A COMPARATIVE ANALYSIS OF GREENROOF DEPTH AS IT AFFECTS RETENTION OF RAINFALL

Prepared By:
Marty Wanielista, PhD. P.E.
and Mike Hardin, M.S, E.I.

FDEP Project number: WM 864
August, 2011

ABSTRACT

In previous green roof reports by the authors, it was shown that annual average retention of rainfall can be predicted for Florida conditions when the green roof design depths were 4, 6 and 8 inches. Design graphs had been developed for eighteen locations in the State (Hardin, 2006 and Wanielista et.al, 2008) that can be used to predict the average annual retention with or without a cistern. If irrigated, the irrigation of these green roofs was assumed to be from a dedicated cistern or not irrigated at all. The cistern stores the filtrate water from the green roof. A lighter weight green roof is desired to reduce the cost of green roofs and thus this report focuses on the stormwater performance of a shallow green roof section.

The purpose of this report is to expand the retention performance data for green roofs by investigating a shallow (2 inches) green roof system called the greensmart blanket. Retention and filtrate data for the deeper green roof systems are compared to the results of the greensmart blanket operation data.

Previous research showed that four to eight inch deep media greenroofs without a cistern can store a minimum of about 33% of the average annual rainfall in Panama City and Niceville to about 51% at Key West. A cistern designed to hold 5 inches of rainfall over the greenroof results in an increase in the average annual retention in most locations of about 80% and up to 90% in Key West. However, hydrograph results show that the 8-inch media design has a lower peak flow and longer attenuation when compared to the 4-inch media design and for the greensmart blanket design.

There are five findings presented within this report for a two inch shallow designed green roof blanket, called greensmart.

1. The average annual and average monthly filtrate factor or the fraction of rain and irrigation water filtering through the media are not significantly different ($\alpha=0.05$) for a shallow 2 inch depth system compared to deeper loose laid green roof systems up to 8 inches in depth.
2. The average annual and average monthly ET losses are not significantly different ($\alpha=0.05$) for a shallow 2 inch depth system compared to deeper loose laid green roof systems up to 8 inches in depth.
3. The retention of rain as a function of cistern size show that a green roof average annual retention efficiency can be improved with the addition of a cistern. For the Orlando area, as cistern size is increased the greensmart retention efficiency increases to 80% at 5 inches of storage. On average the greensmart blanket was only 4% less efficient than the deeper loose laid green roof sections for all sizes of cisterns.
4. Florida native plants are an option for the shallow 2 inch greensmart blanket. In addition, Arachis Glabrata (perennial peanut) was shown to be an option.
5. It was shown that a more frequent volume irrigation cycle with less irrigation volume per week resulted in healthy plants for the greensmart blanket. The results support the conclusions made by Hardin & Wanielista, 2006 that irrigation volumes should vary with season and plant needs.

ACKNOWLEDGMENTS

This research was supported through an Urban Nonpoint Source Research Grant from the Bureau of Watershed Management, Florida Department of Environmental Protection. The financial and technical support of the Florida Department of Environmental Protection is appreciated. The guidance of Eric Livingston throughout the research was very valuable. In addition, the help of the Stormwater Management Academy is noted.

Many students provided technical skills and time, and thus thanks are extended to those who helped with the construction and monitoring, namely Ken Horner, Eric Stuart, and Melike Minarci for helping with collecting data and irrigating the chambers.

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CHAPTER ONE: INTRODUCTION, OBJECTIVES, AND LIMITATIONS

Introduction

Water is a critical resource for the earth's ecosystem as well as human survival. It is a resource for natural and ornamental vegetation, drinking water, recreation, waste carriage, navigation, aquifer recharge, propagation of wildlife habitats, and many other beneficial uses. As the population grows and urbanization spreads, water resources in the ground or on the surface are becoming depleted and management of water will become more critical to offset the effects. The quality of these water resources is being polluted by several factors such as stormwater runoff, domestic and industrial wastewater discharges, and poor air quality. Pollution in stormwater originates from contact with fertilizers and animal feces from lawns and agricultural lands; particulate matter, oil, and grease from roadways and corroded materials from roof surfaces, (Good, 1993) and many other human activities.

The source of surface water pollution is classified into two categories: point source and nonpoint source. Point source pollution is characterized by a steady, often continuous discharge to surface waters and is regulated under the National Pollutant Discharge Elimination System (NPDES) permitting program. One example includes the millions of gallons of wastewater discharged from the pipes of industrial facilities and municipal sewage treatment plants into rivers, streams, lakes, and the ocean (TEP, 2007). On the other hand, nonpoint source pollution comes from many diffuse locations caused by rainfall or temporarily stored water moving over and through the ground and is much more difficult to control and regulate. Examples of nonpoint source pollution include excess fertilizer, herbicides, and insecticides from agricultural lands and residential areas; sediment from improperly managed construction-sites, crop and forest lands, and eroding stream banks; bacteria and nutrients from livestock, pet wastes, and faulty septic systems; as well as, atmospheric deposition and hydro modification (EPA, 2007). A majority of the stormwater runoff generated is discharged to surface waters and if not treated, it will have a negative effect on the quality of the receiving water body.

New technologies and management practices are being developed to mitigate the water pollution problem through volume reduction and filtration of stormwater. One technology that is becoming more widely used in the United States is the vegetated roof, garden roof, or green roof. A green roof is a multi-layer built up roofing system made up of a waterproof layer, protection layer, drainage layer, media layer, and vegetation layer. The green roof system enables water to be detained on the roof during rain events, attenuating the flow of runoff from the roof. Furthermore, stormwater can be stored onsite with the addition of a cistern to capture the filtrate and use it for irrigation, toilet water, and other non-potable water uses. It is recognized that some additional purification of the filtrate water from the green roof may be necessary before some uses.

The findings of this report expand the available research data on green roofs in the state of Florida and further the development of the industry in the United States. It is an extension of the research performed by Mike Hardin in 2006 and Matt Kelly in 2008 at the University of Central Florida. Examined is a shallow and lightweight green roof system called greensmart blanket. Comparisons of water volume retention are presented for the loose laid green roof systems described by Hardin (2006) and Kelly (2008) and the greensmart blanket data collected for this project.

Objectives

Research on filtrate water volume reductions from green roofs in the United States is limited but the benefits of green roofs are providing interest in their use and the industry is growing. Studies have been done on stormwater attenuation, water quality and storage capacity (Hardin, 2006) of a deep (6 inch) green roof of specific design, and on water volume reductions and evapotranspiration for different depths, media combinations, or drainage layers (Kelly, 2008). This research provides data and analysis to answer the questions dealing with these three variables for the shallow, 2 inch depth, greensmart blanket.

The objective statements are:

1. To examine the attenuation of the flow of filtrate water leaving a greensmart blanket green roof system comparing to data presented previously on deeper green roof sections by Hardin (2006) and Kelly (2008).
2. To examine annual evapotranspiration rates and filtrate Factor for the greensmart blanket green roof system comparing to data presented on deeper green roof sections by Hardin (2006) and Kelly (2008).
3. To predict the average annual retention of rain using one year of field data and the latest 30 years of rain fall data using the CSTORM model to calculate the retention efficiency of the greensmart blanket green roof system.

Climate and Design Limitations

Climate

The experiment is limited to the Central Florida climate. From December through May, the climate is dry with average temperatures ranging from about 50^{o}F to 80^{o}F with an average rainfall of 16.89 inches, and from June through November it is wet with average temperatures ranging between 80^{o}F to 92^{o}F with an average rainfall of 31.46 inches (Orange County, 2008).

Design

1. The makeup water for the irrigation is taken from a potable source.
2. The size of each greenroof chamber is 16 sq. ft.
3. The growing media is combination of expanded clay and other materials and only 1.5 inches in depth
4. The cistern is designed as 5.5 inches per square foot of greenroof area

CHAPTER TWO: PREVIOUS GREEN ROOF RESEARCH

Background

Green roofs have "painted" the urban landscape for more than 4,000 years. One example is a green roof dating back to 500 B.C., the Hanging Gardens of Babylon, which was built over arched stone beams and held together and waterproofed with layers of reeds and thick tar with soil, plants, and trees. The United States also has a history of using green roofs; one such roof was built in the 1930's and can still be seen today at Rockefeller Center in New York (Garland, 2007).

The modern green roof industry originated in Germany and emerged in the 1960's. Between 1989 and 1999, more than 350 million square feet of green roofs were built on German buildings (Penn State, 2006). In the U.S., Chicago is leading the green roof industry with over 2.5 million square feet of green roofs in place with more planned (Paulson, 2006). The majority of technical literature available for construction of green roofs is written in German and has slowed the adoption of this technology in the United States (Penn State, 2006).

Depth of Media

Green roofs are categorized into two groups based on the depth of media and intended use; passive (extensive) green roofs and active (intensive) green roofs. Passive green roofs have a media depth between 2 inches and 6 inches and are not intended for public access, only maintenance access is permitted. Active green roofs, on the other hand are those with a media depth of 6 inches or greater and are typically intended for public access. Active green roofs are typically more expensive to construct and maintain due to additional substrate material, plant selection, added structural reinforcement, and safety features (Hunt et al., 2003).

German research has shown that substrate depth, media type, and vegetation type directly influence the moisture-retention characteristics of green roofs (FLL, 2002). Furthermore, the depth of the substrate is also directly related to the sort of vegetation that may be supported by it (Dunnet, 2004). One study of green roofs constructed in Germany showed that a 1.2-inch deep growing media over a 2.4-inch deep drainage layer retains 58% of water; a 2.4 inch deep vegetation layer has approximately 67% retention; and a 4.8 inch deep growth media layer of mixed grass and herbaceous vegetation has around 70% retention (Dunnet, 2004).

Research on green roof soil depths in the United States has mainly focused on plant growth while only a few focus on water retention. A green roof in Portland Oregon in operation since 1999 with a soil depth of 2-3 inches retained 100% of the rainfall in the summer and 20% in the winter (Hunt, 2003). A six inch deep green roof with a cistern at the University of Central Florida retained 87% of the annual precipitation (Hardin, 2006). Investigated in this report is the water retention capacity of a greensmart blanket green roof system.

Evapotranspiration

Evapotranspiration is the total amount of water that is transferred from the earth's surface to the atmosphere and is the combination of water that is lost from the soil through evaporation and from the plants through transpiration. Evaporation and transpiration are important in cooling of plant surfaces, to maintain temperature in the range that permits photosynthetic activity and growth to occur. Transpiration is also required to transport nutrients into and within plants.

In central Florida, the ET rate gradually increases from January to July or August and begins to decrease after that time. "Reference evapotranspiration" or "ET_o" is simply the amount of water needed by a particular plant and is illustrated in Figure 1 (MMWD, 2004).

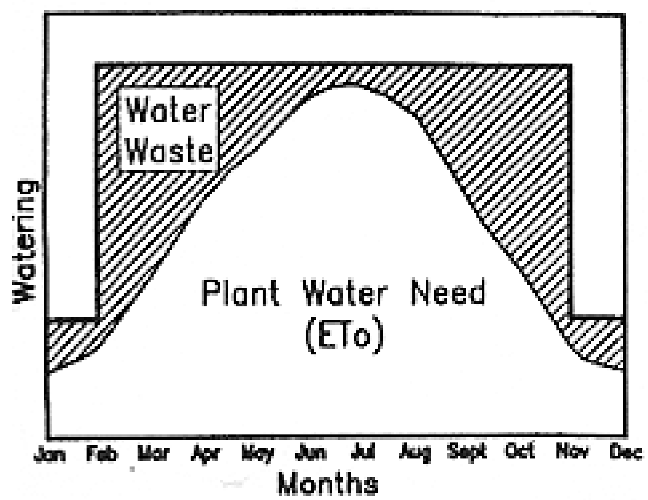

Figure 1: Annual Evapotranspiration Curve (MMWD, 2004)

The area with diagonal lines in Figure 1 shows a constant irrigation rate from February to November and a different rate between December and January. The white area labeled ET_o represents the water needed for the plants, which correlates to the amount of evapotranspiration. Figure 1 helps clarify that the use of a constant irrigation rate throughout the year based on a peak ET is a waste of water and signals a necessary shift towards an irrigation schedule based on the plants needs or ET for a particular area and time of year.

Figure 1 follows both Hardin's (2006) and Kelly's (2008) findings. The ET peaked in June and July and was at a minimum during January and December. Results show that vegetation had little effect on evapotranspiration rates during December and January (Hardin, 2006 and Kelly, 2008). This indicates that irrigation can be reduced during the winter months with no significant effect on plant vitality.

Green Roof Mathematical Model

Green roof mathematical models for stormwater retention have only recently been developed in the United States. Models exist for green roofs without cisterns, but only one with a cistern. Original models predicted the runoff from green roofs using historical evapotranspiration and precipitation data and a modified groundwater-modeling program to determine the filtrate from a green roof without a cistern (Hardin, 2006). More recently a mathematical model was developed for systems with a cistern or other storage device that is similar to a design of a reuse pond, which uses a mass balance approach (Hardin, 2006). The mass balance approach developed by Hardin (2006) is used in this research and summarized in the following sections. An illustration of the inputs and outputs of the mass balance are seen in Figure 2.

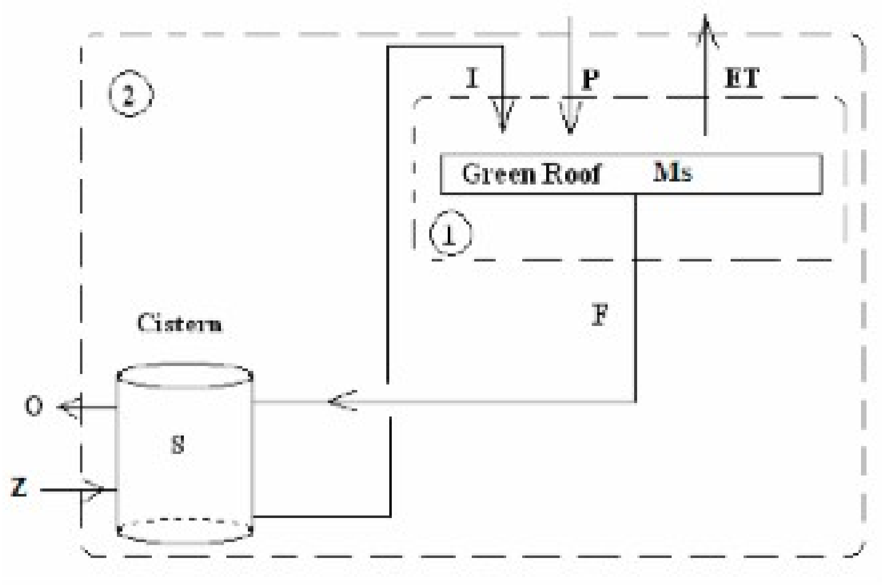

Figure 2: Greenroof Mass Balance (Hardin, 2006)
M_S = Media storage [in/ft_2 of greenroof]
P = Precipitation [in/ft_2 of greenroof*time]
I = Irrigation [in/ft_2 of greenroof*time]
ET = Evapotranspiration [in/ft_2 of greenroof*time]
F = Filtrate [in/ft_2 of greenroof*time]
S = Cistern storage [in/ft_2 of greenroof]
Z = Makeup Water [in/ft_2 of greenroof*time]
O = Overflow [in/ft_2 of greenroof*time]

f Factor

According to Hardin (2006), the main factors that influence the cistern water level are the filtrate from the green roof, the irrigation rate, the rate at which makeup water is added, and the overflow rate. Of these variables, the filtrate from the green roof or f factor is the only one that is unknown. To calculate the f factor, the system boundaries for the first system in Figure 2 were used, and an expression derived as the f factor varies with soil conditions, precipitation, evapotranspiration, and irrigation amount (Hardin, 2006).

$$dMs/dt = P + I - ET - F \qquad (1)$$

By rearranging and substituting variables such as $F' = f(P'+I')$ & $0<f<1$, Where:

f = Filtrate factor, the fractional volume of precipitation and irrigation which becomes filtrate, Equation (1) simplifies to

$$f = (M_{S1} – M_{S2} + P' + I' – ET')/(P' + I') \qquad (2)$$

The resulting equation now has two unknown variables, the final soil storage and f factor, but the final storage can be found by making a few assumptions. The assumptions include that the media saturation is at a volume of 20% of the growing media depth and that any precipitation and irrigation past the point of saturation will contribute to runoff (Hardin, 2006). For the purposes of this experiment, the following research was done over a one-year period and the change in storage was assumed to be negligible compared to the other variables, simplifying equation (2) to

$$f = (P' + I' + ET') / (P' + I') \qquad (3)$$

Cistern Design

An equation that describes how the water level in the cistern fluctuates over time is the second step in developing the green roof model after determining the f factor. The first step to determine how the cistern behaves is to rearrange equation (2) giving:

$$(M_{S1} – M_{S2}) = ET' + f(P' + I') – P' – I' \qquad (4)$$

Next, the boundaries from the second system in Figure 2 are used to develop the following equation:

$$d(S + M_S)/dt = P + Z – ET – O \qquad (5)$$

Assuming a small time step the equation further simplifies to:

$$S_2 = S_1 + (M_{S1} – M_{S2}) + Z' + P' – O' – ET' \qquad (6)$$

The final equation needed to develop the cistern model combines equation 3 and 6 to give:

$$S_2 = S_1 + f(P' + I') - I' + Z' - O' \quad (7)$$

Operating assumptions for the cistern must also be made to maximize the efficiency of the system. First, the initial storage volume of the cistern is equal to the irrigation volume required to provide sufficient water for the first irrigation event. The makeup water added is equal to the difference of the irrigation volume and the current cistern storage volume. Furthermore, the overflow is equal to the difference between the present cistern volume plus the filtrate in that period and the maximum cistern storage capacity.

The efficiency desired can be achieved by using this model and is defined as the volume of stormwater retained divided by the volume of precipitation. The efficiency equation is given as:

$$\text{Efficiency} = [1 - (O/P)*100\%] \quad (8)$$

Hardin's (2006) research also leads to the development of a green roof model software program called CSTORM. The software uses the previously mentioned mass balance approach, utilizing the previously developed equations and regional data to supply the user with a cistern storage value based on desired retention efficiency. Figure 3 illustrates an example of a storage volume curve in the Orlando area using CSTORM. For example, by using Figure 3, a 1000 sq ft green roof in Orlando with a desired retention efficiency of 80% would require a storage volume of 2.5 inches or approximately 1600 gallons.

Reuse Curve for Orlando FL,
1 in. irrigation per week 30 years of data

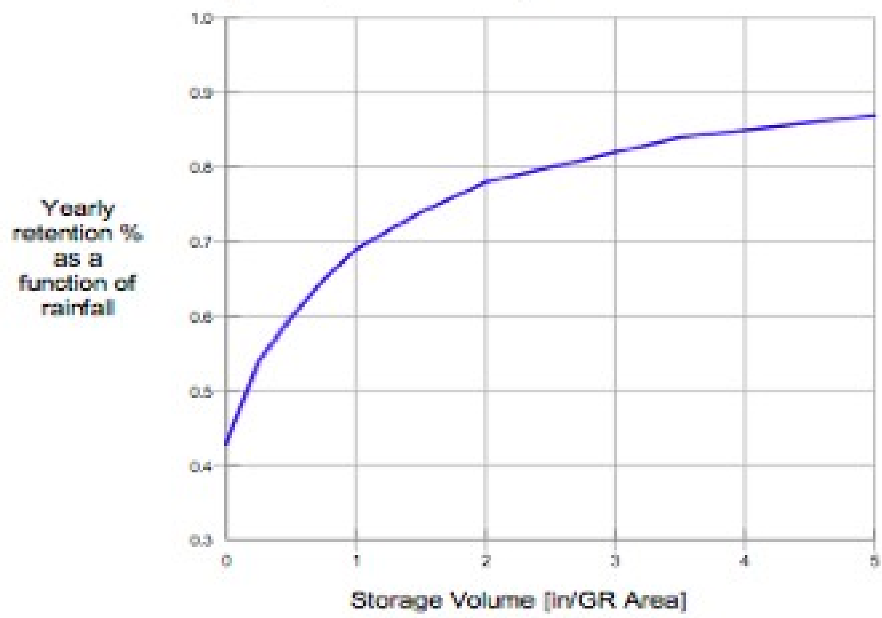

Figure 3: Cistern Storage Curve for Orlando Florida, 6 Inch Media Depth (Hardin, 2006)

The efficiency of the system is dependent on precipitation and evapotranspiration for a certain region, and the cistern storage volume. The lower the precipitation and the higher the evapotranspiration in a region will produce a higher efficiency green roof stormwater treatment system, while the converse yields a lower efficiency for the system. The use of a green roof without a cistern can reduce the runoff by about 33% - 51% throughout Florida (Hardin, 2006). If no cistern is incorporated, there will be more pollutant mass from the green roof than from the control roof and an additional stormwater management technique may be needed to meet water quality standards. Another way to increase the efficiency of the system is to irrigate additional areas, such as ground level landscaping.

Irrigation

To ensure the success of a green roof and healthy plant growth in Florida, the plants need adequate watering. Every geographical region has a different annual precipitation rate and, depending on the climate, may need irrigation to ensure plant survival. In the case of Florida, irrigation is necessary for the plants' continued existence (Hardin and Wanielista, 2006).

According to "Planting Green roofs and Living Walls" (Dunnet, 2004) there are four methods of irrigation (i.e. traditional sprinkler system, capillary systems, standing-water systems, and drip and tube systems). Sprinklers spray water on the plant or soil surface but tend to result in excessive evaporative losses in the extreme temperatures found in Florida. Capillary systems use porous mats that deliver water to the base of the substrate and work well for depths less than 8 inches. Standing water systems maintain a layer of water at the base of the roof and can be maintained by float-control devices. The final method mentioned is drip irrigation, which use plastic tubing either laid on the surface of the media or buried beneath the substrate. This irrigation system loses less water than spray irrigation to evaporation. Weed seedlings are less likely to germinate as well if the surface is kept dry, however, maintenance of the tubing may be more cumbersome if buried. Drip irrigation applied at the surface is the recommended method for green roofs in Florida.

Hardin (2006) found that by increasing the irrigation rate the evapotranspiration rates increased but also significantly increased the filtrate factor due to watering past the point of growth media saturation. By increasing the evapotranspiration, the water budget is maintained and the runoff volume is decreased, while the increase in the filtrate factor increases the runoff. This increase in filtrate factor could potentially be reduced while maintaining high evapotranspiration by more frequent irrigation events at the same weekly volume. Results show that during the winter months the filtrate factors were high and the evapotranspiration rates for the vegetated chambers are equal to the non-vegetated chambers (Hardin, 2006). The higher the soil moisture at the point of water addition, either from irrigation or precipitation, the greater the resulting filtrate factor, which means that the green roof will have larger filtrate volumes if the soil moisture is kept relatively wet during most of the year. Hardin and Wanielista (2006), suggest reducing the irrigation rate during the winter months to 0.5 inches/wk, 1 inch/wk during the spring and fall, and 1.5 inches per week during the summer.

Hardin (2006) suggested a green roof irrigation schedule for the Central Florida area and for the loose laid 4 and 8 inch media depth as follows:

1. December, January, February, and half of March with 0.5 inches/wk
2. The rest of March, April, May, September, October, and November with1.0 inch/wk
3. June, July, and August with 1.50 inches/wk

Type of Plants

Green roof plants vary from region to region. While the majority of green roofs in the United States have been installed in temperate climates (i.e., Northeast, central North, and on the Northern West coast), more green roofs are being installed in Florida and the knowledge about the appropriate plants for green roofs in southern states such as

Florida is growing. Northern regions found that species such as sedums and delosperma are ideal green roof plants for their climate (Berghage et al., 2007). These plant species are not native to the Florida region and are not recommended for use in the southern climate. This was confirmed at Florida's first green roof, in Bonita Springs, which used such traditional green roof plants and no irrigation. Plant survival was very poor leading to the selection of new plants (Florida natives) and the addition of a cistern and irrigation system. Since then several green roofs have been installed in Florida including two on the University of Central Florida (Hardin, 2006; Kelly, 2008, & Minarci, 2010).

The research on green roof plants in Florida is limited and further studies are necessary to increase the list of the ideal plants for the region. The plant data that are available are found in the research done by Hardin (2006), Kelly (2008), Minarci (2010), the green roof at Bonita Springs as well as others. The partial list of plant species successfully used in the state of Florida on green roofs and include Helianthus debilis (Dune sunflower), Gaillardia pulchella or aristata (Blanket flower), Lonicera sempervirens (Coral honeysuckle), Muhlenbergia capillaris (Muhly Grass), Myricanthes fragrans (Simpson's stopper), Clytostoma callistegioides (Argentine trumpet vine), Tecomeria capensis (Cape honeysuckle), and Trachelospermum jasminoides (Confederate jasmine). The first five are native or have existed for a long time in central Florida and the last three are recently introduced but grow well in the area. Hardin's and other studies done in the state of Florida did not attempt to quantify the health or growth capacity of the plants. However, it was noted that after one year all species appeared to have healthy growth and only a few plants had to be replaced (Hardin, 2006). The observation of the plants after five years shows that the plants remain healthy and continue to grow. Similar success with these plants and related ones has occurred at the Bonita Springs green roof and other green roofs in the state of Florida.

For plants, Kelly (2008) used Zamia integrifolia (Coontie Palm), Muhlenbergia capillaris (Muhly Grass), Helianthus debilis (Dune sunflower), and Gaillardia pulchella or aristata (Blanket Sunflower Daisy) in his test chambers. Plants used on other green roofs in Florida include those used on the New American Home and the UCF Stormwater Lab. The New American plants used include Zamia integrifolia (Coontie Palm) and Muhlenbergia capillaris (Muhly Grass); the Stormwater Lab plants are Mimosa Strigillosa (Sunshine Mimosa), Lonicera sempervirens (Coral honeysuckle) and Helianthus debilis (Dune sunflower) (Kelly, Hardin, and Wanielista, 2007). It would appear from past research that native plants are an option to use on green roofs.

CHAPTER THREE: METHODOLOGY AND EXPERIMENTAL DESIGN

Methodologies

The following methodologies were used for the experimentation and comparative analyses in this project:

1. The measurement and comparison of the quantity of water introduced and removed from the greensmart blanket compared to other green roof section designs
2. Comparative analysis of CSTORM retention efficiencies verses the measured greensmart blanket efficiencies

The SOP for the field data collection is shown in Appendix A.

Experimental Design

The experiment was set up by building three 4’ x 4’ chambers with sides built up approximately 12-inches and lifted approximately 24-inches off the ground. Two 20-gallon containers are placed beneath the drains of the chambers to collect the direct runoff and on each of the irrigation dates the filtrate is measured and stored in a 55-gallon barrel (Cistern) in front of each chamber. There are three chambers built as replicates. An example cross section is seen in

Figure 4 which shows the greensmart blanket in a chamber.

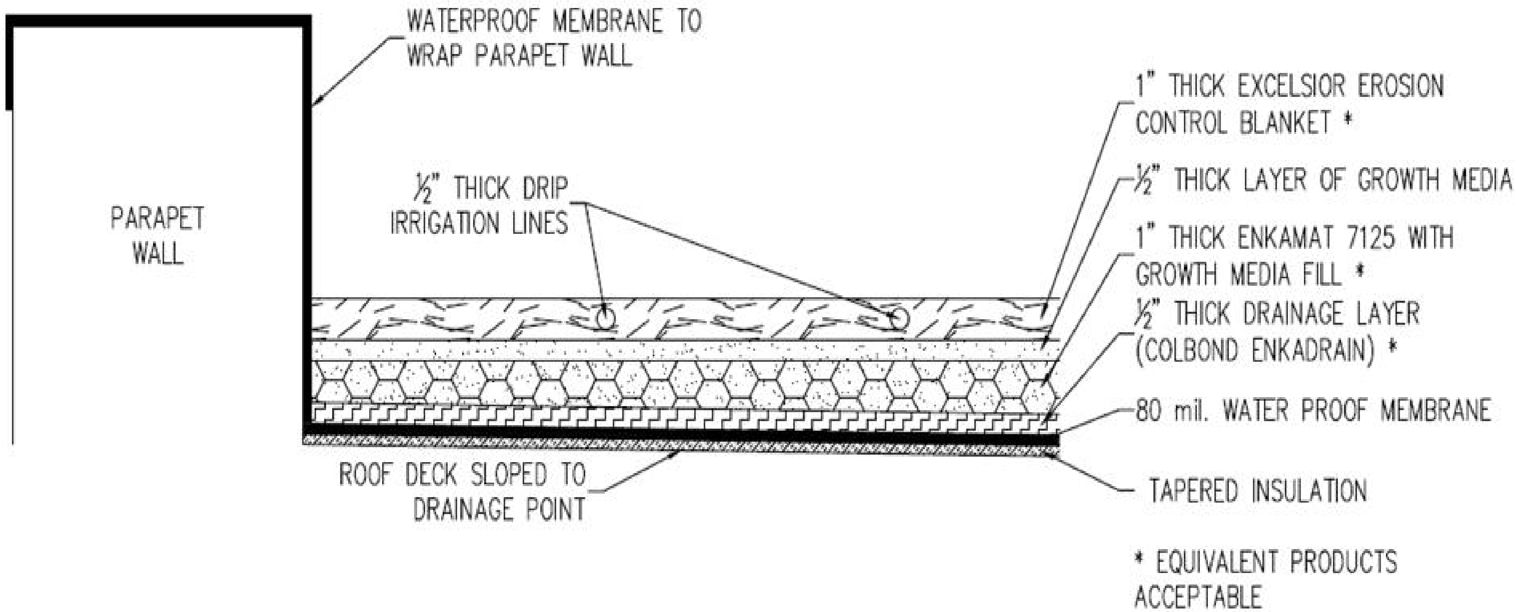

Figure 4: Greensmart Blanket Green Roof Chamber Cross Section

Notes:

1. Equivalent products are acceptable
2. The one inch erosion control blanket on top is a degradable product which will not be present after 6-9 months.
3. The standard waterproof membrane is an 80 mil thickness but other sizes may be approved by local ordinance.

CHAPTER FOUR: ET, F FACTOR, AND HYDROGRAPH RESULTS

ET Results

Shallow Depth vs. Deep Depth

Anova analysis was performed on all the green roof sections examined and the results are presented here. The annual ET results show no significant difference with a 95% confidence interval between the 2-inch deep greensmart blanket, the 4-inch deep loose laid green roof, the 6-inch deep loose laid green roof, and the 8-inch deep loose laid green roof. All the green roof sections examined had an annual average ET of 0.12 or 0.13 inches per day. The average annual ET for every green roof section examined and the number of samples used for the comparisons are shown in Table 1. There is no measurable ET from the control roofs and therefore that data are not presented here.

Table 1: Average Annual ET (inches per day)

Chamber Section	Greensmart Blanket, 2 inch depth	Loose Laid, 4 inch depth	Loose Laid, 6 inch depth	Loose Laid, 8 inch depth
Average	0.12	0.13	0.12	0.13
n	163	98	103	98

The monthly averages in general follow Figure 1 showing a gradual increase in the spring and decrease in the fall. Figure 5 is a comparable graph to Figure 1 for Orlando conditions and climate. There is no significant difference in ET rates ($\alpha=0.05$)

for the different depth green roof sections. Table 2 shows for each month the average daily ET for each green roof section. An ANOVA analysis was done on these data for a 95% confidence interval and no significant difference was shown. It should be noted that the greensmart blanket, loose laid 6 inch depth section, and the loose laid 4 inch and 8 inch depth sections were operate in three different years and thus experienced different weather conditions. This is significant because the annual rainfall received in 2010-2011 was 39.58 inches (greensmart blanket), 2007 was 44 inches (4 & 8 inch media), and 2005-2006 was 44.25 inches (6 inch media) (Hardin, 2006 & Kelly, 2008). There was potentially less water available for evapotranspiration with the greensmart blanket. However, the irrigation frequency of once every other day provides water for ET. The ET comparison on an annual basis is similar because of the irrigation frequency and the tests were done with the same climate conditions.

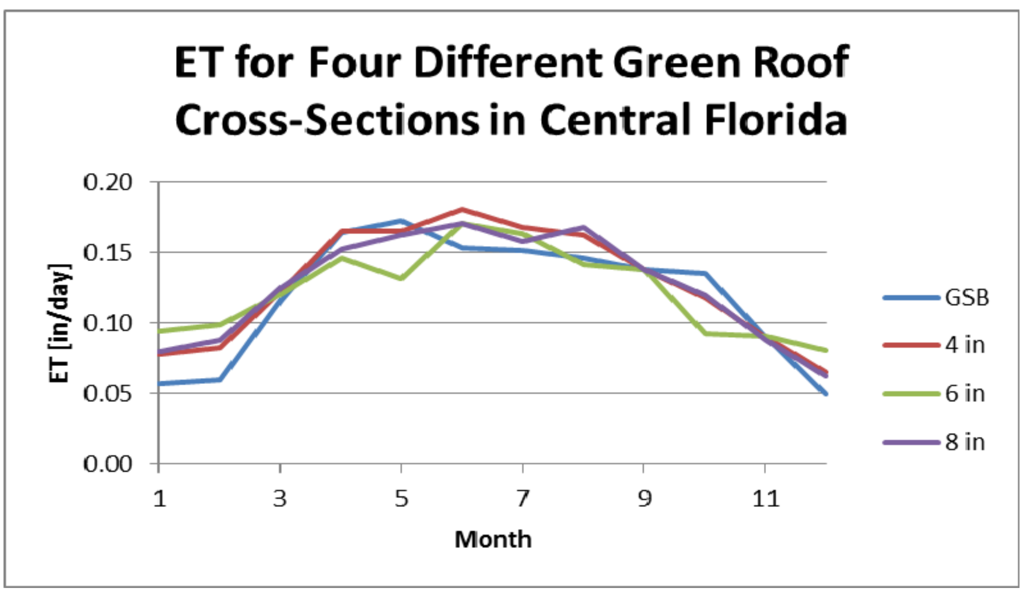

Figure 5: Average ET for Four Different Green Roof Sections in Central Florida

Table 2: Average ET (inches per day) for each Month

Month	Greensmart Blanket, 2 inch depth (2010-2011)	Loose Laid, 4 inch depth (2007)	Loose Laid, 6 inch depth (2005-2006)	Loose Laid, 8 inch depth (2007)
January	0.06	0.08	0.09	0.08
February	0.06	0.08	0.10	0.09
March	0.12	0.12	0.12	0.13
April	0.16	0.17	0.15	0.15
May	0.17	0.17	0.13	0.16
June	0.15	0.18	0.17	0.17
July	0.15	0.17	0.16	0.16
August	0.15	0.16	0.14	0.17
September	0.14	0.14	0.14	0.14
October	0.14	0.12	0.09	0.12
November	0.09	0.09	0.09	0.09
December	0.05	0.07	0.08	0.06

Cumulative ET Comparisons

The cumulative ET results show little difference between any of the loose laid systems. The greensmart blanket system did have a noticeably lower cumulative ET than the loose laid systems however this difference was not significant (α=0.05) as shown in the previous section. This is presumably due to two factors, namely the shallower depth, and thus less storage volume, of the section, and the fact that data were collected on different years with the greensmart blanket data receiving only 39 inches of rain compared to 44 inches for the loose laid systems. A little over 6 inches more evapotranspiration occurred over the course of a year for the 4 and 8 inch (48 inches) loose laid systems compared to the greensmart blanket system (42 inches). The 6 inch loose laid system fell between these systems with a total ET of 46 inches. Figure 6 below shows that all systems have similar trends in that the rate is at a maximum from about April to September and at a minimum from about October to March.

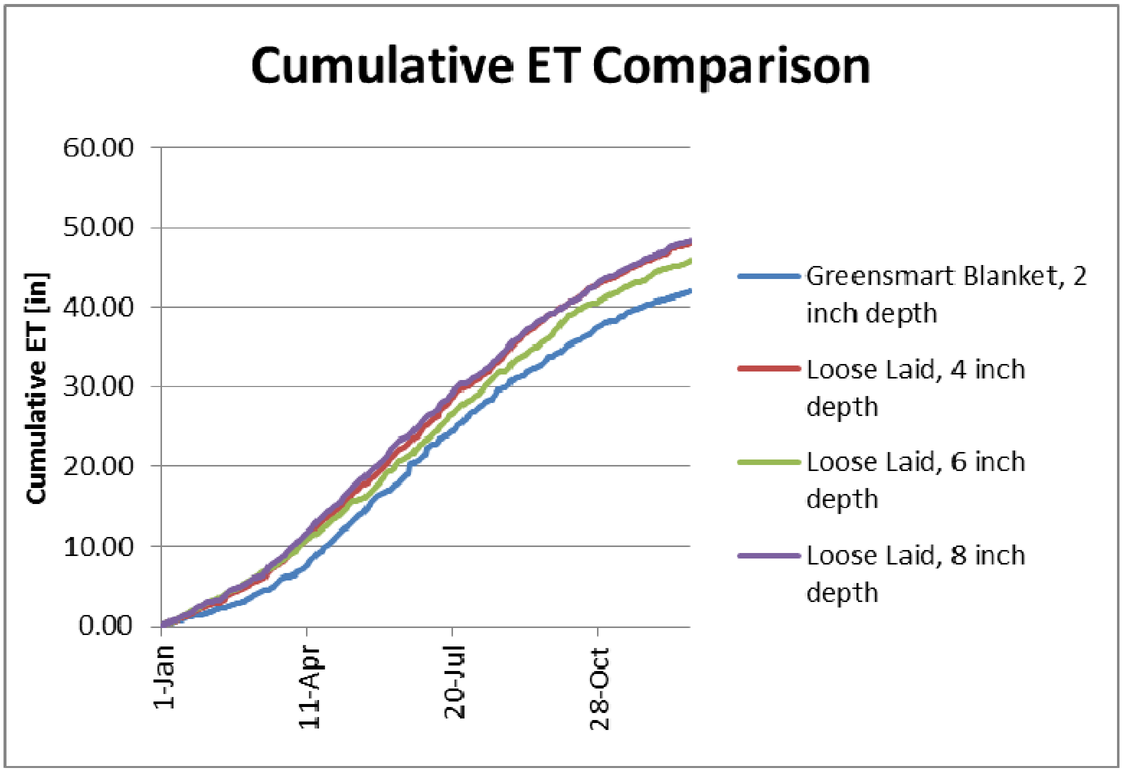

Figure 6: Cumulative ET Comparisons for Each Green Roof Section

f Factor Results

Shallow Depth vs. Deep Depth

An ANOVA analysis was completed on the f factor comparisons for all the data and the results are presented here. The results show that there is no significant difference ($\alpha=0.05$) in the yearly average filtrate factor for any of the green roof sections examined. Table 3 illustrates the average f Factor for each green roof section examined over the year. The filtrate Factor (f), defined as the ratio of filtrate volume to rainfall and irrigation per measured time period, ranges between 0.33 and 0.41. Some of the difference seen in Table 3 can be attributed to the fact that while the data for the 4 and 8 inch systems were collected in the same year, the 2 inch and 6 inch systems data were collected in different years. Thus, differences in weather conditions are a potential source of the observed variation in f factors between system sections. Differences in irrigation schedule could also contribute to this but is examined later in this chapter.

Table 3: Average Annual f Factors (dimensionless)

Chamber Section	Greensmart Blanket, 2 inch depth	Loose Laid, 4 inch depth	Loose Laid, 6 inch depth	Loose Laid, 8 inch depth
Average	0.33	0.37	0.41	0.38
N	163	98	103	98

Examining every section on a monthly basis, the monthly f factors generally vary from one month to another but there is an increase when the monthly rainfall increases. Table 4 shows the monthly f Factor values, Figure 7 illustrates the change in the f Factor for every green roof section throughout the year, and Figure 8 illustrates the change in rainfall throughout the year for each of the years examined. An ANOVA analysis was performed on the data in Table 4 and there was no significant difference (α=0.05) for any green roof section examined. By visual inspection of Figure 7 and Figure 8, the filtrate factor for every green roof section tended to follow the monthly rainfall totals.

Table 4: Average Monthly f Factor (dimensionless)

	Chamber Section			
	Greensmart Blanket, 2 inch depth (2010 - 2011)	Loose Laid, 4 inch depth (2007)	Loose Laid, 6 inch depth (2005 - 2006)	Loose Laid, 8 inch depth (2007)
January	0.32	0.14	0.44	0.12
February	0.03	0.27	0.44	0.25
March	0.15	0.08	0.18	0.10
April	0.29	0.16	0.15	0.19
May	0.68	0.12	0.29	0.14
June	0.40	0.46	0.45	0.49
July	0.24	0.65	0.54	0.69
August	0.47	0.41	0.40	0.40
September	0.29	0.56	0.53	0.60
October	0.34	0.52	0.57	0.54
November	0.39	0.48	0.39	0.51
December	0.41	0.54	0.58	0.57

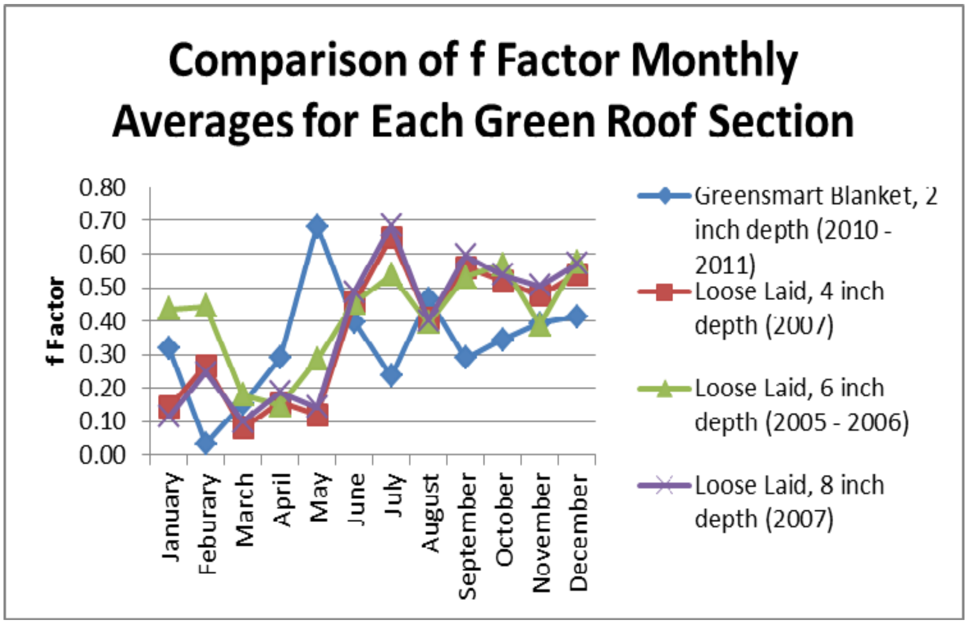

Figure 7: f Factor comparison for each green roof section (dimensionless)

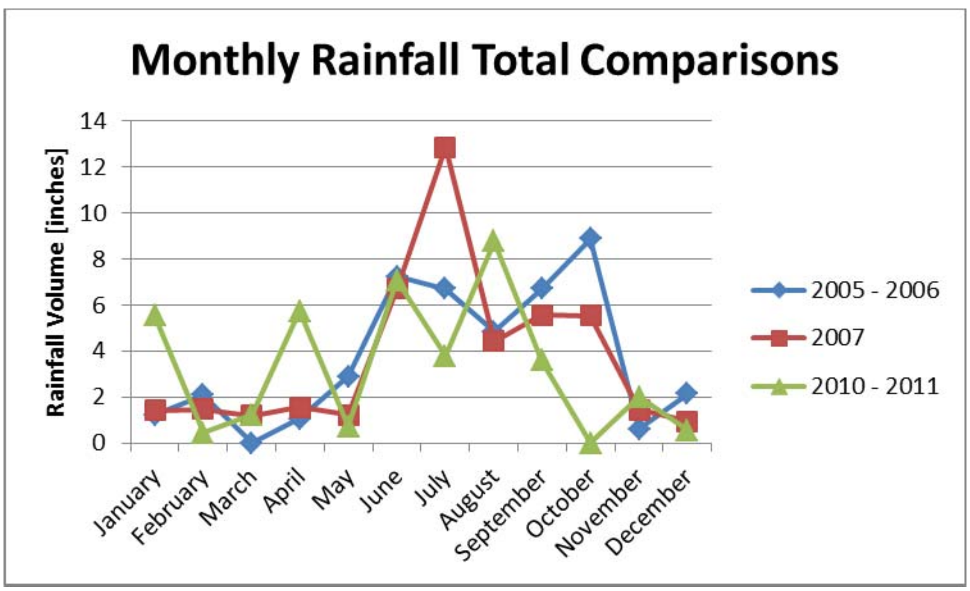

Figure 8: Comparison of total monthly rainfall volumes for each study year

Hydrograph Results

Hydrograph data were collected for the greensmart blanket and compared to previous data collected from a 4 inch, 6 inch, and 8 inch deep loose laid system (Hardin, 2006 and Kelly, 2008). A six-inch per hour storm was applied to each green roof section and measurements of filtrate were taken every minute. It should be pointed out once again that the data for the 4 inch and 8 inch deep loose laid systems was collected in 2007 (Kelly, 2008), data for the 6 inch deep loose laid system was collected in 2005 – 2006 (Hardin, 2006), and the data for the greensmart blanket was collected in 2010 – 2011.

The control chamber data used in this research was from Hardin (2006) to compare with the other sections, as shown in Figure 9.

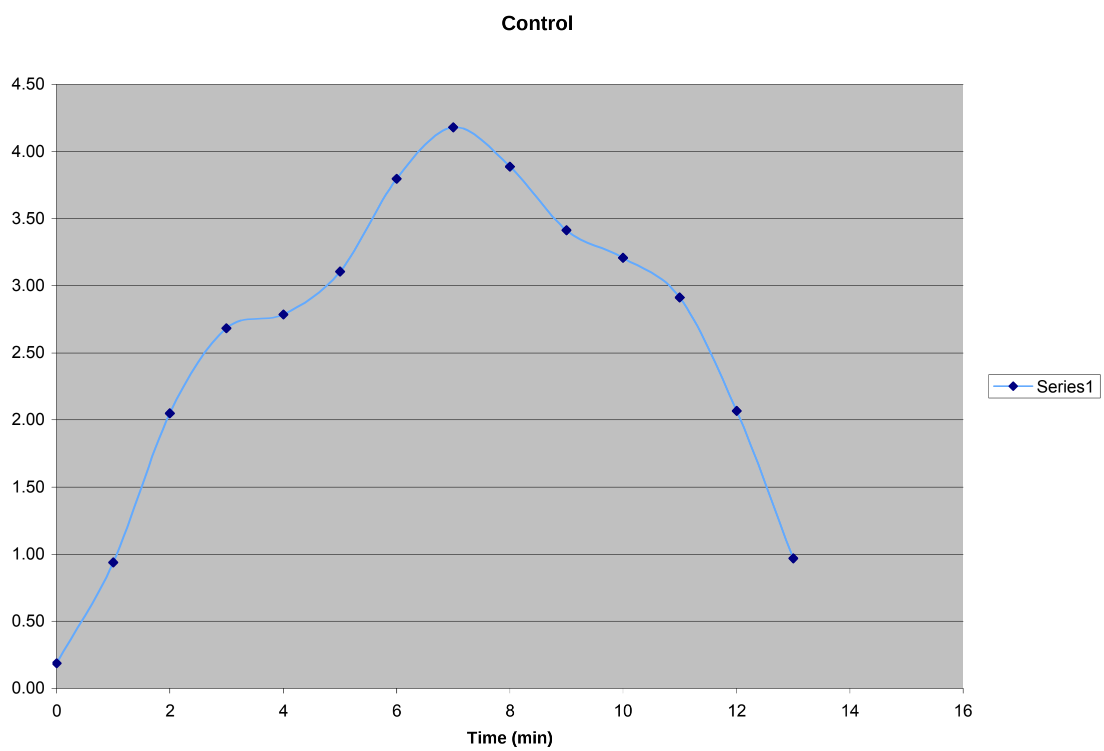

Figure 9: Control Chamber Hydrograph (Hardin, 2006)

The hydrograph results are shown below in Figure 10. An ANOVA analysis, 95% confidence interval, was completed on the hydrograph data to examine the differences between conventional roofing techniques (control roof) and several green roofing techniques. It was shown that the control roof and greensmart blanket were not significantly different ($\alpha=0.05$). However, for a 1 inch rain event the greensmart blanket showed at total volume reduction of about 0.2 inches. The greensmart blanket was also shown to, although not significantly ($\alpha=0.05$), lower peak flow and increase the time to peak compared to the control roof. The control roof was shown to be significantly different ($\alpha=0.05$) from all the 4 inch deep, 6 inch deep, and 8 inch deep loose laid systems. It is shown that the time to peak was longer and the peak runoff was lower for all three of the loose laid systems compared to the control roof.

Observations can also be made between the different green roof sections. It was shown that the greensmart blanket was significantly different from the 4 inch deep and 8 inch deep loose laid systems having a higher peak flow and shorter time to peak. The greensmart blanket also had a higher peak flow and shorter time to peak than the 6 inch deep loose laid system, just not significantly at a 95% confidence interval. The only other significant difference was between the 6 inch deep and 8 inch deep loose laid systems, where the 8 inch deep loose laid system outperformed the 6 inch deep loose laid system. It is noted that, despite the 6 inch deep loose laid system having a higher storage capacity than the 4 inch deep loose laid system, the 6 inch deep system had a higher peak discharge and higher total filtrate volume. A potential reason for this could be due to several factors such as; different plants used in the two systems, the fact that the tests were run and thus the data was collected in different years where weather conditions were likely different, differences in the starting moisture content, and differences in the irrigation schedule.

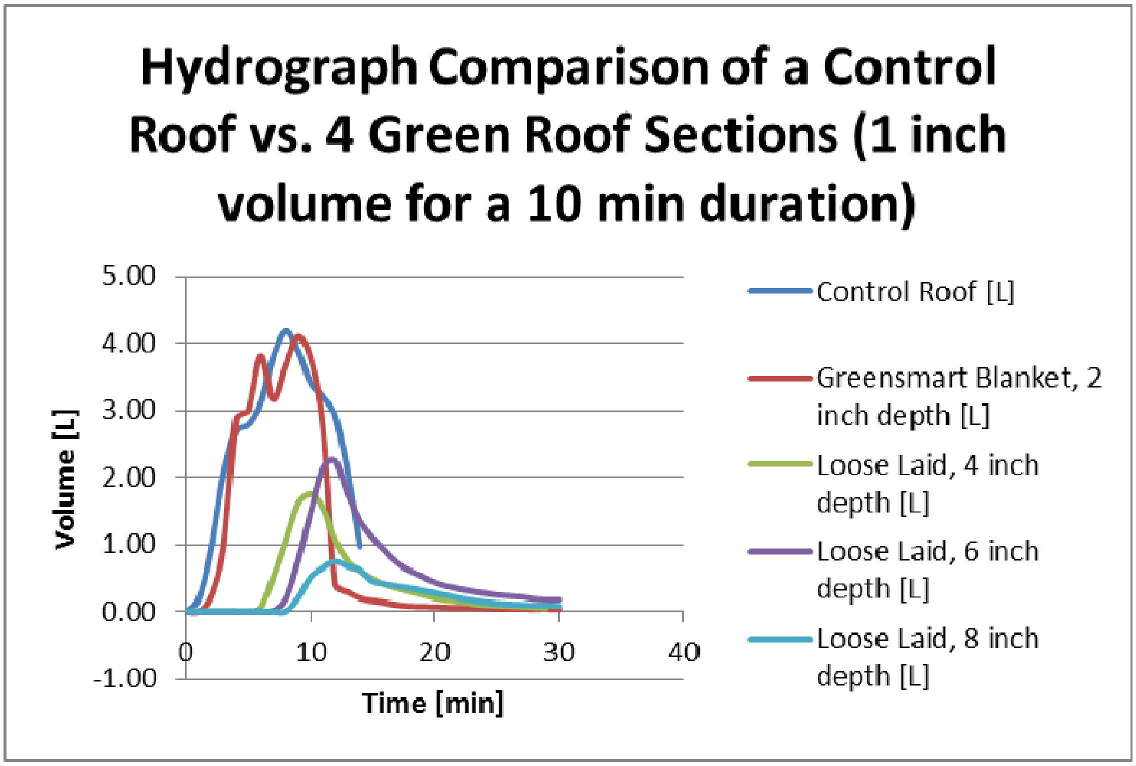

Figure 10: Hydrograph Comparison between the Control, Greensmart Blanket, 4 inch depth, 6 inch depth, and 8 inch depth (L/min)

The cumulative volume was also calculated for the control roof and each green roof section and is graphically displayed in Figure 11. The cumulative volume for the control roof was shown to be 36 L. The cumulative volume for the greensmart blanket was shown to be 30 L. The cumulative volumes for the three loose laid green roof systems were 12 L, 17 L, and 7 L for the 4, 6, and 8 inch deep systems respectively.

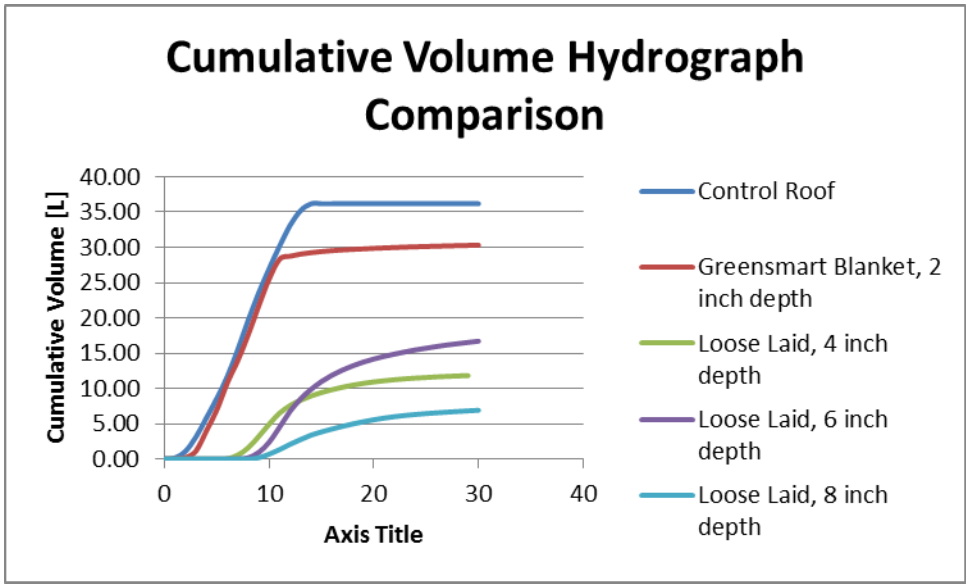

Figure 11: Cumulative Volume Hydrographs

Table 5 below shows the total volume collected after 30 minutes and the fraction of storage to total volume applied for the control roof, greensmart blanket, 4 inch deep loose laid system, 6 inch deep loose laid system, and 8 inch deep loose laid system hydrograph events. It can be seen that the 8 inch deep loose laid system has the greatest storage compared to all the other roof sections examined. This is expected as the 8 inch deep loose laid section has a larger potential storage due to the increase media depth. Factors that could potentially affect these results are the starting soil/media moisture content, the weather conditions during the time of testing, and the irrigation volume/schedule.

Table 5: Roof Section Comparison using Filtrate Total and Storage for a 1 inch 10 minute duration rain event

Comparison of Total Volume Reduction for a 1 Inch, 10 minute Duration Rain Event		
Chambers	**Cumulative Inches after 30 min**	**Storage [in]**
Control Roof	0.96	0.04
Greensmart Blanket, 2 inch depth	0.80	0.20
Loose Laid, 4 inch depth	0.31	0.69
Loose Laid, 6 inch depth	0.44	0.56
Loose Laid, 8 inch depth	0.18	0.82

It should be noted that the 6 inch deep loose laid system had a smaller storage volume than the 4 inch deep loose laid system for the hydrograph event. This could be due to several factors such as the hydrograph test was run in different years for both sections likely resulting in different starting moisture content values and the fact that the 6 inch deep system had an irrigation schedule that was 0.5 inches twice per week while the 4 inch deep system had an irrigation schedule that varied with season as described above. The greensmart blanket storage value is likely so low compared to the loose laid green roof sections due to the more regular irrigation schedule, every other day as opposed to twice a week. In addition, 0.5 inches of the 2 inch greensmart blanket section is the drainage layer and thus only 1.5 inches of the section are available for storage.

Water Volume Efficiency

The annual retention efficiency of a green roof system as defined in this report is estimated from the cistern overflow (O) and precipitation (P) volumes using equation (8). Using the retention efficiency equation and the average overflow from the greensmart blanket system, the 4-inch depth loose laid system, the 6-inch depth loose laid system, and the 8-inch depth loose laid system and the respective precipitation, the annual efficiencies for the year of data collection are calculated as:

Efficiency = [1 – (O/P)*100%]

Efficiency (greensmart blanket) = [1 – (11 in. / 39 in.) * 100%] = 72%

Efficiency (4-inch) = [1 – (9 in. / 43 in.) * 100%] = 80%

Efficiency (6 inch) = [1 – (8 in. / 44 in.) * 100%] = 82%

Efficiency (8-inch) = [1 – (10 in. / 43 in.) * 100%] = 77%

The lowest water volume efficiency is for the greensmart blanket system with an overall retention efficiency of 72% and the highest efficiency is for the 6 inch deep system with an overall retention efficiency of 82%. It should be noted that there is no real difference between these retention efficiencies and the differences observed were likely due to different weather conditions experienced in different years, and/or the starting cistern storage volume.

CSTORM Model Comparisons

The CSTORM model developed by Hardin (2006) was run using the latest 30 years of Orlando, Florida precipitation data on all green roof sections examined. Previous work had used a rainfall from different time periods. The results of the Model were compared to the results from the previous section to see if the CSTORM model closely represents how these different green roof systems perform in the field. Table 6 below shows the annual retention as calculated by the CSTORM Model. There is very little difference in the annual retention for each section. This is due to the fact that a majority of the storage capacity is associated with the cistern storage and all of the green roof sections will release very little filtrate for small volume storm events, which is a majority of the rain events that occur in the Orlando Florida area (Wanielista and Yousef, 1993). Comparing the results in Table 6 for a 5 inch storage volume with the results in the previous section it is shown that the CSTORM Model adequately represents the results obtained in the field. Figure 12 below shows the graphical comparison of the greensmart blanket green roof system to the 6 inch loose laid green roof system. Based on the results shown below in Table 6 and Figure 12 existing CSTORM efficiency curves presented by Hardin, 2006 can be used to predict the efficiency of the greensmart blanket by subtracting 4% from those annual retention efficiency curves for the deeper sections.

Table 6: Comparison of CSTORM Model Results for the Greensmart Blanket and Three Loose Laid Systems for Orlando, Florida

Comparison of CSTROM Results for Orlando Florida Using 30 Years of Data				
	Greensmart 2 inch Depth	4 inch Depth Loose Laid	6 inch Depth Loose Laid	8 inch Depth Loose Laid
Storage Volume [in/GR Area]	Efficiency	Efficiency	Efficiency	Efficiency
0	0.3	0.34	0.33	0.34
0.5	0.51	0.53	0.53	0.53
1	0.6	0.62	0.62	0.62
2	0.67	0.71	0.71	0.71
3	0.71	0.75	0.75	0.75
4	0.74	0.78	0.78	0.78
5	0.76	0.8	0.8	0.8

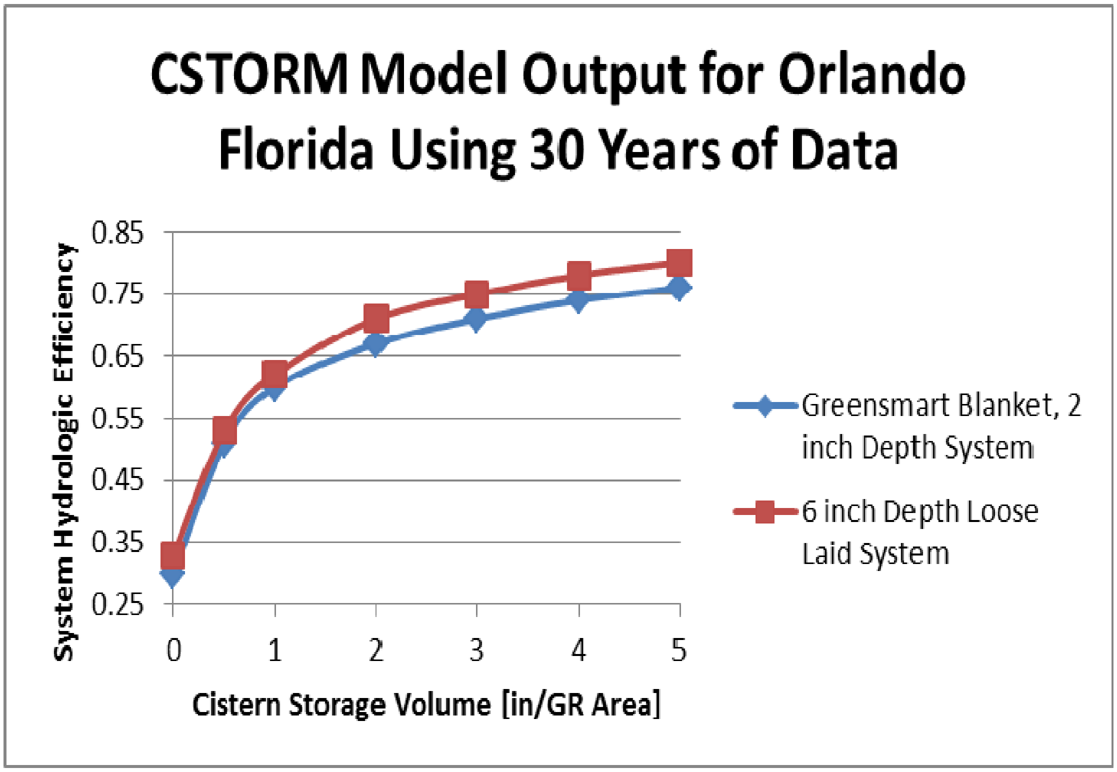

Figure 12: CSTORM Model Output Comparison for the Greensmart Blanket and 6 inch Loose Laid Green Roof Systems

Irrigation Rates

The irrigation rates and frequencies varied for the different green roof sections. For every green roof system examined irrigation occurred on the scheduled day unless a rain event that exceeded the irrigation event occurred within 24 hours of the intended irrigation event. The greensmart blanket irrigation schedule was to vary the irrigation rate with season and perform irrigation every other day. The irrigation rates were about 1 inch per week in the summer months, 0.75 inches per week in the spring and fall months, and 0.5 inches in the winter months. The 4 inch and 8 inch deep loose laid systems were irrigated twice a week with the irrigation volume varying with season. The irrigation rates were about 1.5 inches per week in the summer months, 1.0 inch per week in the spring and fall months, and 0.5 inches per week in the winter months. The 6 inch deep loose laid system was irrigated twice a week for a total volume of 1 inch per week for all seasons. Thus the volume of irrigation for the greensmart blanket was about 40 inches per year or 18% less than that for the loose laid systems (48 inches) on an annual basis even though the frequency of irrigation was higher with the greensmart blanket.

CHAPTER FIVE: SUMMARY AND CONCLUSIONS

Summary

The greensmart blanket is a shallow depth (2 inch), light weight, green roof system capable of providing significant stormwater management benefit. The data collected for this experiment were compared to data collected by Hardin (2006) and Kelly (2008) which presented data for a 6 inch deep loose laid green roof system and a 4 inch and 8 inch deep loose laid green roof system, respectively. It has been shown in this report that there is no significant difference (α=0.05) between the average daily ET rate and f factor on a monthly basis for the greensmart blanket and three different loose laid green roof systems (4, 6, and 8 inch depth). The cumulative ET was also shown to not be significantly different (α=0.05) for the greensmart blanket and the loose laid green roof systems, however the greensmart blanket did have a slightly lower value. This difference is likely due to the differences in weather and environmental conditions experienced in the different years that the experiments were run as well as the different irrigation schedules used for each experiment.

Hydrograph data were collected for the greensmart blanket and compared to a control roof and 6 inch deep loose laid green roof system (Hardin, 2006) and a 4 inch and 8 inch deep loose laid green roof system (Kelly, 2008). Comparing the greensmart blanket to traditional roofing techniques (control roof) for a 1 inch storm event over a 10 minute duration showed a 20% volume reduction with the greensmart blanket. The greensmart blanket hydrograph peak was shown to be significantly different (α=0.05) and higher than both the 4 and 8 inch deep loose laid green roof systems. All the loose laid systems showed a significant reduction in peak flow and time to peak compared to the greensmart blanket. This result is expected due to the significantly lower storage volume available in the greensmart blanket section.

Comparisons were also made for the annual water volume retention efficiency using the CSTORM model output for the greensmart blanket and the loose laid systems. It was shown that there was no significant difference ($\alpha=0.05$) between the greensmart blanket and the loose laid systems examined. The greensmart blanket however did have a 4% lower efficiency than all the loose laid deeper green roof systems.

Conclusions

Developed within this report is a shallow 2 inch depth green roof system called the greensmart blanket. This green roof system like the others can use a cistern for the storage of filtrate from the roof to be used for irrigation and is consistent with the design detail presented in Chapter 3 of this report. The data presented in this report shows that a shallow depth, light weight green roof system can be successfully implemented in the Central Florida area. When the greensmart blanket is used in conjunction with a cistern, the greensmart filtrate and ET on an average monthly and annual basis will perform similar to loose laid systems up to 8 inches in depth.

The vegetation types used for the greensmart blanket system were wild flowers native to the state of Florida and Arachis Glabrata (perennial peanut). The wild flowers were applied in seed form and allowed to establish and reseed naturally while the perennial peanut was planted. All the plants used thrived during the course of the experiment, except during the winter months where Orlando experienced colder than normal temperatures for extended periods of time. However, the plants did recover when warmer weather arrived. For weekly irrigation, it was also shown for the shallow depth greensmart blanket that the volume per event should be reduced and the irrigation events should occur every other day.

Recommendations

Several recommendations based on the results of the research presented within this report are presented here. First, the greensmart blanket can be used for stormwater management and the average annual retention is only about 4% less than the deeper green roof sections for each cistern size up to 5 inches of storage over the green roof area. Next, the greensmart blanket needs to be irrigated every other day to ensure adequate water is available for the vegetation. However, the irrigation weekly volume remains about the same as recommended by Hardin (2006) for deeper (4,6, and 8 inch) green roof sections because less volume is used per irrigation time during all the seasons without negative effects on the vegetation. Since the greensmart blanket is such a shallow system it is imperative that irrigation is not interrupted and thus control systems should be implemented to alert the proper people if failure does occur. All the native plant species and the perennial peanut used in this research performed adequately. Due to the shallow depth of the greensmart blanket system it is recommended that the vegetation be established from seeds, plugs, or 4 inch pots.

Future Research

The research in this report shows that the greensmart blanket performs similar to loose laid green roof systems when comparing small 16 square foot chambers. The greensmart blanket should be examined in a full scale application to verify the results presented in this report. Additional plants may also be examined for their applicability in this green roof application. Creative ways to improve the aesthetics of the greensmart blanket may also be explored.

APPENDIX A: GREENSMART BLANKET FIELD DATA COLLECTION

1) Enter time and date on top of field data sheet
2) Collect water from collection tanks in buckets
3) Bring buckets to concrete pad, set on level area.
4) While buckets are settling, measure initial drum depths, record in column 1 of field data sheet
5) Measure bucket depths and record in column 2 of field data sheet
6) Add bucket contents to drum
7) After water movement has settled, measure drum depth in column 3 of field data sheet
8) Check onsite rain gage and record value.
    a. If less than intended irrigation volume, circle "Y" in column 4 of field data sheet and continue with irrigation (step 9)
    b. if greater than or equal to intended irrigation volume, circle "N" in column 4 of field data sheet and close drums
9) If answer yes in step 8a above continue with irrigation,
    a. Fill orange bucket to the line corresponding with intended irrigation volume
    b. Transfer water to watering can being careful to prevent any spilling.
    c. Water chamber evenly
10) Repeat step nine for each chamber.
11) Measure the depths of each drum and record in column 5 of field data sheet
12) Close drums tightly

APPENDIX B: VOLUME, ET, AND F FACTOR TABLES

Volume Tables

Table 7: Volume of Irrigation, Filtrate, and Overflow per year

	Irrigation [L]	**Total Filtrate [L]**	**Overflow [L]**
Greensmart Blanket, 2 inch depth	1508	1639	429
4 inch depth loose laid	1834	1897	301
6 inch depth loose laid	1829	1821	285
8 inch depth loose laid	1832	1902	317

Table 8: Volume of Precipitation and Control Roof Runoff

	Precipitation [L]	**Total Runoff [L]**
Control Roof	1669	1623

ET Table

ET Comparison of all the Chambers			
Date	A	B	C
5/24/2010	-	-	-
5/25/2010	0.36	0.32	0.30
5/26/2010	0.13	0.11	0.08
5/27/2010	0.25	0.22	0.24
5/28/2010	0.28	0.25	0.24
5/29/2010	0.17	0.18	0.12
5/30/2010	0.15	0.04	0.07
5/31/2010	0.04	0.06	0.03
6/1/2010	0.03	0.02	0.02
6/3/2010	0.14	0.13	0.10
6/4/2010	0.09	0.06	0.05
6/5/2010	0.13	0.04	0.07
6/7/2010	0.00	0.00	0.00
6/9/2010	0.17	0.14	0.15
6/11/2010	0.15	0.15	0.13
6/13/2010	0.16	0.16	0.15
6/15/2010	0.16	0.15	0.14
6/17/2010	0.16	0.14	0.13
6/18/2010	0.23	0.26	0.21
6/19/2010	0.25	0.26	0.22

6/20/2010	0.02	0.01	0.06
6/21/2010	1.21	0.44	0.69
6/23/2010	0.00	0.00	0.00
6/25/2010	0.16	0.12	0.15
6/27/2010	0.15	0.14	0.13
6/29/2010	0.16	0.15	0.14
7/1/2010	0.13	0.12	0.12
7/2/2010	0.90	0.53	0.53
7/3/2010	0.05	0.04	0.05
7/4/2010	0.10	0.10	0.10
7/5/2010	0.11	0.10	0.06
7/7/2010	0.00	0.00	0.00
7/9/2010	0.14	0.13	0.14
Date	A	B	C
7/11/2010	0.15	0.13	0.12
7/13/2010	0.13	0.16	0.14
7/15/2010	0.17	0.12	0.10
7/16/2010	0.05	0.05	0.05
7/17/2010	0.00	0.00	0.00
7/19/2010	0.14	0.14	0.12
7/21/2010	0.15	0.15	0.15
7/23/2010	0.15	0.09	0.13
7/24/2010	0.43	0.40	0.43
7/25/2010	0.10	0.08	0.07
7/27/2010	0.09	0.09	0.09
7/29/2010	0.15	0.15	0.15
7/30/2010	0.42	0.44	0.40

7/31/2010	0.00	0.00	0.00
8/2/2010	0.33	0.33	0.32
8/4/2010	0.00	0.00	0.00
8/9/2010	0.15	0.14	0.13
8/12/2010	0.14	0.14	0.15
8/14/2010	0.12	0.13	0.14
8/16/2010	0.00	0.00	0.00
8/19/2010	0.29	0.22	0.22
8/20/2010	0.36	0.23	0.29
8/24/2010	0.07	0.08	0.64
8/25/2010	0.06	0.04	0.08
8/26/2010	0.10	0.01	0.08
8/30/2010	0.17	0.04	0.03
9/1/2010	0.12	0.06	0.11
9/3/2010	0.13	0.13	0.15
9/7/2010	0.04	0.11	0.11
9/9/2010	0.24	0.22	0.27
9/13/2010	0.09	0.09	0.09
9/15/2010	0.00	0.00	0.00
9/17/2010	0.15	0.14	0.13
9/20/2010	0.08	0.09	0.10
9/21/2010	0.31	0.30	0.27
9/22/2010	0.21	0.22	0.22
9/23/2010	0.15	0.16	0.14
9/24/2010	0.25	0.28	0.29
9/27/2010	0.00	0.02	0.06
9/29/2010	0.21	0.21	0.24

Date	A	B	C
9/30/2010	0.00	0.00	0.00
10/1/2010	0.15	0.11	0.15
10/2/2010	0.12	0.17	0.14
10/3/2010	0.17	0.20	0.18
10/4/2010	0.20	0.20	0.17
10/5/2010	0.11	0.12	0.12
10/6/2010	0.19	0.11	0.14
10/7/2010	0.15	0.14	0.12
10/9/2010	0.10	0.11	0.11
10/12/2010	0.09	0.09	0.09
10/22/2010	0.08	0.08	0.07
10/24/2010	0.16	0.15	0.14
10/26/2010	0.16	0.15	0.15
10/28/2010	0.15	0.14	0.13
10/30/2010	0.12	0.14	0.16
11/1/2010	0.12	0.13	0.13
11/3/2010	0.09	0.04	0.07
11/5/2010	0.07	0.15	0.11
11/8/2010	0.00	0.00	0.00
11/10/2010	0.11	0.13	0.12
11/12/2010	0.15	0.13	0.13
11/14/2010	0.06	0.07	0.08
11/17/2010	0.15	0.16	0.14
11/18/2010	0.09	0.12	0.09
11/21/2010	0.08	0.09	0.08
11/24/2010	0.05	0.05	0.04

11/26/2010	0.09	0.09	0.09
11/28/2010	0.07	0.04	0.07
11/30/2010	0.09	0.12	0.10
12/2/2010	0.00	0.00	0.00
12/6/2010	0.07	0.07	0.04
12/8/2010	0.04	0.09	0.06
12/10/2010	0.07	0.07	0.05
12/13/2010	0.05	0.04	0.04
12/15/2010	0.06	0.07	0.08
12/17/2010	0.08	0.09	0.09
12/20/2010	0.06	0.04	0.06
12/21/2010	0.00	0.00	0.00
12/23/2010	0.05	0.06	0.05
12/27/2010	0.06	0.06	0.06
Date	A	B	C
12/29/2010	0.08	0.06	0.06
12/31/2010	0.04	0.03	0.02
1/2/2011	0.06	0.06	0.06
1/4/2011	0.07	0.06	0.06
1/6/2011	0.10	0.23	0.10
1/8/2011	0.00	0.06	0.00
1/11/2011	0.09	0.08	0.06
1/13/2011	0.00	0.00	0.00
1/15/2011	0.06	0.06	0.05
1/18/2011	0.08	0.06	0.23
1/20/2011	0.00	0.00	0.00
1/23/2011	0.07	0.07	0.20

1/25/2011	0.00	0.00	0.00
1/27/2011	0.08	0.10	0.11
1/29/2011	0.00	0.00	0.00
1/31/2011	0.06	0.04	0.05
2/2/2011	0.05	0.05	0.04
2/4/2011	0.05	0.05	0.04
2/8/2011	0.10	0.11	0.10
2/10/2011	0.05	0.05	0.05
2/14/2011	0.03	0.03	0.05
2/16/2011	0.07	0.07	0.03
2/18/2011	0.04	0.06	0.08
2/20/2011	0.06	0.05	0.08
2/22/2011	0.05	0.06	0.06
2/25/2011	0.04	0.05	0.04
2/27/2011	0.08	0.11	0.11
3/2/2011	0.11	0.15	0.19
3/4/2011	0.09	0.12	0.08
3/6/2011	0.14	0.12	0.04
3/8/2011	0.12	0.11	0.11
3/13/2011	0.09	0.09	0.09
3/15/2011	0.00	0.00	0.00
3/17/2011	0.12	0.12	0.11
3/19/2011	0.16	0.14	0.16
3/21/2011	0.16	0.14	0.15
3/23/2011	0.15	0.15	0.16
3/25/2011	0.17	0.14	0.16
4/2/2011	0.04	0.07	0.06

4/5/2011	0.14	0.14	0.13
Date	A	B	C
4/8/2011	0.10	0.10	0.08
4/11/2011	0.11	0.09	0.14
4/13/2011	0.30	0.28	0.29
4/15/2011	0.20	0.17	0.17
4/17/2011	0.15	0.14	0.16
4/19/2011	0.20	0.20	0.20
4/21/2011	0.17	0.16	0.22
4/23/2011	0.24	0.24	0.20
4/25/2011	0.13	0.11	0.18
4/27/2011	0.20	0.19	0.22
4/29/2011	0.17	0.14	0.17
Average	0.13	0.11	0.12
s	0.134	0.090	0.105
s^2	0.018	0.008	0.011
n	163	163	163

f Factor Table

f Factor Comparison of all the Chambers			
Date	A	B	C

5/24/2010	-	-	-
5/25/2010	0.37	0.44	0.48
5/26/2010	0.78	0.81	0.85
5/27/2010	0.56	0.62	0.58
5/28/2010	0.43	0.48	0.53
5/29/2010	0.67	0.63	0.77
5/30/2010	0.83	0.95	0.92
5/31/2010	0.87	0.83	0.90
6/1/2010	0.97	0.98	0.97
6/3/2010	0.53	0.56	0.66
6/4/2010	0.93	0.95	0.96
6/5/2010	0.67	0.89	0.80
6/7/2010	0.00	0.00	0.00
6/9/2010	0.06	0.18	0.18
6/11/2010	0.06	0.12	0.23
Date	A	B	C
6/13/2010	0.00	0.00	0.03
6/15/2010	0.00	0.06	0.10
6/17/2010	0.06	0.13	0.18
6/18/2010	0.81	0.79	0.82
6/19/2010	0.82	0.82	0.85
6/20/2010	0.88	0.91	0.62
6/21/2010	0.52	0.83	0.73
6/23/2010	0.00	0.00	0.00
6/25/2010	0.03	0.15	0.10
6/27/2010	0.03	0.10	0.17
6/29/2010	0.00	0.03	0.13

7/1/2010	0.14	0.24	0.28
7/2/2010	0.56	0.74	0.74
7/3/2010	0.00	0.11	0.00
7/4/2010	0.67	0.68	0.70
7/5/2010	0.69	0.71	0.83
7/7/2010	0.00	0.00	0.00
7/9/2010	0.04	0.17	0.18
7/11/2010	0.03	0.17	0.21
7/13/2010	0.11	0.03	0.07
7/15/2010	0.77	0.83	0.87
7/16/2010	0.00	0.00	0.00
7/17/2010	0.00	0.00	0.00
7/19/2010	0.10	0.13	0.19
7/21/2010	0.03	0.03	0.07
7/23/2010	0.09	0.19	0.18
7/24/2010	0.11	0.15	0.13
7/25/2010	0.18	0.35	0.44
7/27/2010	0.38	0.43	0.44
7/29/2010	0.03	0.03	0.03
7/30/2010	0.19	0.22	0.21
7/31/2010	0.00	0.00	0.00
8/2/2010	0.46	0.47	0.48
8/4/2010	0.00	0.00	0.00
8/9/2010	0.53	0.57	0.61
8/12/2010	0.74	0.74	0.73
8/14/2010	0.53	0.46	0.42
8/16/2010	0.00	0.00	0.00

8/19/2010	0.14	0.15	0.11
8/20/2010	0.81	0.88	0.85
Date	A	B	C
8/24/2010	0.51	0.62	0.46
8/25/2010	0.67	0.78	0.56
8/26/2010	0.94	0.99	0.93
8/30/2010	0.23	0.18	0.23
9/1/2010	0.22	0.25	0.34
9/3/2010	0.24	0.25	0.18
9/7/2010	0.00	0.00	0.00
9/9/2010	0.40	0.47	0.35
9/13/2010	0.05	0.13	0.05
9/15/2010	0.00	0.00	0.00
9/17/2010	0.04	0.04	0.11
9/20/2010	0.16	0.13	0.06
9/21/2010	0.10	0.10	0.13
9/22/2010	0.39	0.30	0.25
9/23/2010	0.53	0.44	0.57
9/24/2010	0.72	0.72	0.70
9/27/2010	1.02	0.88	0.70
9/29/2010	0.70	0.69	0.64
9/30/2010	0.00	0.00	0.00
10/1/2010	0.53	0.67	0.53
10/2/2010	0.63	0.56	0.59
10/3/2010	0.42	0.42	0.45
10/4/2010	0.41	0.41	0.45
10/5/2010	0.77	0.63	0.65

10/6/2010	0.41	0.67	0.59
10/7/2010	0.60	0.62	0.63
10/9/2010	0.35	0.35	0.35
10/12/2010	0.09	0.17	0.22
10/22/2010	0.00	0.00	0.00
10/24/2010	0.03	0.09	0.13
10/26/2010	0.03	0.07	0.12
10/28/2010	0.10	0.16	0.23
10/30/2010	0.13	0.10	0.06
11/1/2010	0.27	0.24	0.20
11/3/2010	0.50	0.73	0.53
11/5/2010	0.77	0.59	0.71
11/8/2010	0.00	0.00	0.00
11/10/2010	0.23	0.17	0.26
11/12/2010	0.10	0.17	0.20
11/14/2010	0.45	0.52	0.48
Date	A	B	C
11/17/2010	0.10	0.12	0.10
11/18/2010	0.43	0.33	0.40
11/21/2010	0.44	0.39	0.46
11/24/2010	0.52	0.55	0.62
11/26/2010	0.43	0.40	0.43
11/28/2010	0.60	0.76	0.61
11/30/2010	0.89	0.86	0.88
12/2/2010	0.00	0.00	0.00
12/6/2010	0.04	0.13	0.25
12/8/2010	0.32	0.26	0.43

12/10/2010	0.38	0.38	0.57
12/13/2010	0.45	0.57	0.48
12/15/2010	0.51	0.42	0.45
12/17/2010	0.77	0.82	0.82
12/20/2010	0.75	0.81	0.75
12/21/2010	0.00	0.00	0.00
12/23/2010	0.52	0.50	0.52
12/27/2010	0.29	0.30	0.31
12/29/2010	0.27	0.45	0.48
12/31/2010	0.65	0.70	0.79
1/2/2011	0.50	0.50	0.50
1/4/2011	0.43	0.50	0.48
1/6/2011	0.65	0.20	0.65
1/8/2011	0.00	0.00	0.00
1/11/2011	0.43	0.49	0.56
1/13/2011	0.00	0.00	0.00
1/15/2011	0.00	0.00	0.00
1/18/2011	0.87	0.90	0.76
1/20/2011	0.00	0.00	0.00
1/23/2011	0.89	0.88	0.67
1/25/2011	0.00	0.00	0.00
1/27/2011	0.89	0.86	0.84
1/29/2011	0.00	0.00	0.00
1/31/2011	0.00	0.00	0.00
2/2/2011	0.00	0.00	0.00
2/4/2011	0.00	0.00	0.00
2/8/2011	0.17	0.13	0.18

2/10/2011	0.00	0.00	0.00
2/14/2011	0.00	0.00	0.00
2/16/2011	0.00	0.00	0.00
Date	A	B	C
2/18/2011	0.00	0.00	0.00
2/20/2011	0.00	0.00	0.00
2/22/2011	0.00	0.00	0.00
2/25/2011	0.00	0.00	0.00
2/27/2011	0.00	0.00	0.00
3/2/2011	0.00	0.00	0.00
3/4/2011	0.05	0.04	0.21
3/6/2011	0.32	0.43	0.67
3/8/2011	0.23	0.30	0.29
3/13/2011	0.66	0.67	0.66
3/15/2011	0.00	0.00	0.00
3/17/2011	0.00	0.00	0.00
3/19/2011	0.00	0.04	0.03
3/21/2011	0.03	0.04	0.03
3/23/2011	0.07	0.03	0.03
3/25/2011	0.06	0.10	0.06
4/2/2011	0.94	0.89	0.92
4/5/2011	0.00	0.00	0.03
4/8/2011	0.39	0.36	0.48
4/11/2011	0.35	0.43	0.28
4/13/2011	0.02	0.04	0.02
4/15/2011	0.24	0.30	0.27
4/17/2011	0.34	0.39	0.38

4/19/2011	0.20	0.20	0.19
4/21/2011	0.29	0.31	0.16
4/23/2011	0.02	0.00	0.05
4/25/2011	0.48	0.52	0.20
4/27/2011	0.20	0.22	0.19
4/29/2011	0.29	0.39	0.30
Average	0.31	0.33	0.33
S	0.305	0.310	0.300
s^2	0.093	0.096	0.090
N	163	163	163

APPENDIX C: ET AND F FACTOR RAW DATA

[in*] is measured using a tape measure in the 5 gallon bucket

[in-] is measured using the yard stick in the 55 gal. drums which has an area of 452.4 in^2

Note: If the rain gage shows more than the intended irrigation volume DO NOT irrigate the chambers.

Irrigation Master Spreadsheet Chamber A

Date	Volume of Rain (P) [liters]	Initial Drum Volume (S_{1B}) [liters]	Volume of water added or lost (G) [liters]	Water containers volume (F) [liters]	Volume of Irrigation (I) [liters]	Post Irrigation Drum Volume (S_{2B}) [liters]	ΣET [in] delta	ET [in/day]	ET (Monthly Average) [in/day]	f Factor	f Factor (Monthly Average)
5/24/2010	0.00	0.00	10.25	8.87	18.87	0.00	-	-		-	
5/25/2010	0.00	0.00	12.28	7.57	18.87	0.00	0.36	0.36		0.37	
5/26/2010	0.00	0.00	3.97	15.15	18.87	0.00	0.13	0.13		0.78	
5/27/2010	0.00	0.00	38.14	12.74	18.87	32.25	0.25	0.25		0.56	
5/28/2010	0.00	32.25	0.00	8.45	18.87	20.71	0.28	0.28		0.43	
5/29/2010	0.00	20.71	0.00	13.02	18.87	13.94	0.17	0.17		0.67	
5/30/2010	13.97	17.92	0.00	31.12	0.00	45.99	0.15	0.15		0.83	
5/31/2010	13.22	45.99	0.00	11.78	18.87	38.82	0.04	0.04	0.20	0.87	0.64
6/1/2010	14.95	41.01	0.00	33.34	12.56	62.32	0.03	0.03		0.97	
6/3/2010	10.57	61.32	0.00	11.73	12.56	60.53	0.27	0.14		0.53	
6/4/2010	38.52	60.53	0.00	50.15	0.00	107.91	0.09	0.09		0.93	
6/5/2010	14.35	108.31	0.00	11.45	0.00	117.87	0.13	0.13		0.67	
6/7/2010	0.00	118.27	0.00	0.00	12.56	105.92	0.00	0.00		0.00	
6/9/2010	1.13	106.72	0.00	0.83	12.56	95.17	0.34	0.17		0.06	
6/11/2010	0.00	94.77	0.00	1.11	12.56	83.62	0.31	0.15		0.06	

Date	Volume of Rain (P) [liters]	Initial Drum Volume (S_{1B}) [liters]	Volume of water added or lost (G) [liters]	Water containers volume (F) [liters]	Volume of Irrigation (I) [liters]	Post Irrigation Drum Volume (S_{2B}) [liters]	ΣET [in] delta	ET [in/day]	ET (Monthly Average) [in/day]	f Factor	f Factor (Monthly Average)
6/13/2010	0.00	83.62	0.00	0.00	12.56	71.28	0.32	0.16		0.00	
6/15/2010	0.00	71.68	0.00	0.09	12.56	58.93	0.33	0.16		0.00	
6/17/2010	0.00	58.54	0.00	0.65	12.56	48.58	0.32	0.16		0.06	
6/18/2010	33.98	46.99	0.00	37.87	0.00	83.22	0.23	0.23		0.81	
6/19/2010	53.24	82.83	0.00	46.08	0.00	126.63	0.25	0.25		0.82	
6/20/2010	5.66	126.43	0.00	5.59	0.00	131.41	0.02	0.02		0.88	
6/21/2010	95.91	131.01	0.00	54.54	0.00	181.18	1.21	1.21		0.52	
6/23/2010	0.00	181.18	0.00	0.00	12.56	168.44	0.00	0.00		0.00	
6/25/2010	0.00	167.64	0.00	0.83	12.56	156.09	0.33	0.16		0.03	
6/27/2010	0.00	155.70	0.00	0.65	12.56	144.35	0.31	0.15		0.03	
6/29/2010	0.00	143.75	0.00	0.28	12.56	132.20	0.31	0.16	0.19	0.00	0.35
7/1/2010	0.00	132.20	0.00	2.03	12.56	121.05	0.26	0.13		0.14	
7/2/2010	64.19	121.05	0.00	43.87	0.00	164.06	0.90	0.90		0.56	
7/3/2010	1.89	164.46	0.00	0.18	12.56	152.91	0.05	0.05		0.00	
7/4/2010	0.38	152.91	0.00	8.59	0.00	160.87	0.10	0.10		0.67	
7/5/2010	13.22	160.47	0.00	9.97	0.00	169.63	0.11	0.11		0.69	
7/7/2010	0.00	168.44	0.00	0.00	12.56	157.29	0.00	0.00		0.00	
7/9/2010	0.00	157.29	0.00	1.02	12.56	145.74	0.28	0.14		0.04	
7/11/2010	0.00	145.34	0.00	1.29	12.56	134.39	0.31	0.15		0.03	
7/13/2010	0.00	133.80	0.00	1.20	12.56	122.25	0.27	0.13		0.11	
7/15/2010	43.42	121.85	0.00	45.25	0.00	165.25	0.34	0.17		0.77	
7/16/2010	1.89	166.05	0.00	0.00	0.00	166.05	0.05	0.05		0.00	

Date	Volume of Rain (P) [liters]	Initial Drum Volume (S_{1B}) [liters]	Volume of water added or lost (G) [liters]	Water containers volume (F) [liters]	Volume of Irrigation (I) [liters]	Post Irrigation Drum Volume (S_{2B}) [liters]	ΣET [in] delta	ET [in/day]	ET (Monthly Average) [in/day]	f Factor	f Factor (Monthly Average)
7/17/2010	0.00	165.85	0.00	0.00	12.56	153.90	0.00	0.00		0.00	
7/19/2010	0.00	153.71	0.00	1.11	12.56	143.35	0.28	0.14		0.10	
7/21/2010	0.00	143.35	0.00	0.74	12.56	131.01	0.30	0.15		0.03	
7/23/2010	0.00	130.61	0.00	1.29	12.56	119.46	0.31	0.15		0.09	
7/24/2010	6.04	119.86	0.00	2.49	0.00	121.85	0.43	0.43		0.11	
7/25/2010	4.53	121.85	0.00	1.48	12.56	111.10	0.10	0.10		0.18	
7/27/2010	0.00	111.50	0.00	5.36	12.56	104.13	0.19	0.09		0.38	
7/29/2010	0.00	103.73	0.00	0.18	12.56	91.98	0.30	0.15		0.03	
7/30/2010	7.17	91.98	0.00	3.88	0.00	95.57	0.42	0.42		0.19	
7/31/2010	0.00	95.57	0.00	0.00	12.56	83.62	0.00	0.00	0.17	0.00	0.20
8/2/2010	34.74	83.22	0.00	25.30	0.00	104.73	0.67	0.33		0.46	
8/4/2010	0.00	105.12	0.00	0.00	12.56	92.78	0.00	0.00		0.00	
8/9/2010	49.09	95.57	0.00	35.37	0.00	128.22	0.76	0.15		0.53	
8/12/2010	61.17	127.82	-22.30	45.02	0.00	150.52	0.42	0.14		0.74	
8/14/2010	18.88	146.14	0.00	9.79	0.00	156.09	0.24	0.12		0.53	
8/16/2010	0.00	156.09	0.00	0.00	12.56	146.54	0.00	0.00		0.00	
8/19/2010	16.24	146.54	0.00	4.43	0.00	150.52	0.58	0.29		0.14	
8/20/2010	72.50	149.72	0.00	63.72	0.00	208.66	0.36	0.36		0.81	
8/24/2010	33.23	203.88	-33.34	21.70	0.00	188.35	0.28	0.07		0.51	
8/25/2010	7.17	188.35	0.00	4.25	12.56	180.38	0.06	0.06		0.67	
8/26/2010	30.59	180.38	-19.58	39.71	0.00	180.38	0.10	0.10		0.94	

Date	Volume of Rain (P) [liters]	Initial Drum Volume (S_{1B}) [liters]	Volume of water added or lost (G) [liters]	Water containers volume (F) [liters]	Volume of Irrigation (I) [liters]	Post Irrigation Drum Volume (S_{2B}) [liters]	ΣET [in] delta	ET [in/day]	ET (Monthly Average) [in/day]	f Factor	f Factor (Monthly Average)
8/30/2010	6.80	200.29	-15.70	1.85	12.56	174.81	0.68	0.17	0.15	0.23	0.46
9/1/2010	0.00	173.62	0.00	2.59	12.56	163.66	0.24	0.12		0.22	
9/3/2010	0.00	163.26	0.00	2.31	12.56	163.66	0.25	0.13		0.24	
9/7/2010	3.78	152.91	0.00	0.00	12.56	140.96	0.17	0.04		0.00	
9/9/2010	18.88	140.56	0.00	13.39	0.00	153.31	0.48	0.24		0.40	
9/13/2010	15.10	152.91	0.00	1.66	0.00	153.71	0.38	0.09		0.05	
9/15/2010	0.00	153.31	0.00	0.00	12.56	141.76	0.00	0.00		0.00	
9/17/2010	0.00	141.76	0.00	1.11	12.56	130.61	0.30	0.15		0.04	
9/20/2010	0.00	129.02	0.00	1.48	12.56	118.27	0.25	0.08		0.16	
9/21/2010	0.00	117.87	0.00	0.37	12.56	106.72	0.31	0.31		0.10	
9/22/2010	0.00	106.72	0.00	5.36	12.56	99.15	0.21	0.21		0.39	
9/23/2010	0.00	100.35	19.39	7.20	12.56	113.09	0.15	0.15		0.53	
9/24/2010	24.17	113.09	0.00	28.72	0.00	139.77	0.25	0.25		0.72	
9/27/2010	22.66	136.18	0.00	22.16	0.00	159.28	-0.01	0.00		1.02	
9/29/2010	50.98	159.28	0.00	36.66	0.00	194.72	0.41	0.21		0.70	
9/30/2010	0.00	195.12	0.00	0.00	12.56	183.17	0.00	0.00	0.13	0.00	0.30
10/1/2010	0.00	181.98	0.00	7.20	12.56	176.00	0.15	0.15		0.53	
10/2/2010	0.00	176.00	0.00	8.13	12.56	172.42	0.12	0.12		0.63	
10/3/2010	0.00	172.02	0.00	5.54	12.56	164.85	0.17	0.17		0.42	
10/4/2010	0.00	164.06	0.00	5.17	12.56	155.30	0.20	0.20		0.41	
10/5/2010	0.00	155.30	0.00	8.68	12.56	152.51	0.11	0.11		0.77	

Date	Volume of Rain (P) [liters]	Initial Drum Volume (S_{1B}) [liters]	Volume of water added or lost (G) [liters]	Water containers volume (F) [liters]	Volume of Irrigation (I) [liters]	Post Irrigation Drum Volume (S_{2B}) [liters]	ΣET [in] delta	ET [in/day]	ET (Monthly Average) [in/day]	f Factor	f Factor (Monthly Average)
10/6/2010	0.00	153.71	0.00	7.76	12.56	146.14	0.19	0.19		0.41	
10/7/2010	0.00	146.54	0.00	8.03	12.56	141.76	0.15	0.15		0.60	
10/9/2010	0.00	141.36	0.00	4.62	12.56	133.80	0.20	0.10		0.35	
10/12/2010	0.00	133.40	0.00	2.22	12.56	122.25	0.28	0.09		0.09	
10/22/2010	0.00	150.12	0.00	0.00	12.56	137.38	0.33	0.08		0.00	
10/24/2010	0.00	137.78	0.00	0.37	12.56	125.83	0.33	0.16		0.03	
10/26/2010	0.00	125.83	0.00	0.55	12.56	113.89	0.32	0.16		0.03	
10/28/2010	0.00	113.49	0.00	1.66	12.56	104.33	0.30	0.15		0.10	
10/30/2010	0.00	103.53	0.00	2.22	12.56	93.18	0.23	0.12	0.14	0.13	0.32
11/1/2010	0.00	92.38	0.00	3.32	12.56	82.83	0.23	0.12		0.27	
11/3/2010	0.00	82.43	35.83	7.85	12.56	111.50	0.18	0.09		0.50	
11/5/2010	15.10	111.50	0.00	21.43	0.00	132.20	0.14	0.07		0.77	
11/8/2010	0.00	130.61	0.00	0.00	12.56	119.86	0.00	0.00		0.00	
11/10/2010	0.00	119.86	0.00	2.68	12.56	109.90	0.21	0.11		0.23	
11/12/2010	0.00	109.90	0.00	1.85	12.56	101.14	0.31	0.15		0.10	
11/14/2010	0.00	100.74	0.00	6.46	12.56	93.58	0.13	0.06		0.45	
11/17/2010	0.00	92.78	0.00	1.02	12.56	82.03	0.30	0.15		0.10	
11/18/2010	0.00	82.03	35.46	5.54	12.56	108.71	0.18	0.09		0.43	
11/21/2010	3.78	108.31	0.00	8.13	12.56	103.93	0.24	0.08		0.44	
11/24/2010	0.00	103.53	0.00	6.37	12.56	97.56	0.15	0.05		0.52	
11/26/2010	0.00	96.76	0.00	5.91	12.56	89.99	0.18	0.09		0.43	

Date	Volume of Rain (P) [liters]	Initial Drum Volume (S_{1B}) [liters]	Volume of water added or lost (G) [liters]	Water containers volume (F) [liters]	Volume of Irrigation (I) [liters]	Post Irrigation Drum Volume (S_{2B}) [liters]	ΣET [in] delta	ET [in/day]	ET (Monthly Average) [in/day]	f Factor	f Factor (Monthly Average)
11/28/2010	1.89	89.60	0.00	8.68	9.43	88.80	0.14	0.07		0.60	
11/30/2010	54.75	89.20	0.00	60.40	0.00	146.14	0.18	0.09	0.09	0.89	0.41
12/2/2010	0.00	146.14	0.00	0.00	9.43	134.99	0.00	0.00		0.00	
12/6/2010	0.00	138.18	0.00	0.92	9.43	129.81	0.28	0.07		0.04	
12/8/2010	0.00	129.81	0.00	2.96	9.43	124.24	0.16	0.04		0.32	
12/10/2010	0.00	124.24	0.00	4.53	9.43	118.66	0.14	0.07		0.38	
12/13/2010	1.89	118.66	0.00	4.80	9.43	114.68	0.16	0.05		0.45	
12/15/2010	0.00	114.28	27.34	4.71	27.78	119.14	0.11	0.06		0.51	
12/17/2010	0.00	119.14	-20.69	21.06	9.43	110.30	0.16	0.08		0.77	
12/20/2010	16.99	110.70	0.00	19.67	0.00	129.81	0.17	0.06		0.75	
12/21/2010	0.00	129.42	0.00	0.00	9.43	121.05	0.00	0.00		0.00	
12/23/2010	0.00	121.05	0.00	5.17	9.43	116.67	0.11	0.05		0.52	
12/27/2010	3.78	116.67	0.00	3.97	9.43	111.50	0.24	0.06		0.29	
12/29/2010	0.00	111.50	0.00	3.05	9.43	105.92	0.17	0.08		0.27	
12/31/2010	0.00	105.52	0.00	5.91	9.43	101.94	0.07	0.04	0.05	0.65	0.38
1/2/2011	0.00	101.94	0.00	4.99	9.43	97.16	0.12	0.06		0.50	
1/4/2011	0.00	97.16	0.00	4.06	4.71	96.76	0.14	0.07		0.43	
1/6/2011	16.99	97.16	0.00	14.87	0.00	111.10	0.20	0.10		0.65	
1/8/2011	0.00	110.70	0.00	0.00	4.71	106.32	0.00	0.00		0.00	
1/11/2011	13.22	106.72	0.00	8.87	0.00	114.28	0.27	0.09		0.43	
1/13/2011	0.00	113.89	0.00	0.00	4.71	109.51	0.00	0.00		0.00	

Date	Volume of Rain (P) [liters]	Initial Drum Volume (S_{1B}) [liters]	Volume of water added or lost (G) [liters]	Water containers volume (F) [liters]	Volume of Irrigation (I) [liters]	Post Irrigation Drum Volume (S_{2B}) [liters]	ΣET [in] delta	ET [in/day]	ET (Monthly Average) [in/day]	f Factor	f Factor (Monthly Average)
1/15/2011	0.00	109.51	0.00	0.00	4.71	104.73	0.12	0.06		0.00	
1/18/2011	66.46	104.73	0.00	64.65	0.00	166.45	0.25	0.08		0.87	
1/20/2011	0.00	166.45	0.00	0.00	4.71	161.67	0.00	0.00		0.00	
1/23/2011	64.19	161.67	-62.34	62.34	0.00	161.67	0.20	0.07		0.89	
1/25/2011	0.00	161.67	0.00	0.00	4.71	156.49	0.00	0.00		0.00	
1/27/2011	48.33	156.49	-47.01	47.01	0.00	156.49	0.16	0.08		0.89	
1/29/2011	0.00	156.49	0.00	0.00	4.71	151.71	0.00	0.00		0.00	
1/31/2011	0.00	151.71	0.00	0.00	4.71	148.13	0.13	0.06	0.05	0.00	0.33
2/2/2011	0.00	147.33	0.00	0.00	4.71	143.35	0.09	0.05		0.00	
2/4/2011	0.00	143.35	0.00	0.00	4.71	138.18	0.11	0.05		0.00	
2/8/2011	13.59	138.57	0.00	3.88	0.00	141.76	0.41	0.10		0.17	
2/10/2011	3.40	142.16	0.00	0.00	4.71	138.18	0.09	0.05		0.00	
2/14/2011	0.00	137.38	0.00	0.00	4.71	132.20	0.11	0.03		0.00	
2/16/2011	0.00	132.20	0.00	0.00	4.71	129.42	0.14	0.07		0.00	
2/18/2011	0.00	129.02	0.00	0.00	4.71	124.24	0.07	0.04		0.00	
2/20/2011	0.00	124.24	0.00	0.00	4.71	120.26	0.13	0.06		0.00	
2/22/2011	0.00	120.65	0.00	0.00	4.71	115.88	0.11	0.05		0.00	
2/25/2011	0.00	115.88	0.00	0.00	4.71	107.12	0.13	0.04		0.00	
2/27/2011	0.00	106.32	0.00	0.00	9.43	102.34	0.23	0.08	0.06	0.00	0.02
3/2/2011	7.93	97.16	0.00	0.00	9.43	89.60	0.32	0.11		0.00	
3/4/2011	0.00	88.40	0.00	1.11	9.43	76.45	0.19	0.09		0.05	

Date	Volume of Rain (P) [liters]	Initial Drum Volume (S_{1B}) [liters]	Volume of water added or lost (G) [liters]	Water containers volume (F) [liters]	Volume of Irrigation (I) [liters]	Post Irrigation Drum Volume (S_{2B}) [liters]	ΣET [in] delta	ET [in/day]	ET (Monthly Average) [in/day]	f Factor	f Factor (Monthly Average)
3/6/2011	3.78	76.45	0.00	5.91	9.43	69.69	0.29	0.14		0.32	
3/8/2011	0.00	69.69	0.00	3.23	9.43	60.53	0.24	0.12		0.23	
3/13/2011	37.76	60.53	0.00	34.36	0.00	93.18	0.45	0.09		0.66	
3/15/2011	0.00	92.38	0.00	0.00	9.43	83.62	0.00	0.00		0.00	
3/17/2011	0.00	83.62	0.00	0.00	9.43	71.68	0.23	0.12		0.00	
3/19/2011	0.00	72.07	0.00	0.00	9.43	59.73	0.32	0.16		0.00	
3/21/2011	0.00	59.33	0.00	1.02	9.43	47.78	0.32	0.16		0.03	
3/23/2011	0.00	47.78	0.00	0.55	9.43	35.04	0.30	0.15		0.07	
3/25/2011	0.00	35.04	36.94	0.55	9.43	60.53	0.34	0.17	0.12	0.06	0.13
4/2/2011	196.35	60.53	-125.60	195.05	0.00	132.20	0.32	0.04		0.94	
4/5/2011	15.48	128.62	0.00	0.09	18.87	110.30	0.41	0.14		0.00	
4/8/2011	0.00	110.30	0.00	7.85	18.87	99.15	0.30	0.10		0.39	
4/11/2011	0.00	98.75	0.00	7.76	18.87	86.81	0.32	0.11		0.35	
4/13/2011	4.53	87.21	0.00	0.83	18.87	68.09	0.59	0.30		0.02	
4/15/2011	0.00	68.49	0.00	6.65	18.87	55.75	0.39	0.20		0.24	
4/17/2011	0.00	55.35	0.00	6.35	18.87	43.01	0.31	0.15		0.34	
4/19/2011	0.00	40.62	0.00	2.77	18.87	26.28	0.39	0.20		0.20	
4/21/2011	0.00	26.28	121.35	4.43	18.87	133.40	0.34	0.17		0.29	
4/23/2011	0.00	133.00	0.00	0.37	18.87	115.08	0.49	0.24		0.02	
4/25/2011	0.00	114.68	0.00	7.39	18.87	105.12	0.25	0.13		0.48	
4/27/2011	0.00	98.75	0.00	4.43	18.87	84.42	0.39	0.20		0.20	

Date	Volume of Rain (P) [liters]	Initial Drum Volume (S_{1B}) [liters]	Volume of water added or lost (G) [liters]	Water containers volume (F) [liters]	Volume of Irrigation (I) [liters]	Post Irrigation Drum Volume (S_{2B}) [liters]	ΣET [in] delta	ET [in/day]	ET (Monthly Average) [in/day]	f Factor	f Factor (Monthly Average)
4/29/2011	0.00	90.39	0.00	5.63	18.87	76.45	0.34	0.17	0.16	0.29	0.29

[in*] is measured using a tape measure in the 5 gallon bucket

[in-] is measured using the yard stick in the 55 gal. drums which has an area of 452.4 in^2

Note: If the rain gage shows more than the intended irrigation volume DO NOT irrigate the chambers.

Irrigation Master Spreadsheet Chamber B

Date	Volume of Rain (P) [liters]	Initial Drum Volume (S_{1B}) [liters]	Volume of water added or lost (G) [liters]	Water containers volume (F) [liters]	Volume of Irrigation (I) [liters]	Post Irrigation Drum Volume (S_{2B}) [liters]	ΣET [in] delta	ET [in/day]	ET (Monthly Average) [in/day]	f Factor	f Factor (Monthly Average)
5/24/2010	0.00	0.00	9.51	9.60	18.87	0.00	-	-		-	
5/25/2010	0.00	0.00	11.54	7.57	18.87	0.00	0.32	0.32		0.44	
5/26/2010	0.00	0.00	3.51	15.61	18.87	0.00	0.11	0.11		0.81	
5/27/2010	0.00	0.00	38.42	12.74	18.87	34.64	0.22	0.22		0.62	

Date	Volume of Rain (P) [liters]	Initial Drum Volume (S_{1B}) [liters]	Volume of water added or lost (G) [liters]	Water containers volume (F) [liters]	Volume of Irrigation (I) [liters]	Post Irrigation Drum Volume (S_{2B}) [liters]	ΣET [in] delta	ET [in/day]	ET (Monthly Average) [in/day]	f Factor	f Factor (Monthly Average)
5/28/2010	0.00	34.64	0.00	9.60	18.87	24.89	0.25	0.25		0.48	
5/29/2010	0.00	24.89	0.00	13.30	18.87	18.91	0.18	0.18		0.63	
5/30/2010	13.97	18.91	0.00	31.12	0.00	49.18	0.04	0.04		0.95	
5/31/2010	13.22	49.18	0.00	12.28	18.87	42.21	0.06	0.06	0.17	0.83	0.68
6/1/2010	14.95	44.60	0.00	33.99	12.56	64.71	0.02	0.02		0.98	
6/3/2010	10.57	64.51	0.00	13.48	12.56	65.30	0.26	0.13		0.56	
6/4/2010	38.14	65.30	0.00	50.06	0.00	113.09	0.06	0.06		0.95	
6/5/2010	14.35	111.50	0.00	12.10	0.00	124.24	0.04	0.04		0.89	
6/7/2010	0.00	123.84	0.00	0.00	12.56	111.89	0.00	0.00		0.00	
6/9/2010	1.13	111.89	0.00	2.22	12.56	101.14	0.28	0.14		0.18	
6/11/2010	0.00	101.94	0.00	2.03	12.56	91.19	0.31	0.15		0.12	
6/13/2010	0.00	91.98	0.00	0.18	12.56	79.64	0.33	0.16		0.00	
6/15/2010	0.00	80.04	0.00	0.83	12.56	68.49	0.31	0.15		0.06	
6/17/2010	0.00	68.09	0.00	1.52	12.56	58.14	0.28	0.14		0.13	
6/18/2010	33.98	58.14	0.00	39.44	0.00	93.98	0.26	0.26		0.79	
6/19/2010	53.24	94.37	0.00	47.16	0.00	137.78	0.26	0.26		0.82	
6/20/2010	5.66	137.78	0.00	5.73	0.00	142.95	0.01	0.01		0.91	
6/21/2010	95.91	132.60	0.00	72.13	0.00	211.84	0.44	0.44		0.83	
6/23/2010	0.00	213.44	-36.11	0.00	12.56	166.05	0.00	0.00		0.00	
6/25/2010	0.00	164.06	0.00	1.11	12.56	153.71	0.24	0.12		0.15	
6/27/2010	0.00	154.50	0.00	1.66	12.56	144.15	0.28	0.14		0.10	

Date	Volume of Rain (P) [liters]	Initial Drum Volume (S_{1B}) [liters]	Volume of water added or lost (G) [liters]	Water containers volume (F) [liters]	Volume of Irrigation (I) [liters]	Post Irrigation Drum Volume (S_{2B}) [liters]	ΣET [in] delta	ET [in/day]	ET (Monthly Average) [in/day]	f Factor	f Factor (Monthly Average)
6/29/2010	0.00	143.35	0.00	0.74	12.56	132.20	0.30	0.15	0.13	0.03	0.42
7/1/2010	0.00	131.41	0.00	2.59	12.56	122.65	0.23	0.12		0.24	
7/2/2010	64.19	122.65	0.00	57.07	0.00	178.39	0.53	0.53		0.74	
7/3/2010	1.89	178.79	0.00	0.28	12.56	167.44	0.04	0.04		0.11	
7/4/2010	0.38	167.64	0.00	9.14	0.00	175.81	0.10	0.10		0.68	
7/5/2010	13.22	175.61	-7.53	10.16	0.00	178.00	0.10	0.10		0.71	
7/7/2010	0.00	177.20	0.00	0.00	12.56	165.65	0.00	0.00		0.00	
7/9/2010	0.00	165.25	0.00	1.85	12.56	155.30	0.25	0.13		0.17	
7/11/2010	0.00	155.30	0.00	2.12	12.56	144.55	0.26	0.13		0.17	
7/13/2010	0.00	144.55	0.00	1.11	12.56	133.00	0.33	0.16		0.03	
7/15/2010	43.42	132.20	0.00	48.30	0.00	178.39	0.24	0.12		0.83	
7/16/2010	1.89	179.19	0.00	0.00	0.00	179.19	0.05	0.05		0.00	
7/17/2010	0.00	179.19	0.00	0.00	12.56	167.24	0.00	0.00		0.00	
7/19/2010	0.00	167.24	0.00	1.57	12.56	156.89	0.27	0.14		0.13	
7/21/2010	0.00	153.71	0.00	0.55	12.56	145.74	0.31	0.15		0.03	
7/23/2010	0.00	145.34	0.00	1.66	12.56	134.99	0.18	0.09		0.19	
7/24/2010	6.04	134.99	0.00	3.05	0.00	137.78	0.40	0.40		0.15	
7/25/2010	4.53	137.38	0.00	1.66	12.56	127.03	0.08	0.08		0.35	
7/27/2010	0.00	127.03	0.00	6.19	12.56	120.26	0.18	0.09		0.43	
7/29/2010	0.00	120.65	0.00	1.06	12.56	106.92	0.31	0.15		0.03	
7/30/2010	7.17	108.71	0.00	5.17	0.00	113.49	0.44	0.44		0.22	

Date	Volume of Rain (P) [liters]	Initial Drum Volume (S_{1B}) [liters]	Volume of water added or lost (G) [liters]	Water containers volume (F) [liters]	Volume of Irrigation (I) [liters]	Post Irrigation Drum Volume (S_{2B}) [liters]	ΣET [in] delta	ET [in/day]	ET (Monthly Average) [in/day]	f Factor	f Factor (Monthly Average)
7/31/2010	0.00	113.49	0.00	0.00	12.56	101.54	0.00	0.00	0.14	0.00	0.25
8/2/2010	34.74	101.14	0.00	24.94	0.00	123.04	0.66	0.33		0.47	
8/4/2010	0.00	124.24	0.00	0.00	12.56	112.29	0.00	0.00		0.00	
8/9/2010	49.09	109.90	0.00	34.91	0.00	144.94	0.69	0.14		0.57	
8/12/2010	61.17	144.15	0.00	42.94	0.00	189.15	0.43	0.14		0.74	
8/14/2010	18.88	189.54	0.00	10.16	0.00	198.30	0.27	0.13		0.46	
8/16/2010	0.00	199.50	0.00	0.00	12.56	186.36	0.00	0.00		0.00	
8/19/2010	16.24	186.76	0.00	4.62	0.00	191.14	0.66	0.22		0.15	
8/20/2010	72.50	191.14	-52.83	63.54	0.00	200.69	0.23	0.23		0.88	
8/24/2010	33.23	200.69	-34.63	21.70	0.00	188.35	0.33	0.08		0.62	
8/25/2010	7.17	187.15	0.00	4.80	12.56	180.38	0.04	0.04		0.78	
8/26/2010	30.59	177.60	-19.21	41.28	0.00	201.89	0.01	0.01		0.99	
8/30/2010	6.80	201.89	-16.81	1.48	12.56	174.01	0.15	0.04	0.11	0.18	0.49
9/1/2010	0.00	173.62	0.00	3.32	12.56	164.85	0.25	0.06		0.25	
9/3/2010	0.00	163.26	0.00	2.31	12.56	153.31	0.25	0.13		0.25	
9/7/2010	3.78	154.10	0.00	0.00	12.56	142.16	0.45	0.11		0.00	
9/9/2010	18.88	142.16	0.00	14.96	0.00	156.49	0.44	0.22		0.47	
9/13/2010	15.10	155.30	0.00	1.39	0.00	157.29	0.35	0.09		0.13	
9/15/2010	0.00	157.29	0.00	0.00	12.56	146.14	0.00	0.00		0.00	
9/17/2010	0.00	145.74	0.00	1.11	12.56	133.80	0.28	0.14		0.04	
9/20/2010	0.00	133.80	0.00	1.75	12.56	123.04	0.28	0.09		0.13	

Date	Volume of Rain (P) [liters]	Initial Drum Volume (S_{1B}) [liters]	Volume of water added or lost (G) [liters]	Water containers volume (F) [liters]	Volume of Irrigation (I) [liters]	Post Irrigation Drum Volume (S_{2B}) [liters]	ΣET [in] delta	ET [in/day]	ET (Monthly Average) [in/day]	f Factor	f Factor (Monthly Average)
9/21/2010	0.00	122.25	0.00	1.20	12.56	111.50	0.30	0.30		0.10	
9/22/2010	0.00	111.50	0.00	4.80	12.56	104.33	0.22	0.22		0.30	
9/23/2010	0.00	104.73	18.84	6.28	12.56	114.68	0.16	0.16		0.44	
9/24/2010	24.17	115.48	0.00	28.91	0.00	142.16	0.28	0.28		0.72	
9/27/2010	22.66	142.56	0.00	22.07	0.00	162.47	0.07	0.02		0.88	
9/29/2010	50.98	162.86	0.00	36.02	0.00	197.91	0.42	0.21		0.69	
9/30/2010	0.00	197.91	0.00	0.00	12.56	185.96	0.00	0.00	0.14	0.00	0.29
10/1/2010	0.00	182.38	0.00	6.93	12.56	176.00	0.11	0.11		0.67	
10/2/2010	0.00	178.39	0.00	7.76	12.56	173.22	0.17	0.17		0.56	
10/3/2010	0.00	174.41	0.00	6.28	12.56	167.24	0.20	0.20		0.42	
10/4/2010	0.00	167.24	0.00	5.36	12.56	160.47	0.20	0.20		0.41	
10/5/2010	0.00	160.47	0.00	8.50	12.56	156.09	0.12	0.12		0.63	
10/6/2010	0.00	154.90	0.00	7.67	12.56	149.33	0.11	0.11		0.67	
10/7/2010	0.00	150.12	0.00	8.13	12.56	146.14	0.14	0.14		0.62	
10/9/2010	0.00	146.14	0.00	5.17	12.56	138.57	0.21	0.11		0.35	
10/12/2010	0.00	138.18	0.00	2.96	12.56	128.62	0.26	0.09		0.17	
10/22/2010	0.00	147.33	0.00	2.96	12.56	134.59	0.31	0.08		0.00	
10/24/2010	0.00	134.99	0.00	1.48	12.56	124.24	0.31	0.15		0.09	
10/26/2010	0.00	124.24	0.00	0.83	12.56	112.29	0.30	0.15		0.07	
10/28/2010	0.00	112.69	0.00	2.03	12.56	102.74	0.28	0.14		0.16	
10/30/2010	0.00	102.74	0.00	1.66	12.56	90.79	0.28	0.14	0.13	0.10	0.35

Date	Volume of Rain (P) [liters]	Initial Drum Volume (S_{1B}) [liters]	Volume of water added or lost (G) [liters]	Water containers volume (F) [liters]	Volume of Irrigation (I) [liters]	Post Irrigation Drum Volume (S_{2B}) [liters]	ΣET [in] delta	ET [in/day]	ET (Monthly Average) [in/day]	f Factor	f Factor (Monthly Average)
11/1/2010	0.00	89.99	0.00	2.59	12.56	81.23	0.26	0.13		0.24	
11/3/2010	0.00	78.05	37.59	6.83	12.56	109.90	0.08	0.04		0.73	
11/5/2010	15.10	109.90	0.00	20.87	0.00	129.02	0.29	0.15		0.59	
11/8/2010	0.00	128.62	0.00	0.00	12.56	116.67	0.00	0.00		0.00	
11/10/2010	0.00	116.67	0.00	2.49	12.56	106.72	0.26	0.13		0.17	
11/12/2010	0.00	106.72	0.00	1.85	12.56	97.16	0.26	0.13		0.17	
11/14/2010	0.00	97.16	0.00	6.10	12.56	89.60	0.15	0.07		0.52	
11/17/2010	0.00	89.20	0.00	2.12	12.56	77.65	0.32	0.16		0.12	
11/18/2010	0.00	85.21	35.28	4.99	12.56	104.73	0.23	0.12		0.33	
11/21/2010	3.78	105.52	0.00	7.76	12.56	100.35	0.27	0.09		0.39	
11/24/2010	0.00	100.35	0.00	7.02	12.56	94.77	0.14	0.05		0.55	
11/26/2010	0.00	93.98	0.00	5.73	12.56	87.21	0.19	0.09		0.40	
11/28/2010	0.00	87.60	0.00	9.60	9.43	86.01	0.07	0.04		0.76	
11/30/2010	54.75	86.01	0.00	59.66	0.00	142.16	0.24	0.12	0.09	0.86	0.42
12/2/2010	0.00	142.16	0.00	0.00	9.43	133.00	0.00	0.00		0.00	
12/6/2010	0.00	134.99	0.00	1.11	9.43	127.03	0.21	0.07		0.13	
12/8/2010	0.00	127.03	0.00	3.69	9.43	121.05	0.18	0.09		0.26	
12/10/2010	0.00	121.05	0.00	4.71	9.43	116.27	0.14	0.07		0.38	
12/13/2010	1.89	115.88	0.00	4.99	9.43	112.29	0.11	0.04		0.57	
12/15/2010	0.00	111.50	37.68	3.69	37.68	115.08	0.14	0.07		0.42	
12/17/2010	0.00	115.08	-29.92	31.40	9.43	108.31	0.18	0.09		0.82	

Date	Volume of Rain (P) [liters]	Initial Drum Volume (S_{1B}) [liters]	Volume of water added or lost (G) [liters]	Water containers volume (F) [liters]	Volume of Irrigation (I) [liters]	Post Irrigation Drum Volume (S_{2B}) [liters]	ΣET [in] delta	ET [in/day]	ET (Monthly Average) [in/day]	f Factor	f Factor (Monthly Average)
12/20/2010	16.99	108.71	0.00	21.61	0.00	129.02	0.12	0.04		0.81	
12/21/2010	0.00	129.02	0.00	0.00	9.43	120.26	0.00	0.00		0.00	
12/23/2010	0.00	120.26	0.00	5.08	9.43	116.27	0.12	0.06		0.50	
12/27/2010	3.78	115.88	0.00	5.63	9.43	110.70	0.23	0.06		0.30	
12/29/2010	0.00	109.11	0.00	3.14	9.43	105.12	0.13	0.06		0.45	
12/31/2010	0.00	105.12	0.00	6.37	9.43	101.94	0.06	0.03	0.05	0.70	0.41
1/2/2011	0.00	100.74	0.00	4.89	9.43	96.36	0.12	0.06		0.50	
1/4/2011	0.00	97.16	0.00	4.53	4.71	97.16	0.12	0.06		0.50	
1/6/2011	16.99	97.16	0.00	4.53	4.71	97.16	0.45	0.23		0.20	
1/8/2011	0.00	110.30	0.00	0.00	4.71	106.32	0.12	0.06		0.00	
1/11/2011	13.22	105.92	0.00	9.14	0.00	114.28	0.23	0.08		0.49	
1/13/2011	0.00	114.28	0.00	0.00	4.71	109.90	0.00	0.00		0.00	
1/15/2011	0.00	109.90	0.00	0.00	4.71	105.92	0.12	0.06		0.00	
1/18/2011	66.46	105.92	0.00	64.46	0.00	169.63	0.18	0.06		0.90	
1/20/2011	0.00	169.63	0.00	0.00	4.71	165.65	0.00	0.00		0.00	
1/23/2011	64.19	164.85	-60.40	60.40	0.00	164.85	0.22	0.07		0.88	
1/25/2011	0.00	165.65	0.00	0.00	4.71	161.27	0.00	0.00		0.00	
1/27/2011	48.33	161.67	-45.16	45.16	0.00	161.67	0.19	0.10		0.86	
1/29/2011	0.00	160.87	0.00	0.00	4.71	157.69	0.00	0.00		0.00	
1/31/2011	0.00	157.69	0.00	0.00	4.71	153.71	0.08	0.04	0.06	0.00	0.31
2/2/2011	0.00	153.31	0.00	0.00	4.71	149.33	0.11	0.05		0.00	

Date	Volume of Rain (P) [liters]	Initial Drum Volume (S_{1B}) [liters]	Volume of water added or lost (G) [liters]	Water containers volume (F) [liters]	Volume of Irrigation (I) [liters]	Post Irrigation Drum Volume (S_{2B}) [liters]	ΣET [in] delta	ET [in/day]	ET (Monthly Average) [in/day]	f Factor	f Factor (Monthly Average)
2/4/2011	0.00	150.12	0.00	0.00	4.71	145.34	0.11	0.05		0.00	
2/8/2011	13.59	145.34	0.00	2.96	0.00	147.73	0.42	0.11		0.13	
2/10/2011	3.40	148.93	0.00	0.00	4.71	144.15	0.09	0.05		0.00	
2/14/2011	0.00	144.55	0.00	0.00	4.71	138.97	0.13	0.03		0.00	
2/16/2011	0.00	138.97	0.00	0.00	4.71	134.59	0.15	0.07		0.00	
2/18/2011	0.00	134.59	0.00	0.00	4.71	131.01	0.12	0.06		0.00	
2/20/2011	0.00	131.01	0.00	0.00	4.71	126.63	0.09	0.05		0.00	
2/22/2011	0.00	126.63	0.00	0.00	4.71	121.45	0.12	0.06		0.00	
2/25/2011	0.00	121.45	0.00	0.00	4.71	113.49	0.14	0.05		0.00	
2/27/2011	0.00	113.09	0.00	0.00	9.43	104.33	0.21	0.11	0.06	0.00	0.07
3/2/2011	7.93	104.73	0.00	0.00	9.43	95.57	0.44	0.15		0.00	
3/4/2011	0.00	95.97	0.00	0.92	9.43	84.42	0.23	0.12		0.04	
3/6/2011	3.78	84.02	0.00	7.20	9.43	78.84	0.24	0.12		0.43	
3/8/2011	0.00	78.84	0.00	3.60	9.43	70.08	0.22	0.11		0.30	
3/13/2011	37.76	69.69	0.00	35.37	0.00	103.13	0.44	0.09		0.67	
3/15/2011	0.00	102.34	0.00	0.00	9.43	93.18	0.00	0.00		0.00	
3/17/2011	0.00	93.18	0.00	0.00	9.43	82.03	0.24	0.12		0.00	
3/19/2011	0.00	82.03	0.00	1.11	9.43	71.28	0.28	0.14		0.04	
3/21/2011	0.00	70.88	0.00	0.92	9.43	59.33	0.28	0.14		0.04	
3/23/2011	0.00	58.93	0.00	0.65	9.43	47.78	0.31	0.15		0.03	
3/25/2011	0.00	47.78	36.94	0.65	9.43	73.27	0.27	0.14	0.12	0.10	0.15

Date	Volume of Rain (P) [liters]	Initial Drum Volume (S_{1B}) [liters]	Volume of water added or lost (G) [liters]	Water containers volume (F) [liters]	Volume of Irrigation (I) [liters]	Post Irrigation Drum Volume (S_{2B}) [liters]	ΣET [in] delta	ET [in/day]	ET (Monthly Average) [in/day]	f Factor	f Factor (Monthly Average)
4/2/2011	196.35	72.47	-118.21	184.71	0.00	141.76	0.59	0.07		0.89	
4/5/2011	15.48	138.18	0.00	0.09	18.87	120.26	0.41	0.14		0.00	
4/8/2011	0.00	120.26	0.00	7.48	18.87	109.11	0.31	0.10		0.36	
4/11/2011	0.00	107.91	0.00	8.31	18.87	97.96	0.26	0.09		0.43	
4/13/2011	4.53	97.16	0.00	1.11	18.87	79.64	0.56	0.28		0.04	
4/15/2011	0.00	78.84	0.00	6.65	18.87	66.90	0.34	0.17		0.30	
4/17/2011	0.00	67.30	0.00	6.65	18.87	55.75	0.28	0.14		0.39	
4/19/2011	0.00	55.75	0.00	4.43	18.87	41.41	0.39	0.20		0.20	
4/21/2011	0.00	41.41	108.61	5.17	18.87	136.98	0.33	0.16		0.31	
4/23/2011	0.00	136.98	0.00	0.00	18.87	119.46	0.49	0.24		0.00	
4/25/2011	0.00	119.46	0.00	5.73	18.87	110.30	0.22	0.11		0.52	
4/27/2011	0.00	104.33	0.00	4.80	18.87	90.79	0.38	0.19		0.22	
4/29/2011	0.00	95.97	0.00	6.65	18.87	84.02	0.28	0.14	0.16	0.39	0.31

[in*] is measured using a tape measure in the 5 gallon bucket
[in-] is measured using the yard stick in the 55 gal. drums which has an area of 452.4 in^2

Note: If the rain gage shows more than the intended irrigation volume DO NOT irrigate the chambers.

Irrigation Master Spreadsheet Chamber C

Date	Volume of Rain (P) [liters]	Initial Drum Volume (S_{1B}) [liters]	Volume of water added or lost (G) [liters]	Water containers volume (F) [liters]	Volume of Irrigation (I) [liters]	Post Irrigation Drum Volume (S_{2B}) [liters]	ΣET [in] delta	ET [in/day]	ET (Monthly Average) [in/day]	f Factor	f Factor (Monthly Average)
5/24/2010	0.00	0.00	7.85	11.27	18.77	0.00	-	-		-	
5/25/2010	0.00	0.00	9.60	9.51	18.77	0.00	0.30	0.30		0.48	
5/26/2010	0.00	0.00	3.05	16.07	18.77	0.00	0.08	0.08		0.85	
5/27/2010	0.00	0.00	38.97	14.22	18.77	34.84	0.24	0.24		0.58	
5/28/2010	0.00	35.24	0.00	11.04	18.77	26.28	0.24	0.24		0.53	
5/29/2010	0.00	26.28	0.00	14.13	18.77	21.90	0.12	0.12		0.77	
5/30/2010	13.97	21.90	0.00	30.75	0.00	52.36	0.07	0.07		0.92	
5/31/2010	13.22	52.36	0.00	12.28	18.77	44.80	0.03	0.03	0.15	0.90	0.72
6/1/2010	13.59	47.78	0.00	34.17	12.56	68.89	0.02	0.02		0.97	
6/3/2010	10.57	67.30	0.00	14.87	12.56	69.69	0.20	0.10		0.66	
6/4/2010	38.14	69.69	0.00	49.69	0.00	117.87	0.05	0.05		0.96	
6/5/2010	14.35	116.27	0.00	12.28	0.00	127.82	0.07	0.07		0.80	
6/7/2010	0.00	128.22	0.00	0.00	12.56	115.88	0.00	0.00		0.00	
6/9/2010	1.13	115.88	0.00	2.68	12.56	105.92	0.29	0.15		0.18	
6/11/2010	0.00	105.92	0.00	1.94	12.56	96.76	0.25	0.13		0.23	
6/13/2010	0.00	96.36	0.00	0.37	12.56	84.82	0.31	0.15		0.03	

Date	Volume of Rain (P) [liters]	Initial Drum Volume (S_{1B}) [liters]	Volume of water added or lost (G) [liters]	Water containers volume (F) [liters]	Volume of Irrigation (I) [liters]	Post Irrigation Drum Volume (S_{2B}) [liters]	ΣET [in] delta	ET [in/day]	ET (Monthly Average) [in/day]	f Factor	f Factor (Monthly Average)
6/15/2010	0.00	84.82	0.00	1.66	12.56	74.07	0.28	0.14		0.10	
6/17/2010	0.00	74.07	0.00	2.77	12.56	64.31	0.26	0.13		0.18	
6/18/2010	33.98	64.51	0.00	40.17	0.00	102.34	0.21	0.21		0.82	
6/19/2010	53.24	102.74	0.00	47.24	0.00	147.73	0.22	0.22		0.85	
6/20/2010	5.66	147.81	0.00	4.89	0.00	151.32	0.06	0.06		0.62	
6/21/2010	95.91	152.11	-18.93	71.39	0.00	203.88	0.69	0.69		0.73	
6/23/2010	0.00	203.08	-35.56	0.00	12.56	156.49	0.00	0.00		0.00	
6/25/2010	0.00	156.49	0.00	0.65	12.56	145.74	0.30	0.15		0.10	
6/27/2010	0.00	146.14	0.00	2.12	12.56	135.99	0.26	0.13		0.17	
6/29/2010	0.00	135.39	0.00	1.11	12.56	124.24	0.28	0.14	0.14	0.13	0.42
7/1/2010	0.00	124.24	0.00	3.69	12.56	116.27	0.24	0.12		0.28	
7/2/2010	64.19	116.27	0.00	57.07	0.00	172.02	0.53	0.53		0.74	
7/3/2010	1.89	172.42	0.00	0.09	12.56	160.28	0.05	0.05		0.00	
7/4/2010	0.38	160.08	0.00	9.79	0.00	168.84	0.10	0.10		0.70	
7/5/2010	13.22	168.84	-11.27	10.11	0.00	167.64	0.06	0.06		0.83	
7/7/2010	0.00	168.84	0.00	0.00	12.56	155.70	0.00	0.00		0.00	
7/9/2010	0.00	155.70	0.00	2.77	12.56	146.54	0.28	0.14		0.18	
7/11/2010	0.00	146.14	0.00	2.77	12.56	136.98	0.24	0.12		0.21	
7/13/2010	0.00	136.58	0.00	1.20	12.56	126.23	0.28	0.14		0.07	
7/15/2010	43.42	127.03	0.00	46.82	0.00	174.41	0.19	0.10		0.87	
7/16/2010	1.89	173.22	0.00	0.00	0.00	173.22	0.05	0.05		0.00	

Date	Volume of Rain (P) [liters]	Initial Drum Volume (S_{1B}) [liters]	Volume of water added or lost (G) [liters]	Water containers volume (F) [liters]	Volume of Irrigation (I) [liters]	Post Irrigation Drum Volume (S_{2B}) [liters]	ΣET [in] delta	ET [in/day]	ET (Monthly Average) [in/day]	f Factor	f Factor (Monthly Average)
7/17/2010	0.00	173.22	0.00	0.00	12.56	161.67	0.00	0.00		0.00	
7/19/2010	0.00	161.67	0.00	2.12	12.56	151.71	0.25	0.12		0.19	
7/21/2010	0.00	151.32	0.00	1.11	12.56	140.17	0.30	0.15		0.07	
7/23/2010	0.00	139.77	0.00	2.59	12.56	129.42	0.26	0.13		0.18	
7/24/2010	6.04	130.61	0.00	3.74	0.00	133.00	0.43	0.43		0.13	
7/25/2010	4.53	133.00	0.00	2.12	12.56	122.84	0.07	0.07		0.44	
7/27/2010	0.00	123.04	0.00	6.65	12.56	116.87	0.18	0.09		0.44	
7/29/2010	0.00	116.67	0.00	0.74	12.56	105.12	0.30	0.15		0.03	
7/30/2010	7.17	105.52	0.00	5.13	0.00	109.51	0.40	0.40		0.21	
7/31/2010	0.00	109.90	0.00	0.00	12.56	97.76	0.00	0.00	0.14	0.00	0.26
8/2/2010	34.74	97.56	0.00	24.84	0.00	120.26	0.64	0.32		0.48	
8/4/2010	0.00	120.65	0.00	0.00	12.56	109.11	0.00	0.00		0.00	
8/9/2010	49.09	107.91	0.00	33.16	0.00	144.94	0.63	0.13		0.61	
8/12/2010	61.17	138.97	0.00	47.10	0.00	183.57	0.44	0.15		0.73	
8/14/2010	18.88	184.76	0.00	9.60	0.00	192.73	0.29	0.14		0.42	
8/16/2010	0.00	192.73	0.00	0.00	12.56	181.18	0.00	0.00		0.00	
8/19/2010	16.24	181.58	0.00	3.42	0.00	184.76	0.65	0.22		0.11	
8/20/2010	72.50	183.57	-55.04	63.91	0.00	181.18	0.29	0.29		0.85	
8/24/2010	33.23	192.73	-33.71	21.43	0.00	180.78	0.64	0.64		0.46	
8/25/2010	7.17	179.99	0.00	4.25	12.56	172.42	0.08	0.08		0.56	
8/26/2010	30.59	172.42	-19.95	41.37	0.00	191.53	0.08	0.08		0.93	

Date	Volume of Rain (P) [liters]	Initial Drum Volume (S_{1B}) [liters]	Volume of water added or lost (G) [liters]	Water containers volume (F) [liters]	Volume of Irrigation (I) [liters]	Post Irrigation Drum Volume (S_{2B}) [liters]	ΣET [in] delta	ET [in/day]	ET (Monthly Average) [in/day]	f Factor	f Factor (Monthly Average)
8/30/2010	6.80	191.14	-15.33	0.92	12.56	163.26	0.14	0.03	0.17	0.23	0.45
9/1/2010	0.00	163.66	0.00	4.80	12.56	154.50	0.22	0.11		0.34	
9/3/2010	0.00	155.30	0.00	2.68	12.56	145.34	0.30	0.15		0.18	
9/7/2010	3.78	145.34	0.00	0.00	12.56	132.60	0.43	0.11		0.00	
9/9/2010	18.88	133.00	0.00	12.01	0.00	144.15	0.54	0.27		0.35	
9/13/2010	15.10	144.15	0.00	0.83	0.00	144.94	0.38	0.09		0.05	
9/15/2010	0.00	144.15	0.00	0.00	12.56	133.40	0.00	0.00		0.00	
9/17/2010	0.00	133.40	0.00	2.40	12.56	122.25	0.25	0.13		0.11	
9/20/2010	0.00	122.25	0.00	1.02	12.56	111.10	0.31	0.10		0.06	
9/21/2010	0.00	109.90	0.00	1.11	12.56	100.35	0.27	0.27		0.13	
9/22/2010	0.00	100.35	0.00	3.32	12.56	91.19	0.22	0.22		0.25	
9/23/2010	0.00	91.59	18.29	6.37	12.56	102.74	0.14	0.14		0.57	
9/24/2010	24.17	102.34	0.00	27.24	0.00	128.22	0.29	0.29		0.70	
9/27/2010	22.66	127.82	0.00	16.81	0.00	143.75	0.18	0.06		0.70	
9/29/2010	50.98	144.55	0.00	35.19	0.00	177.20	0.49	0.24		0.64	
9/30/2010	0.00	176.80	0.00	0.00	12.56	164.85	0.00	0.00	0.15	0.00	0.27
10/1/2010	0.00	165.65	0.00	7.20	12.56	159.28	0.15	0.15		0.53	
10/2/2010	0.00	159.28	0.00	7.94	12.56	154.50	0.14	0.14		0.59	
10/3/2010	0.00	154.50	0.00	6.37	12.56	148.53	0.18	0.18		0.45	
10/4/2010	0.00	148.13	0.00	5.26	12.56	140.96	0.17	0.17		0.45	
10/5/2010	0.00	140.96	0.00	8.13	12.56	136.18	0.12	0.12		0.65	

Date	Volume of Rain (P) [liters]	Initial Drum Volume (S_{1B}) [liters]	Volume of water added or lost (G) [liters]	Water containers volume (F) [liters]	Volume of Irrigation (I) [liters]	Post Irrigation Drum Volume (S_{2B}) [liters]	ΣET [in] delta	ET [in/day]	ET (Monthly Average) [in/day]	f Factor	f Factor (Monthly Average)
10/6/2010	0.00	136.18	0.00	7.76	12.56	131.80	0.14	0.14		0.59	
10/7/2010	0.00	131.41	0.00	8.13	12.56	126.63	0.12	0.12		0.63	
10/9/2010	0.00	126.23	0.00	4.99	12.56	117.87	0.21	0.11		0.35	
10/12/2010	0.00	117.47	0.00	3.69	12.56	109.11	0.26	0.09		0.22	
10/22/2010	0.00	146.54	0.00	0.00	12.56	134.19	0.30	0.07		0.00	
10/24/2010	0.00	133.40	0.00	1.11	12.56	121.85	0.28	0.14		0.13	
10/26/2010	0.00	121.05	0.00	1.85	12.56	110.30	0.31	0.15		0.12	
10/28/2010	0.00	109.90	0.00	2.77	12.56	99.95	0.25	0.13		0.23	
10/30/2010	0.00	100.35	0.00	2.40	12.56	89.20	0.32	0.16	0.13	0.06	0.36
11/1/2010	0.00	89.20	0.00	3.69	12.56	79.64	0.25	0.13		0.20	
11/3/2010	0.00	79.64	36.85	7.20	12.56	109.11	0.15	0.07		0.53	
11/5/2010	15.10	108.31	0.00	21.43	0.00	127.42	0.21	0.11		0.71	
11/8/2010	0.00	128.22	0.00	0.00	12.56	115.88	0.00	0.00		0.00	
11/10/2010	0.00	116.27	0.00	3.69	12.56	107.51	0.24	0.12		0.26	
11/12/2010	0.00	107.51	0.00	2.40	12.56	98.36	0.25	0.13		0.20	
11/14/2010	0.00	97.96	0.00	6.28	12.56	91.59	0.16	0.08		0.48	
11/17/2010	0.00	91.98	0.00	1.48	12.56	81.23	0.28	0.14		0.10	
11/18/2010	0.00	81.23	36.66	5.82	12.56	109.11	0.19	0.09		0.40	
11/21/2010	3.78	108.31	0.00	8.13	12.56	103.93	0.23	0.08		0.46	
11/24/2010	0.00	103.53	0.00	7.85	12.56	98.75	0.12	0.04		0.62	
11/26/2010	0.00	98.36	0.00	6.46	12.56	92.38	0.18	0.09		0.43	

Date	Volume of Rain (P) [liters]	Initial Drum Volume (S_{1B}) [liters]	Volume of water added or lost (G) [liters]	Water containers volume (F) [liters]	Volume of Irrigation (I) [liters]	Post Irrigation Drum Volume (S_{2B}) [liters]	ΣET [in] delta	ET [in/day]	ET (Monthly Average) [in/day]	f Factor	f Factor (Monthly Average)
11/28/2010	1.89	92.38	0.00	9.79	9.43	92.38	0.13	0.07		0.61	
11/30/2010	54.75	91.59	0.00	58.64	0.00	146.54	0.21	0.10	0.09	0.88	0.42
12/2/2010	0.00	146.54	0.00	0.00	9.43	138.57	0.00	0.00		0.00	
12/6/2010	0.00	139.37	0.00	2.40	9.43	133.00	0.16	0.04		0.25	
12/8/2010	0.00	133.00	0.00	4.25	9.43	127.42	0.13	0.06		0.43	
12/10/2010	0.00	127.42	0.00	5.17	9.43	124.24	0.11	0.05		0.57	
12/13/2010	0.00	122.65	0.00	5.54	9.43	116.27	0.12	0.04		0.48	
12/15/2010	0.00	117.87	37.68	4.43	37.68	122.65	0.15	0.08		0.45	
12/17/2010	0.00	122.65	-30.96	31.52	9.43	113.89	0.18	0.09		0.82	
12/20/2010	16.99	114.28	0.00	21.52	0.00	133.80	0.18	0.06		0.75	
12/21/2010	0.00	134.19	0.00	0.00	9.43	125.83	0.00	0.00		0.00	
12/23/2010	0.00	125.83	0.00	5.17	9.43	121.05	0.11	0.05		0.52	
12/27/2010	3.78	121.45	0.00	4.16	9.43	117.07	0.24	0.06		0.31	
12/29/2010	0.00	115.48	0.00	3.14	9.43	111.89	0.12	0.06		0.48	
12/31/2010	0.00	110.70	0.00	6.10	9.43	107.91	0.04	0.02	0.05	0.79	0.45
1/2/2011	0.00	107.51	0.00	5.54	9.43	102.74	0.12	0.06		0.50	
1/4/2011	0.00	103.53	0.00	4.80	4.71	103.93	0.13	0.06		0.48	
1/6/2011	16.99	96.36	0.00	14.87	0.00	109.90	0.20	0.10		0.65	
1/8/2011	0.00	116.27	0.00	0.00	4.71	113.09	0.00	0.00		0.00	
1/11/2011	13.22	112.29	0.00	9.24	0.00	121.45	0.19	0.06		0.56	
1/13/2011	0.00	120.65	0.00	0.00	4.71	116.67	0.00	0.00		0.00	

Date	Volume of Rain (P) [liters]	Initial Drum Volume (S_{1B}) [liters]	Volume of water added or lost (G) [liters]	Water containers volume (F) [liters]	Volume of Irrigation (I) [liters]	Post Irrigation Drum Volume (S_{2B}) [liters]	ΣET [in] delta	ET [in/day]	ET (Monthly Average) [in/day]	f Factor	f Factor (Monthly Average)
1/15/2011	0.00	116.67	0.00	0.00	4.71	112.29	0.11	0.05		0.00	
1/18/2011	66.46	112.29	0.00	53.66	0.00	166.05	0.45	0.23		0.76	
1/20/2011	0.00	166.45	0.00	0.00	4.71	162.47	0.00	0.00		0.00	
1/23/2011	64.19	162.47	-45.25	45.25	0.00	162.47	0.60	0.20		0.67	
1/25/2011	0.00	163.66	0.00	0.00	4.71	159.28	0.00	0.00		0.00	
1/27/2011	48.33	158.88	-44.33	44.33	0.00	158.88	0.23	0.11		0.84	
1/29/2011	0.00	157.29	0.00	0.00	4.71	153.71	0.00	0.00		0.00	
1/31/2011	0.00	153.71	0.00	0.00	4.71	150.92	0.09	0.05	0.07	0.00	0.32
2/2/2011	0.00	150.52	0.00	0.00	4.71	147.33	0.07	0.04		0.00	
2/4/2011	0.00	146.94	0.00	0.00	4.71	142.56	0.08	0.04		0.00	
2/8/2011	13.59	142.56	0.00	3.69	0.00	145.74	0.39	0.10		0.18	
2/10/2011	3.40	145.74	0.00	0.00	4.71	141.76	0.09	0.05		0.00	
2/14/2011	0.00	141.76	0.00	0.00	4.71	139.37	0.11	0.05		0.00	
2/16/2011	0.00	139.37	0.00	0.00	4.71	133.40	0.06	0.03		0.00	
2/18/2011	0.00	134.59	0.00	0.00	4.71	128.62	0.16	0.08		0.00	
2/20/2011	0.00	128.62	0.00	0.00	4.71	123.84	0.16	0.08		0.00	
2/22/2011	0.00	124.64	0.00	0.00	4.71	119.86	0.13	0.06		0.00	
2/25/2011	0.00	119.86	0.00	0.00	4.71	111.89	0.13	0.04		0.00	
2/27/2011	0.00	111.10	0.00	0.00	9.43	97.96	0.21	0.11	0.06	0.00	0.02
3/2/2011	7.93	101.94	0.00	0.00	9.43	94.37	0.56	0.19		0.00	
3/4/2011	0.00	93.98	0.00	1.66	9.43	86.01	0.16	0.08		0.21	

Date	Volume of Rain (P) [liters]	Initial Drum Volume (S_{1B}) [liters]	Volume of water added or lost (G) [liters]	Water containers volume (F) [liters]	Volume of Irrigation (I) [liters]	Post Irrigation Drum Volume (S_{2B}) [liters]	ΣET [in] delta	ET [in/day]	ET (Monthly Average) [in/day]	f Factor	f Factor (Monthly Average)
3/6/2011	0.00	83.62	0.00	7.02	9.43	78.84	0.08	0.04		0.67	
3/8/2011	0.00	78.84	0.00	4.43	9.43	70.08	0.21	0.11		0.29	
3/13/2011	37.76	69.29	0.00	34.45	0.00	102.34	0.44	0.09		0.66	
3/15/2011	0.00	102.34	0.00	0.00	9.43	94.37	0.00	0.00		0.00	
3/17/2011	0.00	93.98	0.00	0.00	9.43	81.23	0.21	0.11		0.00	
3/19/2011	0.00	81.23	0.00	0.74	9.43	70.08	0.33	0.16		0.03	
3/21/2011	0.00	70.48	0.00	0.74	9.43	58.14	0.30	0.15		0.03	
3/23/2011	0.00	58.54	0.00	0.74	9.43	46.19	0.33	0.16		0.03	
3/25/2011	0.00	46.19	32.51	0.92	9.43	66.50	0.32	0.16	0.11	0.06	0.18
4/2/2011	196.35	66.90	-118.21	189.14	0.00	139.77	0.47	0.06		0.92	
4/5/2011	15.48	137.38	0.00	0.18	18.87	120.26	0.40	0.13		0.03	
4/8/2011	0.00	118.27	0.00	8.03	18.87	103.93	0.24	0.08		0.48	
4/11/2011	0.00	107.51	0.00	7.85	18.87	96.36	0.43	0.14		0.28	
4/13/2011	4.53	97.16	0.00	1.11	18.87	79.64	0.57	0.29		0.02	
4/15/2011	0.00	78.05	0.00	5.91	18.87	63.71	0.35	0.17		0.27	
4/17/2011	0.00	64.11	0.00	7.20	18.87	52.56	0.32	0.16		0.38	
4/19/2011	0.00	53.36	0.00	3.69	18.87	37.03	0.40	0.20		0.19	
4/21/2011	0.00	37.03	115.26	3.69	18.87	140.17	0.44	0.22		0.16	
4/23/2011	0.00	140.17	0.00	0.46	18.87	123.44	0.40	0.20		0.05	
4/25/2011	0.00	123.84	0.00	4.99	18.87	106.72	0.37	0.18		0.20	
4/27/2011	0.00	106.72	0.00	5.17	18.87	92.38	0.44	0.22		0.19	

Date	Volume of Rain (P) [liters]	Initial Drum Volume (S_{1B}) [liters]	Volume of water added or lost (G) [liters]	Water containers volume (F) [liters]	Volume of Irrigation (I) [liters]	Post Irrigation Drum Volume (S_{2B}) [liters]	ΣET [in] delta	ET [in/day]	ET (Monthly Average) [in/day]	f Factor	f Factor (Monthly Average)
4/29/2011	0.00	99.55	0.00	5.54	18.87	86.01	0.34	0.17	0.17	0.30	0.27

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