	4	0	11	32	2.82	0.75	2.25	0.59	2.81	0.74
378	18	6	0	11	32	2.50	0.66	0.42	0.11	2.75	0.73
380	20	8	0	11	32	2.38	0.63	0.44	0.12	3.08	0.81
382	22	10	0	11	32	2.22	0.59	2.87	0.76	2.77	0.73
384	24	12	0	11	32	2.36	0.62	4.10	1.08	2.96	0.78
386	26	2	0	11	33	2.53	0.67	3.05	0.80	2.59	0.68
388	28	4	0	11	33	2.43	0.64	2.64	0.70	2.44	0.65
390	30	6	0	11	33	2.49	0.66	2.50	0.66	2.44	0.64
392	32	8	0	11	33	2.35	0.62	0.00	0.00	2.44	0.64
394	34	10	0	11	33	2.38	0.63	2.41	0.64	2.43	0.64
396	36	12	0	11	33	2.72	0.72	0.00	0.00	2.76	0.73

Emitter	Lateral Position	Line Position	Slope	Lateral	Line	Initial Average Flow Rate (L/hr)	Initial Average Flow Rate (gph)	After Test Average Flow Rate (L/hr)	After Test Average Flow Rate (gph)	After Flush Average Flow Rate (L/hr)	After Flush Average Flow Rate (gph)
398	2	2	0	12	34	2.33	0.61	2.40	0.63	2.44	0.65
400	4	4	0	12	34	2.47	0.65	2.49	0.66	2.55	0.67
402	6	6	0	12	34	2.57	0.68	2.54	0.67	2.58	0.68
404	8	8	0	12	34	2.32	0.61	2.47	0.65	2.37	0.63
406	10	10	0	12	34	2.54	0.67	2.60	0.69	2.59	0.68
408	12	12	0	12	34	2.27	0.60	2.29	0.61	2.35	0.62
410	14	2	0	12	35	2.56	0.68	0.04	0.01	3.25	0.86
412	16	4	0	12	35	2.67	0.70	2.99	0.79	5.33	1.41
414	18	6	0	12	35	2.55	0.67	3.30	0.87	4.27	1.13
416	20	8	0	12	35	2.05	0.54	2.91	0.77	3.65	0.96
418	22	10	0	12	35	2.16	0.57	1.94	0.51	3.29	0.87
420	24	12	0	12	35	2.34	0.62	2.53	0.67	2.78	0.73
422	26	2	0	12	36	2.45	0.65	2.88	0.76	2.65	0.70
424	28	4	0	12	36	2.43	0.64	2.34	0.62	2.61	0.69
426	30	6	0	12	36	2.36	0.62	2.11	0.56	2.47	0.65
428	32	8	0	12	36	2.31	0.61	2.31	0.61	2.25	0.59
430	34	10	0	12	36	2.35	0.62	2.57	0.68	2.30	0.61
432	36	12	0	12	36	2.19	0.58	2.52	0.67	2.39	0.63
434	2	2	c2	13	37	2.33	0.62	2.45	0.65	2.36	0.62
436	4	4	c2	13	37	2.53	0.67	2.57	0.68	2.60	0.69
438	6	6	c2	13	37	2.64	0.70	3.28	0.87	2.67	0.71
440	8	8	c2	13	37	2.29	0.60	0.38	0.10	0.93	0.25

Emitter	Lateral Position	Line Position	Slope	Lateral	Line	Initial Average Flow Rate (L/hr)	Initial Average Flow Rate (gph)	After Test Average Flow Rate (L/hr)	After Test Average Flow Rate (gph)	After Flush Average Flow Rate (L/hr)	After Flush Average Flow Rate (gph)
442	10	10	c2	13	37	2.22	0.59	1.81	0.48	2.13	0.56
444	12	12	c2	13	37	2.32	0.61	2.23	0.59	2.26	0.60
446	14	2	c2	13	38	2.62	0.69	3.32	0.88	3.54	0.94
448	16	4	c2	13	38	2.93	0.77	3.77	1.00	3.15	0.83
450	18	6	c2	13	38	2.46	0.65	0.47	0.12	2.89	0.76
452	20	8	c2	13	38	1.89	0.50	2.86	0.76	2.71	0.72
454	22	10	c2	13	38	2.17	0.57	2.89	0.76	2.84	0.75
456	24	12	c2	13	38	2.38	0.63	3.16	0.83	3.35	0.89
458	26	2	c2	13	39	2.40	0.63	3.38	0.89	2.48	0.66
460	28	4	c2	13	39	2.07	0.55	0.38	0.10	2.10	0.56
462	30	6	c2	13	39	2.31	0.61	0.07	0.02	2.34	0.62
464	32	8	c2	13	39	2.33	0.62	2.53	0.67	2.56	0.68
466	34	10	c2	13	39	2.35	0.62	0.00	0.00	2.37	0.63
468	36	12	c2	13	39	2.44	0.64	0.00	0.00	0.09	0.02
470	2	2	c2	14	40	2.25	0.59	0.03	0.01	2.27	0.60
472	4	4	c2	14	40	2.36	0.62	2.57	0.68	2.31	0.61
474	6	6	c2	14	40	2.34	0.62	2.50	0.66	2.24	0.59
476	8	8	c2	14	40	2.45	0.65	0.49	0.13	2.33	0.62
478	10	10	c2	14	40	2.28	0.60	2.45	0.65	2.35	0.62
480	12	12	c2	14	40	2.51	0.66	2.81	0.74	2.41	0.64
482	14	2	c2	14	41	2.68	0.71	0.28	0.07	1.07	0.28
484	16	4	c2	14	41	2.68	0.71	0.77	0.20	5.32	1.40

Emitter	Lateral Position	Line Position	Slope	Lateral	Line	Initial Average Flow Rate (L/hr)	Initial Average Flow Rate (gph)	After Test Average Flow Rate (L/hr)	After Test Average Flow Rate (gph)	After Flush Average Flow Rate (L/hr)	After Flush Average Flow Rate (gph)
486	18	6	c2	14	41	2.59	0.68	4.34	1.15	3.66	0.97
488	20	8	c2	14	41	2.09	0.55	0.64	0.17	4.44	1.17
490	22	10	c2	14	41	2.07	0.55	0.34	0.09	3.78	1.00
492	24	12	c2	14	41	2.40	0.63	0.95	0.25	3.77	0.99
494	26	2	c2	14	42	2.46	0.65	0.07	0.02	0.12	0.03
496	28	4	c2	14	42	2.53	0.67	2.62	0.69	2.58	0.68
498	30	6	c2	14	42	2.25	0.59	0.97	0.26	2.27	0.60
500	32	8	c2	14	42	2.28	0.60	0.18	0.05	2.38	0.63
502	34	10	c2	14	42	2.47	0.65	0.13	0.04	2.52	0.67
504	36	12	c2	14	42	2.36	0.62	0.00	0.00	0.00	0.00
506	2	2	c2	15	43	2.39	0.63	2.61	0.69	2.36	0.62
508	4	4	c2	15	43	2.41	0.64	2.49	0.66	2.45	0.65
510	6	6	c2	15	43	2.40	0.63	2.93	0.77	2.37	0.63
512	8	8	c2	15	43	2.41	0.64	1.21	0.32	2.43	0.64
514	10	10	c2	15	43	2.48	0.66	2.30	0.61	2.45	0.65
516	12	12	c2	15	43	2.26	0.60	2.62	0.69	2.41	0.64
518	14	2	c2	15	44	2.71	0.71	3.84	1.01	3.00	0.79
520	16	4	c2	15	44	2.62	0.69	3.70	0.98	3.06	0.81
522	18	6	c2	15	44	2.33	0.62	3.98	1.05	2.62	0.69
524	20	8	c2	15	44	2.22	0.59	0.64	0.17	4.10	1.08
526	22	10	c2	15	44	2.03	0.54	4.30	1.13	4.46	1.18
528	24	12	c2	15	44	2.43	0.64	0.50	0.13	3.17	0.84

						Initial		After Test		After Flush	
Emitter	Lateral Position	Line Position	Slope	Lateral	Line	Average Flow Rate (L/hr)	Average Flow Rate (gph)	Average Flow Rate (L/hr)	Average Flow Rate (gph)	Average Flow Rate (L/hr)	Average Flow Rate (gph)
530	26	2	c2	15	45	2.38	0.63	2.63	0.69	2.43	0.64
532	28	4	c2	15	45	2.18	0.58	0.14	0.04	0.90	0.24
534	30	6	c2	15	45	2.35	0.62	0.27	0.07	2.36	0.62
536	32	8	c2	15	45	2.29	0.61	2.44	0.65	2.36	0.62
538	34	10	c2	15	45	2.34	0.62	2.60	0.69	2.47	0.65
540	36	12	c2	15	45	2.57	0.68	2.68	0.71	2.67	0.71
542	2	2	c1	16	46	2.35	0.62	2.36	0.62	2.60	0.69
544	4	4	c1	16	46	2.56	0.68	2.46	0.65	2.57	0.68
546	6	6	c1	16	46	2.35	0.62	3.03	0.80	2.43	0.64
548	8	8	c1	16	46	2.35	0.62	2.96	0.78	2.44	0.64
550	10	10	c1	16	46	2.35	0.62	3.57	0.94	2.42	0.64
552	12	12	c1	16	46	2.38	0.63	1.74	0.46	2.40	0.63
554	14	2	c1	16	47	2.55	0.67	0.19	0.05	3.50	0.92
556	16	4	c1	16	47	2.38	0.63	0.29	0.08	4.89	1.29
558	18	6	c1	16	47	2.42	0.64	3.30	0.87	3.55	0.94
560	20	8	c1	16	47	1.87	0.49	3.48	0.92	2.39	0.63
562	22	10	c1	16	47	2.05	0.54	3.78	1.00	2.47	0.65
564	24	12	c1	16	47	2.15	0.57	3.66	0.97	3.38	0.89
566	26	2	c1	16	48	2.33	0.62	2.56	0.68	2.39	0.63
568	28	4	c1	16	48	2.30	0.61	0.02	0.01	0.04	0.01
570	30	6	c1	16	48	2.33	0.62	2.26	0.60	2.34	0.62
572	32	8	c1	16	48	2.29	0.60	2.66	0.70	2.26	0.60

						Initial		After Test		After Flush	
Emitter	**Lateral Position**	**Line Position**	**Slope**	**Lateral**	**Line**	**Average Flow Rate (L/hr)**	**Average Flow Rate (gph)**	**Average Flow Rate (L/hr)**	**Average Flow Rate (gph)**	**Average Flow Rate (L/hr)**	**Average Flow Rate (gph)**
574	34	10	c1	16	48	2.36	0.62	2.74	0.72	2.34	0.62
576	36	12	c1	16	48	2.15	0.57	2.19	0.58	2.18	0.58
578	2	2	c1	17	49	2.51	0.66	2.50	0.66	2.59	0.68
580	4	4	c1	17	49	2.46	0.65	2.69	0.71	2.56	0.68
582	6	6	c1	17	49	2.40	0.63	2.36	0.62	2.39	0.63
584	8	8	c1	17	49	2.51	0.66	2.50	0.66	2.56	0.68
586	10	10	c1	17	49	2.29	0.60	2.54	0.67	2.42	0.64
588	12	12	c1	17	49	2.42	0.64	2.65	0.70	2.42	0.64
590	14	2	c1	17	50	2.66	0.70	0.05	0.01	2.60	0.69
592	16	4	c1	17	50	2.75	0.73	2.84	0.75	2.50	0.66
594	18	6	c1	17	50	2.26	0.60	2.53	0.67	2.27	0.60
596	20	8	c1	17	50	2.02	0.53	3.37	0.89	2.65	0.70
598	22	10	c1	17	50	1.92	0.51	5.10	1.35	6.69	1.77
600	24	12	c1	17	50	2.11	0.56	3.79	1.00	7.46	1.97
602	26	2	c1	17	51	2.51	0.66	2.47	0.65	2.61	0.69
604	28	4	c1	17	51	2.38	0.63	2.62	0.69	2.44	0.64
606	30	6	c1	17	51	2.29	0.60	2.17	0.57	2.31	0.61
608	32	8	c1	17	51	2.51	0.66	2.53	0.67	2.54	0.67
610	34	10	c1	17	51	2.35	0.62	2.33	0.62	2.36	0.62
612	36	12	c1	17	51	2.47	0.65	2.41	0.64	2.40	0.63
614	2	2	c1	18	52	2.36	0.62	2.51	0.66	2.43	0.64
616	4	4	c1	18	52	2.26	0.60	2.28	0.60	2.46	0.65

Emitter	Lateral Position	Line Position	Slope	Lateral	Line	Initial Average Flow Rate (L/hr)	Initial Average Flow Rate (gph)	After Test Average Flow Rate (L/hr)	After Test Average Flow Rate (gph)	After Flush Average Flow Rate (L/hr)	After Flush Average Flow Rate (gph)
618	6	6	c1	18	52	2.38	0.63	2.41	0.64	2.44	0.65
620	8	8	c1	18	52	2.47	0.65	2.55	0.67	2.61	0.69
622	10	10	c1	18	52	2.51	0.66	3.18	0.84	2.47	0.65
624	12	12	c1	18	52	2.51	0.66	3.69	0.97	2.84	0.75
626	14	2	c1	18	53	2.55	0.67	0.10	0.03	2.69	0.71
628	16	4	c1	18	53	2.63	0.69	0.52	0.14	1.05	0.28
630	18	6	c1	18	53	2.40	0.63	5.02	1.33	5.20	1.37
632	20	8	c1	18	53	2.27	0.60	3.17	0.84	3.27	0.86
634	22	10	c1	18	53	2.26	0.60	5.10	1.35	3.36	0.89
636	24	12	c1	18	53	2.33	0.62	3.63	0.96	5.33	1.41
638	26	2	c1	18	54	2.33	0.61	2.48	0.65	2.50	0.66
640	28	4	c1	18	54	2.42	0.64	2.67	0.71	2.60	0.69
642	30	6	c1	18	54	2.38	0.63	2.82	0.74	2.53	0.67
644	32	8	c1	18	54	2.52	0.67	2.58	0.68	2.61	0.69
646	34	10	c1	18	54	2.26	0.60	2.55	0.67	2.61	0.69
648	36	12	c1	18	54	2.06	0.54	0.00	0.00	0.00	0.00

APPENDIX C

EMITTER FLOW VOLUMES FROM SITE A

The volume of water collected from individual emitters from site A. This appendix lists all emitters used in this research by location and volume of flow in milliliters (ml).

Emitter	Group	Emission Volume (ml) Lateral A1	Lateral A2	Lateral A3
1	1	411.33	367.10	449.20
2	1	406.00	384.90	406.57
3	1	397.33	365.47	452.20
4	1	413.33	385.70	374.90
5	1	418.67	311.07	543.23
6	1	390.00	348.40	408.67
7	1	444.67	452.77	493.27
8	1	416.67	373.13	543.90
9	1	428.33	362.90	469.33
10	1	428.33	389.80	448.23
11	1	385.33	355.97	270.77
12	1	411.33	301.10	220.57
13	2	566.33	660.73	405.37
14	2	604.00	0.00	245.93
15	2	661.67	635.57	798.07
16	2	589.67	549.00	802.60
17	2	650.67	428.47	135.93
18	2	608.67	599.80	605.97
19	2	686.67	3.53	825.90
20	2	501.67	2.90	583.30
21	2	634.67	691.50	794.67
22	2	488.00	0.00	829.10
23	2	622.00	434.17	679.53
24	2	650.33	432.33	451.93
25	3	0.00	282.97	445.00
26	3	308.00	0.80	384.37
27	3	0.00	318.43	20.03
28	3	13.00	0.00	401.57
29	3	0.67	273.60	371.43
30	3	228.67	0.00	365.07
31	3	283.00	303.97	352.37
32	3	282.67	418.97	0.00
33	3	2.33	288.30	7.10
34	3	266.67	0.00	393.63
35	3	190.33	292.70	155.87
36	3	237.33	260.20	334.53

APPENDIX D

EMITTER FLOW VOLUMES FROM SITE B

The volume of water collected from individual emitters from site B. This appendix lists all emitters used in this research by location and volume of flow in milliliters (ml).

Emitter	Group	Emission Volume (ml) Lateral B1	Lateral B2	Lateral B3
1	1	449.00	438.90	432.97
2	1	340.97	370.83	422.40
3	1	453.77	433.00	404.30
4	1	386.27	430.57	419.07
5	1	410.23	388.80	421.57
6	1	374.87	430.23	447.23
7	1	495.70	345.37	420.13
8	1	300.50	386.47	460.23
9	1	400.10	399.53	373.43
10	1	388.20	344.10	411.50
11	1	468.37	396.53	423.27
12	1	444.20	322.47	340.60
13	2	425.70	470.23	357.87
14	2	464.60	523.20	414.97
15	2	488.63	390.93	497.13
16	2	312.57	484.10	450.23
17	2	541.33	468.37	435.13
18	2	465.93	454.60	418.80
19	2	469.27	421.97	403.07
20	2	350.77	483.13	426.23
21	2	441.90	483.97	411.27
22	2	506.53	481.30	438.97
23	2	455.53	381.73	406.97
24	2	411.77	470.13	431.57
25	3	269.10	373.97	365.73
26	3	516.63	375.33	394.73
27	3	237.90	369.10	384.17
28	3	315.97	399.27	391.43
29	3	531.93	351.50	245.63
30	3	473.10	406.63	458.57
31	3	354.63	335.90	311.03
32	3	365.40	334.83	395.33
33	3	265.07	302.30	345.70
34	3	416.93	299.77	214.43
35	3	278.90	166.43	237.47
36	3	329.23	133.63	278.93

APPENDIX E

EMITTER FLOW VOLUMES FROM SITE C

The volume of water collected from individual emitters from site C. This appendix lists all emitters used in this research by location and volume of flow in milliliters (ml).

		Emission Volume (ml)		
Emitter	Group	Lateral C1	Lateral C2	Lateral C3
1	1	658.03	451.93	460.30
2	1	646.57	726.17	444.23
3	1	750.43	115.47	317.93
4	1	598.47	1.17	31.53
5	1	746.50	742.83	295.67
6	1	661.30	666.50	101.47
7	1	774.53	845.30	434.63
8	1	786.50	0.00	409.87
9	1	740.43	463.90	260.13
10	1	588.67	738.60	424.27
11	1	0.00	830.23	310.37
12	1	515.43	0.00	375.20
13	2	146.37	0.00	310.40
14	2	208.57	0.00	484.30
15	2	0.00	0.00	21.97
16	2	4.27	0.00	395.47
17	2	0.00	0.00	210.97
18	2	0.00	0.00	284.57
19	2	0.00	0.00	510.37
20	2	0.00	110.80	204.17
21	2	0.00	0.00	240.57
22	2	0.00	348.03	384.43
23	2	0.00	318.70	235.60
24	2	34.00	494.70	394.90
25	3	0.00	4.33	69.07
26	3	0.00	222.20	244.67
27	3	0.00	0.00	277.03
28	3	0.00	0.00	251.03
29	3	151.90	72.67	106.80
30	3	0.00	0.00	279.93
31	3	0.00	0.00	243.57
32	3	35.47	12.63	129.00
33	3	0.00	62.07	41.60
34	3	0.00	0.00	114.37
35	3	0.00	0.00	51.53
36	3	0.00	0.00	17.37

APPENDIX F

EMITTER FLOW RATES FROM SITE A

Flow rate measurements were conducted on 108 Netafim Bioline 2.34 L/hr (0.62 gph) Pressure Compensating Emitters. This appendix lists all emitters used in this research by location and reporting the average flow rate for each emitter in liters per hour (L/hr) and gallons per hour (gph). There are values reported for 108 emitters 1 emitter was damaged during harvesting, and one extra emitter was taken from lateral 2 because the emitter did not flow in the field and was overlooked during the field test.

Emitter	Group	Initial Flow Rate (L/hr) Lateral A1	Lateral A2	Lateral A3	Initial Flow Rate (gph) Lateral A1	Lateral A2	Lateral A3
1	1	2.23	2.32	3.36	0.58	0.61	0.88
2	1	2.53	2.41	2.23	0.66	0.63	0.58
3	1	2.27	2.19	2.39	0.59	0.57	0.63
4	1	2.50	2.38	2.47	0.65	0.62	0.65
5	1	2.22	2.01	3.15	0.58	0.53	0.82
6	1	2.30	2.46	1.87	0.60	0.64	0.49
7	1	2.51	3.71	2.67	0.66	0.97	0.70
8	1	2.51	2.64	2.59	0.66	0.69	0.68
9	1	2.36	2.32	3.14	0.62	0.61	0.82
10	1	2.44	2.64	2.84	0.64	0.69	0.74
11	1	2.17	2.29	3.07	0.57	0.60	0.80
12	1	2.60	2.66	2.71	0.68	0.70	0.71
13	2	2.29	2.46	3.35	0.60	0.64	0.88
14	2	2.20	0.03	1.12	0.58	0.01	0.29
15	2	2.46	2.79	2.85	0.64	0.73	0.75
16	2	2.36	2.42	2.58	0.62	0.63	0.68
17	2	2.50	3.35	1.61	0.65	0.88	0.42
18	2	2.33	2.54	1.96	0.61	0.66	0.51
19	2	2.47	0.13	2.94	0.65	0.04	0.77
20	2	1.56	3.06	2.35	0.41	0.80	0.61
21	2	2.07	3.31	2.80	0.54	0.87	0.73
22	2	2.03	0.02	3.35	0.53	0.00	0.88
23	2	1.84	3.23	2.25	0.48	0.85	0.59
24	2	2.76	3.23	3.43	0.72	0.85	0.90
25	3	***	2.92	2.58	***	0.76	0.68
26	3	3.23	0.04	2.66	0.84	0.01	0.70
27	3	0.00	3.66	0.86	0.00	0.96	0.23
28	3	0.13	0.59	2.48	0.03	0.15	0.65
29	3	0.00	2.49	3.69	0.00	0.65	0.97
30	3	3.14	0.06	2.59	0.82	0.01	0.68
31	3	2.96	2.44	2.47	0.77	0.64	0.65
32	3	2.98	4.86	3.20	0.78	1.27	0.84
33	3	0.07	3.63	0.06	0.02	0.95	0.02
34	3	2.71	0.11	2.56	0.71	0.03	0.67
35	3	4.09	0.02	2.96	1.07	0.01	0.78
36	3	2.67	3.32	3.03	0.70	0.87	0.79
37	3		2.21			0.58	

APPENDIX G

EMITTER FLOW RATES FROM SITE B

Flow rate measurements were conducted on 108 Netafim Bioline 2.34 L/hr (0.62 gph) Pressure Compensating Emitters. This appendix lists all emitters used in this research by location and reporting the average flow rate for each emitter in liters per hour (L/hr) and gallons per hour (gph).

Emitter	Group	Initial Flow Rate (L/hr) Lateral B1	Lateral B2	Lateral B3	Initial Flow Rate (gph) Lateral B1	Lateral B2	Lateral B3
1	1	2.61	2.23	2.57	0.68	0.58	0.67
2	1	2.30	2.23	2.39	0.60	0.58	0.62
3	1	2.54	2.36	2.39	0.66	0.62	0.63
4	1	2.39	2.62	2.53	0.63	0.69	0.66
5	1	4.58	2.34	2.44	1.20	0.61	0.64
6	1	2.15	2.00	2.66	0.56	0.52	0.70
7	1	2.52	2.13	2.33	0.66	0.56	0.61
8	1	2.46	2.01	2.70	0.64	0.53	0.71
9	1	2.28	1.92	2.13	0.60	0.50	0.56
10	1	2.25	2.23	2.11	0.59	0.58	0.55
11	1	2.29	2.27	2.42	0.60	0.59	0.63
12	1	3.12	2.54	2.40	0.82	0.67	0.63
13	2	2.36	2.57	2.50	0.62	0.67	0.65
14	2	2.29	2.19	1.98	0.60	0.57	0.52
15	2	2.14	2.35	2.12	0.56	0.62	0.56
16	2	2.09	2.20	2.37	0.55	0.58	0.62
17	2	2.55	2.31	2.21	0.67	0.60	0.58
18	2	2.10	2.52	2.33	0.55	0.66	0.61
19	2	2.38	2.48	2.23	0.62	0.65	0.58
20	2	1.94	2.29	2.19	0.51	0.60	0.57
21	2	2.49	2.30	2.38	0.65	0.60	0.62
22	2	2.38	2.36	2.37	0.62	0.62	0.62
23	2	2.67	1.74	2.32	0.70	0.46	0.61
24	2	2.39	2.35	2.34	0.63	0.62	0.61
25	3	2.51	2.20	2.74	0.66	0.58	0.72
26	3	2.87	2.36	2.53	0.75	0.62	0.66
27	3	2.47	2.32	3.07	0.65	0.61	0.80
28	3	2.43	1.90	3.36	0.64	0.50	0.88
29	3	2.67	2.66	3.10	0.70	0.70	0.81
30	3	2.35	2.54	3.05	0.62	0.66	0.80
31	3	2.59	2.27	2.22	0.68	0.59	0.58
32	3	2.33	2.35	3.16	0.61	0.62	0.83
33	3	2.62	2.40	2.10	0.69	0.63	0.55
34	3	2.63	2.38	2.75	0.69	0.62	0.72
35	3	2.41	0.02	2.48	0.63	0.01	0.65
36	3	2.18	2.55	2.20	0.57	0.67	0.58

APPENDIX H

EMITTER FLOW RATES FROM SITE C

Flow rate measurements were conducted on 108 Netafim Bioline 2.34 L/hr (0.62 gph) Pressure Compensating Emitters. This appendix lists all emitters used in this research by location and reporting the average flow rate for each emitter in liters per hour (L/hr) and gallons per hour (gph).

Emitter	Group	Initial Flow Rate (L/hr) Lateral C1	Lateral C2	Lateral C3	Initial Flow Rate (gph) Lateral C1	Lateral C2	Lateral C3
1	1	1.91	2.25	2.41	0.50	0.59	0.63
2	1	2.34	2.15	2.40	0.61	0.56	0.63
3	1	0.60	1.90	1.96	0.16	0.50	0.51
4	1	0.00	1.44	0.86	0.00	0.38	0.23
5	1	2.22	2.20	1.65	0.58	0.58	0.43
6	1	1.77	2.05	2.22	0.46	0.54	0.58
7	1	2.02	2.20	2.47	0.53	0.58	0.65
8	1	1.29	2.02	2.21	0.34	0.53	0.58
9	1	2.24	2.03	1.88	0.59	0.53	0.49
10	1	2.38	2.30	2.27	0.62	0.60	0.59
11	1	0.30	1.20	2.08	0.08	0.31	0.54
12	1	0.05	0.00	2.17	0.01	0.00	0.57
13	2	2.26	0.00	2.34	0.59	0.00	0.61
14	2	0.93	0.71	2.27	0.24	0.19	0.59
15	2	0.40	0.00	1.85	0.10	0.00	0.48
16	2	0.00	0.00	2.02	0.00	0.00	0.53
17	2	0.00	0.00	2.09	0.00	0.00	0.55
18	2	0.00	0.00	2.33	0.00	0.00	0.61
19	2	0.00	1.71	2.34	0.00	0.45	0.61
20	2	0.00	1.72	2.13	0.00	0.45	0.56
21	2	0.00	0.00	2.01	0.00	0.00	0.53
22	2	0.00	1.72	2.07	0.00	0.45	0.54
23	2	0.00	2.35	1.74	0.00	0.62	0.46
24	2	0.00	1.59	2.52	0.00	0.41	0.66
25	3	0.00	1.43	2.15	0.00	0.37	0.56
26	3	0.16	1.83	2.62	0.04	0.48	0.68
27	3	0.00	0.00	2.33	0.00	0.00	0.61
28	3	0.00	0.00	1.79	0.00	0.00	0.47
29	3	0.00	0.00	2.30	0.00	0.00	0.60
30	3	0.00	0.00	2.09	0.00	0.00	0.55
31	3	1.98	0.00	2.52	0.52	0.00	0.66
32	3	0.46	0.00	2.34	0.12	0.00	0.61
33	3	0.43	2.25	2.07	0.11	0.59	0.54
34	3	0.45	0.00	2.28	0.12	0.00	0.60
35	3	1.19	0.00	1.81	0.31	0.00	0.47
36	3	0.00	0.00	2.31	0.00	0.00	0.61

APPENDIX I

RECOVERY FLOW RATES FOR SITE A

Recovery procedures were conducted on all emitters collected from site A. This Appendix lists all flow rates after each regiment with the lateral and position reporting the average flow rate in liters per hr (L/hr).

Emitter	Lateral	Group	Initial (L/hr)	Flush 0.15 m/s (L/hr)	Cl Shock Flush 0.15 m/s (L/hr)	Cl Shock Flush 0.6 m/s (L/hr)
1	A1	1	2.23	2.15	2.14	2.17
2	A1	1	2.53	2.46	2.52	2.45
3	A1	1	2.27	2.17	2.24	2.18
4	A1	1	2.50	2.56	2.56	2.50
5	A1	1	2.22	2.71	2.35	2.29
6	A1	1	2.30	2.50	2.41	2.30
7	A1	1	2.51	2.49	2.44	2.36
8	A1	1	2.51	2.54	2.32	2.22
9	A1	1	2.36	2.48	2.56	2.83
10	A1	1	2.44	2.47	2.53	2.44
11	A1	1	2.17	2.19	2.21	2.29
12	A1	1	2.60	2.38	2.32	2.36
13	A1	2	2.29	2.22	2.25	2.22
14	A1	2	2.20	2.15	2.46	2.39
15	A1	2	2.46	2.39	2.42	2.31
16	A1	2	2.36	2.28	2.27	2.44
17	A1	2	2.50	2.50	2.49	2.42
18	A1	2	2.33	2.32	2.39	2.50
19	A1	2	2.47	2.40	2.42	2.31
20	A1	2	1.56	2.04	2.46	2.03
21	A1	2	2.07	2.35	2.40	2.33
22	A1	2	2.03	2.05	2.53	2.47
23	A1	2	1.84	2.46	2.54	2.19
24	A1	2	2.76	2.35	2.54	2.39
25	A1	3	***	***	***	***
26	A1	3	3.23	2.58	2.55	3.09
27	A1	3	0.00	0.02	0.04	3.19
28	A1	3	0.13	0.07	0.49	5.09
29	A1	3	0.00	0.03	1.54	2.82
30	A1	3	3.14	2.29	2.28	2.52
31	A1	3	2.96	2.26	2.50	2.44

Emitter	Lateral	Group	Initial (L/hr)	Flush 0.15 m/s (L/hr)	Cl Shock Flush 0.15 m/s (L/hr)	Cl Shock Flush 0.6 m/s (L/hr)
32	A1	3	2.98	2.50	2.72	2.63
33	A1	3	0.07	0.22	1.02	3.28
34	A1	3	2.71	2.69	2.56	2.46
35	A1	3	4.09	0.74	1.76	2.45
36	A1	3	2.67	2.70	2.44	2.43
1	A2	1	2.32	2.28	2.30	2.34
2	A2	1	2.41	2.45	2.54	2.56
3	A2	1	2.19	2.65	2.15	2.35
4	A2	1	2.38	2.39	2.40	2.38
5	A2	1	2.01	2.10	2.18	2.25
6	A2	1	2.46	2.40	2.41	2.43
7	A2	1	3.71	3.37	3.05	2.44
8	A2	1	2.64	2.41	2.51	2.27
9	A2	1	2.32	2.29	2.24	1.87
10	A2	1	2.64	2.60	2.53	2.27
11	A2	1	2.29	2.24	2.38	2.40
12	A2	1	2.66	2.57	2.49	2.51
13	A2	2	2.46	2.41	2.39	2.44
14	A2	2	0.03	0.04	2.77	2.47
15	A2	2	2.79	2.22	2.26	2.30
16	A2	2	2.42	2.12	2.26	2.37
17	A2	2	3.35	2.42	2.60	2.62
18	A2	2	2.54	2.26	2.32	2.56
19	A2	2	0.13	0.17	1.13	3.00
20	A2	2	3.06	1.93	2.39	2.40
21	A2	2	3.31	2.49	2.37	2.42
22	A2	2	0.02	0.02	3.03	2.68
23	A2	2	3.23	2.36	2.39	2.40
24	A2	2	3.23	2.48	2.77	2.58
25	A2	3	2.92	2.76	2.14	2.50
26	A2	3	0.04	0.15	2.75	2.81
27	A2	3	3.66	2.59	2.11	2.47
28	A2	3	0.59	2.42	2.54	2.35

Emitter	Lateral	Group	Initial (L/hr)	Flush 0.15 m/s (L/hr)	Cl Shock Flush 0.15 m/s (L/hr)	Cl Shock Flush 0.6 m/s (L/hr)
29	A2	3	2.49	2.51	2.72	2.41
30	A2	3	0.06	0.05	0.52	2.25
31	A2	3	2.44	2.35	2.38	2.37
32	A2	3	4.86	3.46	3.49	3.90
33	A2	3	3.63	2.24	2.26	2.25
34	A2	3	0.11	0.11	0.42	2.80
35	A2	3	0.02	0.03	2.26	2.27
36	A2	3	3.32	2.46	2.32	2.55
37	A2	3	2.21	2.27	2.52	2.70
1	A3	1	3.36	2.35	2.46	2.38
2	A3	1	2.23	2.29	2.87	2.56
3	A3	1	2.39	2.38	2.44	2.50
4	A3	1	2.47	2.53	2.47	2.49
5	A3	1	3.15	2.65	4.79	4.13
6	A3	1	1.87	2.30	2.60	2.97
7	A3	1	2.67	2.32	2.63	3.54
8	A3	1	2.59	2.54	2.44	2.48
9	A3	1	3.14	2.32	2.66	2.68
10	A3	1	2.84	2.61	2.34	2.38
11	A3	1	3.07	2.54	2.68	2.97
12	A3	1	2.71	2.57	2.40	3.14
13	A3	2	3.35	2.33	2.36	2.33
14	A3	2	1.12	0.82	0.39	0.36
15	A3	2	2.85	2.47	2.46	2.38
16	A3	2	2.58	2.37	2.47	2.39
17	A3	2	1.61	2.44	1.95	2.20
18	A3	2	1.96	1.96	2.37	2.28
19	A3	2	2.94	2.64	2.45	2.47
20	A3	2	2.35	2.43	2.36	2.34
21	A3	2	2.80	2.45	2.52	2.35
22	A3	2	3.35	3.12	2.42	2.42
23	A3	2	2.25	2.81	2.31	2.76
24	A3	2	3.43	3.50	2.47	3.27

Emitter	Lateral	Group	Initial (L/hr)	Flush 0.15 m/s (L/hr)	Cl Shock Flush 0.15 m/s (L/hr)	Cl Shock Flush 0.6 m/s (L/hr)
25	A3	3	2.58	2.48	2.41	2.42
26	A3	3	2.66	2.37	2.25	2.30
27	A3	3	0.86	1.76	1.54	2.57
28	A3	3	2.48	2.41	2.55	2.40
29	A3	3	3.69	3.22	3.60	3.15
30	A3	3	2.59	2.30	2.33	2.30
31	A3	3	2.47	2.31	2.31	2.28
32	A3	3	3.20	2.42	2.75	2.37
33	A3	3	0.06	0.06	0.02	2.33
34	A3	3	2.56	2.52	2.54	2.38
35	A3	3	2.96	2.47	2.58	2.53
36	A3	3	3.03	2.34	2.45	2.31

APPENDIX J

RECOVERY FLOW RATES FOR SITE B

Recovery procedures were conducted on all emitters collected from site B. This Appendix lists all flow rates after each regiment with the lateral and position reporting the average flow rate in liters per hr (L/hr).

Emitter	Lateral	Group	Initial (L/hr)	Flush 0.15 m/s (L/hr)	Cl Shock Flush 0.15 m/s (L/hr)	Cl Shock Flush 0.6 m/s (L/hr)
1	B1	1	2.61	2.84	2.45	2.54
2	B1	1	2.30	2.30	2.27	2.20
3	B1	1	2.54	2.51	2.49	2.52
4	B1	1	2.39	2.39	2.34	2.38
5	B1	1	4.58	4.48	6.86	7.71
6	B1	1	2.15	2.19	2.42	2.52
7	B1	1	2.52	2.42	2.43	2.47
8	B1	1	2.46	2.45	2.54	2.54
9	B1	1	2.28	2.35	2.39	2.40
10	B1	1	2.25	2.26	2.33	2.31
11	B1	1	2.29	2.32	2.36	2.59
12	B1	1	3.12	2.53	2.50	2.52
13	B1	2	2.36	2.25	2.15	2.29
14	B1	2	2.29	2.33	2.16	2.17
15	B1	2	2.14	2.24	2.23	2.20
16	B1	2	2.09	2.27	2.31	2.24
17	B1	2	2.55	2.52	2.29	2.27
18	B1	2	2.10	2.25	2.27	2.26
19	B1	2	2.38	2.37	2.31	2.33
20	B1	2	1.94	2.14	2.26	2.31
21	B1	2	2.49	2.51	2.35	2.23
22	B1	2	2.38	2.29	2.23	2.25
23	B1	2	2.67	2.62	2.51	2.51
24	B1	2	2.39	2.31	2.28	2.29
25	B1	3	2.51	2.12	2.25	2.17
26	B1	3	2.87	2.39	2.34	2.32
27	B1	3	2.47	2.59	2.28	2.20
28	B1	3	2.43	2.30	2.18	2.13
29	B1	3	2.67	2.10	2.07	2.06
30	B1	3	2.35	2.25	2.23	2.21
31	B1	3	2.59	2.37	2.36	2.50

Emitter	Lateral	Group	Initial (L/hr)	Flush 0.15 m/s (L/hr)	Cl Shock Flush 0.15 m/s (L/hr)	Cl Shock Flush 0.6 m/s (L/hr)
32	B1	3	2.33	2.39	2.15	2.35
33	B1	3	2.62	2.16	2.33	2.40
34	B1	3	2.63	2.61	2.41	2.33
35	B1	3	2.41	2.45	2.35	2.36
36	B1	3	2.18	2.25	2.26	2.28
1	B2	1	2.23	2.22	2.15	2.20
2	B2	1	2.23	2.21	2.18	2.20
3	B2	1	2.36	2.37	2.34	2.35
4	B2	1	2.62	2.57	2.61	2.53
5	B2	1	2.34	2.32	2.28	2.35
6	B2	1	2.00	2.27	2.24	2.22
7	B2	1	2.13	1.99	2.19	2.33
8	B2	1	2.01	2.05	2.30	2.19
9	B2	1	1.92	2.28	2.55	2.46
10	B2	1	2.23	2.22	2.27	2.28
11	B2	1	2.27	2.27	2.29	2.29
12	B2	1	2.54	2.38	2.39	2.38
13	B2	2	2.57	2.78	2.73	2.51
14	B2	2	2.19	2.17	2.16	2.16
15	B2	2	2.35	2.44	2.40	2.35
16	B2	2	2.20	2.15	2.26	2.27
17	B2	2	2.31	2.27	2.27	2.24
18	B2	2	2.52	2.11	2.21	2.29
19	B2	2	2.48	2.45	2.29	2.35
20	B2	2	2.29	2.37	2.37	2.38
21	B2	2	2.30	2.27	2.28	2.25
22	B2	2	2.36	2.42	2.37	2.34
23	B2	2	1.74	2.21	2.48	2.34
24	B2	2	2.35	2.31	2.28	2.24
25	B2	3	2.20	2.39	2.25	2.24
26	B2	3	2.36	2.07	2.26	2.23
27	B2	3	2.32	2.36	2.29	2.25
28	B2	3	1.90	2.59	2.37	2.29

Emitter	Lateral	Group	Initial (L/hr)	Flush 0.15 m/s (L/hr)	Cl Shock Flush 0.15 m/s (L/hr)	Cl Shock Flush 0.6 m/s (L/hr)
29	B2	3	2.66	2.35	2.45	2.35
30	B2	3	2.54	2.46	2.29	2.39
31	B2	3	2.27	2.25	2.26	2.25
32	B2	3	2.35	2.28	2.27	2.36
33	B2	3	2.40	2.40	2.06	2.49
34	B2	3	2.38	2.35	2.43	2.47
35	B2	3	0.02	1.92	2.29	2.30
36	B2	3	2.55	2.37	2.41	2.40
1	B3	1	2.57	2.67	2.30	2.30
2	B3	1	2.39	2.38	2.25	2.32
3	B3	1	2.39	2.29	2.30	2.33
4	B3	1	2.53	2.55	2.43	2.50
5	B3	1	2.44	2.43	2.43	2.39
6	B3	1	2.66	2.58	2.39	2.91
7	B3	1	2.33	2.34	2.34	2.56
8	B3	1	2.70	2.70	2.40	2.33
9	B3	1	2.13	2.13	2.29	2.34
10	B3	1	2.11	2.12	2.33	2.30
11	B3	1	2.42	2.45	2.39	2.42
12	B3	1	2.40	2.48	2.29	2.36
13	B3	2	2.50	2.45	2.35	2.38
14	B3	2	1.98	2.06	2.40	2.35
15	B3	2	2.12	2.09	2.33	2.26
16	B3	2	2.37	2.22	2.18	2.23
17	B3	2	2.21	2.12	2.13	2.14
18	B3	2	2.33	2.29	2.29	2.11
19	B3	2	2.23	2.37	2.36	2.40
20	B3	2	2.19	2.14	2.11	2.17
21	B3	2	2.38	2.35	2.31	2.37
22	B3	2	2.37	2.18	2.17	2.17
23	B3	2	2.32	2.32	2.30	2.32
24	B3	2	2.34	2.29	2.11	2.16
25	B3	3	2.74	2.50	2.27	2.25

Emitter	Lateral	Group	Initial (L/hr)	Flush 0.15 m/s (L/hr)	Cl Shock Flush 0.15 m/s (L/hr)	Cl Shock Flush 0.6 m/s (L/hr)
26	B3	3	2.53	2.44	2.32	2.31
27	B3	3	3.07	2.18	2.16	2.20
28	B3	3	3.36	2.42	2.24	2.29
29	B3	3	3.10	2.28	2.26	2.29
30	B3	3	3.05	2.75	2.74	2.34
31	B3	3	2.22	2.20	2.21	2.20
32	B3	3	3.16	2.48	2.29	2.29
33	B3	3	2.10	2.38	2.34	2.33
34	B3	3	2.75	2.30	2.29	2.30
35	B3	3	2.48	2.22	2.20	2.22
36	B3	3	2.20	2.29	2.28	1.99

APPENDIX K

RECOVERY FLOW RATES FOR SITE C

Recovery procedures were conducted on all emitters collected from site C. This Appendix lists all flow rates after each regiment with the lateral and position reporting the average flow rate in liters per hr (L/hr).

Emitter	Lateral	Group	Initial (L/hr)	Flush 0.15 m/s (L/hr)	Cl Shock Flush 0.15 m/s (L/hr)	Cl Shock Flush 0.6 m/s (L/hr)
1	C1	1	1.91	1.85	2.03	2.03
2	C1	1	2.34	2.21	1.93	2.07
3	C1	1	0.60	0.50	0.90	1.68
4	C1	1	0.00	0.00	0.23	1.86
5	C1	1	2.22	2.30	2.26	2.22
6	C1	1	1.77	1.21	2.25	2.27
7	C1	1	2.02	1.34	2.19	2.20
8	C1	1	1.29	2.10	2.12	2.15
9	C1	1	2.24	2.24	2.21	2.49
10	C1	1	2.38	2.25	2.22	2.13
11	C1	1	0.30	2.37	2.12	2.18
12	C1	1	0.05	1.54	1.39	1.77
13	C1	2	2.26	2.22	2.29	2.26
14	C1	2	0.93	1.79	2.02	1.93
15	C1	2	0.40	0.21	0.77	1.15
16	C1	2	0.00	0.00	0.00	2.14
17	C1	2	0.00	0.00	1.50	1.85
18	C1	2	0.00	0.00	0.45	1.71
19	C1	2	0.00	0.00	2.27	2.35
20	C1	2	0.00	0.00	0.00	0.00
21	C1	2	0.00	0.00	0.00	0.00
22	C1	2	0.00	1.78	2.28	2.22
23	C1	2	0.00	0.00	0.06	0.54
24	C1	2	0.00	1.93	1.35	1.99
25	C1	3	0.00	0.00	0.00	0.43
26	C1	3	0.16	0.37	0.83	2.12
27	C1	3	0.00	0.00	0.47	1.91
28	C1	3	0.00	0.00	0.00	0.26
29	C1	3	0.00	2.27	2.21	2.19
30	C1	3	0.00	0.00	0.00	0.00
31	C1	3	1.98	2.11	2.27	2.29

Emitter	Lateral	Group	Initial (L/hr)	Flush 0.15 m/s (L/hr)	Cl Shock Flush 0.15 m/s (L/hr)	Cl Shock Flush 0.6 m/s (L/hr)
32	C1	3	0.46	0.47	1.89	1.90
33	C1	3	0.43	0.31	0.46	1.95
34	C1	3	0.45	0.66	1.84	2.21
35	C1	3	1.19	1.55	1.81	1.91
36	C1	3	0.00	0.00	0.86	2.05
1	C2	1	2.25	2.29	2.27	2.27
2	C2	1	2.15	2.06	2.08	2.08
3	C2	1	1.90	2.21	2.18	2.18
4	C2	1	1.44	2.22	2.20	2.20
5	C2	1	2.20	2.25	2.20	2.20
6	C2	1	2.05	2.27	2.21	2.21
7	C2	1	2.20	1.97	2.27	2.27
8	C2	1	2.02	2.34	2.33	2.33
9	C2	1	2.03	0.56	2.16	2.16
10	C2	1	2.30	1.72	2.20	2.20
11	C2	1	1.20	0.77	1.04	1.04
12	C2	1	0.00	1.43	2.06	2.06
13	C2	2	0.00	0.00	0.00	0.00
14	C2	2	0.71	0.93	2.25	2.25
15	C2	2	0.00	2.17	2.42	2.42
16	C2	2	0.00	0.00	0.00	0.00
17	C2	2	0.00	0.00	0.00	0.00
18	C2	2	0.00	0.00	0.00	0.00
19	C2	2	1.71	2.15	2.30	2.30
20	C2	2	1.72	1.99	2.24	2.24
21	C2	2	0.00	0.00	0.00	0.00
22	C2	2	1.72	1.49	1.52	1.52
23	C2	2	2.35	2.56	2.56	2.56
24	C2	2	1.59	2.29	1.87	1.87
25	C2	3	1.43	2.17	2.09	2.09
26	C2	3	1.83	2.13	2.37	2.37
27	C2	3	0.00	0.00	0.00	0.00
28	C2	3	0.00	0.00	0.00	0.00

Emitter	Lateral	Group	Initial (L/hr)	Flush 0.15 m/s (L/hr)	Cl Shock Flush 0.15 m/s (L/hr)	Cl Shock Flush 0.6 m/s (L/hr)
29	C2	3	0.00	0.00	0.00	0.00
30	C2	3	0.00	0.00	0.00	0.00
31	C2	3	0.00	0.00	0.00	0.00
32	C2	3	0.00	0.00	0.13	0.13
33	C2	3	2.25	2.23	2.13	2.13
34	C2	3	0.00	0.00	0.69	0.69
35	C2	3	0.00	0.00	0.00	0.00
36	C2	3	0.00	0.00	0.29	0.29
1	C3	1	2.41	2.36	2.36	2.37
2	C3	1	2.40	2.40	2.40	2.53
3	C3	1	1.96	2.02	2.02	2.23
4	C3	1	0.86	1.49	1.09	2.24
5	C3	1	1.65	1.85	1.85	2.32
6	C3	1	2.22	2.23	2.23	2.28
7	C3	1	2.47	2.48	2.48	2.50
8	C3	1	2.21	2.19	2.19	2.33
9	C3	1	1.88	2.09	2.09	2.31
10	C3	1	2.27	2.00	2.00	2.29
11	C3	1	2.08	2.06	2.06	2.09
12	C3	1	2.17	2.42	2.42	2.34
13	C3	2	2.34	2.36	2.36	2.31
14	C3	2	2.27	2.26	2.26	2.25
15	C3	2	1.85	1.89	1.89	2.27
16	C3	2	2.02	2.27	2.27	2.27
17	C3	2	2.09	2.01	2.01	2.14
18	C3	2	2.33	2.25	2.25	2.22
19	C3	2	2.34	2.31	2.29	2.35
20	C3	2	2.13	2.11	2.11	2.27
21	C3	2	2.01	2.02	2.02	2.32
22	C3	2	2.07	2.20	2.20	2.32
23	C3	2	1.74	2.15	2.15	2.21
24	C3	2	2.52	2.33	2.33	2.36
25	C3	3	2.15	2.35	2.35	2.28

Emitter	Lateral	Group	Initial (L/hr)	Flush 0.15 m/s (L/hr)	Cl Shock Flush 0.15 m/s (L/hr)	Cl Shock Flush 0.6 m/s (L/hr)
26	C3	3	2.62	2.55	2.55	2.53
27	C3	3	2.33	2.34	2.34	2.27
28	C3	3	1.79	2.19	2.19	2.22
29	C3	3	2.30	2.35	2.35	2.33
30	C3	3	2.09	2.30	2.30	2.34
31	C3	3	2.52	2.30	2.30	2.35
32	C3	3	2.34	2.22	2.22	2.24
33	C3	3	2.07	2.22	2.22	2.22
34	C3	3	2.28	2.23	2.23	2.20
35	C3	3	1.81	2.26	2.26	2.24
36	C3	3	2.31	2.35	2.35	2.36

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