THE EFFECTIVENESS OF GREEN ROOF STORMWATER TREATMENT SYSTEMS IRRIGATED WITH RECYCLED GREEN ROOF FILTRATE TO ACHIEVE POLLUTANT REMOVAL WITH PEAK AND VOLUME REDUCTION IN FLORIDA

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ABSTRACT

The effectiveness of a green roof constructed and operated in Florida that is irrigated with recycled green roof filtrate water is examined using experimental chambers and reported on within this research publication. The intensive flat green roof depth is eight inches, and is composed of drainage, pollution control, and growth media with vegetation commonly found in Florida. The purpose of the research is to document the reduction of pollutants and water from the green roof as compared to a conventional roof. Experiments are designed to document the effectiveness of vegetation, irrigation rate and pollution control media. The green roof properties of interest are the filtration and biological processes as well as the green roof's ability to hold water and increase evapotranspiration.

This experiment consists of water quality analysis and a water budget done on several experimental chambers modeled after the green roof on the student union building at the University of Central Florida. The green roof chambers are used to study different types of growing media, different irrigation rates, and the addition of plants and how the filtrate quality and quantity are affected. There are also control chambers built to model the conventional roof on the student union building. The control is used to compare the water quality and quantity effectiveness of the plants, irrigation rates, and different pollution control media's filtration/adsorption processes.

The results showed that a specifically designed green roof stormwater treatment system (one with a cistern) is an effective way to reduce both the volume and mass of pollutants from stormwater runoff. The year long water budget calculations showed that this system can reduce the volume of stormwater runoff relative to that from a

conventional roof. The green roof model developed within this work showed similar results for the same green roof conditions. Design curves produced by the model have also been presented for several different geographic regions in Florida.

The green roof stormwater treatment system presented within this work was effective at reducing the mass of pollutants relative to that from a conventional roof. Nitrate and Ammonia were among those that had a lower concentration than the control roof.

The use of a pollution control growing media was also encouraging. The results showed that the Black & Gold™ growing media is effective at removing both ortho-phosphorus and total phosphorus. Despite the promise of the Black & Gold™ growing media on the surface to remove phosphorus the plants did not grow as well as in the Black & Gold™ growing media. It is suggested that the pollution control media be used as a layer under the expanded clay growing media in order to get the benefits of both media.

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ACRONYMS/ABBREVIATIONS

LID	Low Impact Development
pH	Potential of Hydrogen
TP	Total Phosphorous
OP	Ortho-phosphorous
BMP	Best Management Practices
TN	Total Nitrogen
TKN	Total Kjeldahl Nitrogen
P	Precipitation
I	Irrigation
ET	Evapotranspiration
R	Runoff from the Cistern
Ms	Green Roof Media Storage
S	Cistern Storage
Z	Supplementary Water Source
O	Cistern Overflow
F	Green Roof Filtrate
f	Filtrate Factor
CSTORM	Continuous Stormwater Treatment Outflow Reduction Model

INTRODUCTION

The control of stormwater runoff is a pressing issue facing most urban areas where land availability for stormwater ponds is either not physically available or other stormwater options are very expensive. Stormwater runoff into separate or combined sewers can be polluted in several ways such as contact with corroded and deposited roof materials (Good 1993), contact with polluted particulate matter on roadways (Vaze and Chiew 2004), and contact with fecal matter, fertilizers and pesticides from lawns and agricultural land (Hoffman 2006). One possible solution for treatment of roof runoff water is the use of a green roof stormwater treatment system, which includes a cistern or holding pond from which water is returned to the green roof, and less water is discharged to receiving waters.

A green roof with a cistern from which irrigation water is used offers an aesthetically pleasing treatment solution that utilizes unused space to treat and store stormwater runoff. With the adaptabilities of a green roof system, it can be applied to almost any roof structure. The results in this paper will give developers and builders new options for stormwater management source control that will allow them to treat polluted stormwater and reduce the volume of discharge and thus eliminate an impervious surface and pollution contributor (Hunt and Moran 2004).

Recycling the stormwater runoff and irrigating the green roof with stored water enhances hydrologic related factors such as evapotranspiration, the filtering abilities of the plants and media, and the water holding abilities of the plants and media, as well as greatly reduce the volume of stormwater runoff leaving the site. In order to achieve this, a cistern needs to be used to store the water between irrigation events. The only two ways water will leave the system is through evapotranspiration and as stormwater runoff when the system reaches storage capacity from large storm events. The only two ways water will enter the system is from precipitation and from a supplemental source that is used for irrigation. The efficiency of the system will be determined from the total precipitation and the total overflow. Design equations and a model are developed to estimate the size of a cistern given a desired efficiency.

A most practical approach to the problem of stormwater runoff is to try to treat the water as close to where it was contaminated as possible. This concept is called source control (Ellis 2000). Developing an undeveloped land reduces the evapotranspiration and increases the stormwater runoff for that area, thereby changing the hydrologic cycle for the watershed. The practice of using plant- and soil-based techniques for treating and holding stormwater at the source to decrease stormwater runoff and increase evapotranspiration rates is called low-impact development (LID) (Davis et al. 2003). Within this paper, introduced is a new LID treatment option - the use of a green roof and cistern system. If green roofs are shown to remove pollutants from stormwater, then this will be a way to utilize the unused roof space, which is in many cases a source of stormwater pollution.

Hunt and Moran (2004) completed a water budget on a non-irrigated green roof and found that for small precipitation events, the green roof was able to retain approximately 75% of the precipitation and reduce the peak flow by as much as 90% as well as increase the time of concentration to almost four hours. The time of concentration is the amount of time it takes for stormwater runoff to occur after a precipitation event has begun (Hunt and Moran, 2004).

MacMillan (2004) studied the water quantity of stormwater runoff from an irrigated green roof in Toronto. He found that green roofs were able to significantly reduce the total stormwater runoff volume and the peak flows coming off a roof for small storm events, around 55% and 85%, respectively, for storm events less than or equal to 10 mm (MacMillan, 2004). Also addressed in MacMillan's paper is the fact that green roof volume control efficiency changes with time of year noting that the efficiency is higher in the spring and summer months and lower in the winter and fall months.

Moran et al. (2004) studied green roofs in North Carolina to examine runoff quantity and quality as well as evaluate plant growth. During the nine month period examined it was found that a green roof was able to retain about 60% of the total rainfall volume while reducing the peak flow by about 80% (Moran et al., 2004). There was no comparison to a control roof, but it is common to assume a conventional roof retains about 3-5% of the total rainfall volume.

APPROACH

Irrigated green roof experimental chambers in Central Florida were instrumented to quantify the water quantity of the runoff leaving the roof. The water quantity parameters of interest are those listed in Table 1. There were 18 experimental green roof chambers built to model the 1600 ft^2 green roof system which is located on the Student Union building at the University of Central Florida (UCF). These chambers were located at the stormwater management laboratory at UCF and used to isolate certain variables of interest. There were eighteen green roof chambers with an area of 16 ft^2. The overall green roof design section used to construct the 1600 ft^2 green roof was held constant in all of the chambers. This includes the use of insulation with an R (insulation efficiency) value of 19, which is installed directly onto the roof structure. The same waterproof membrane was used, which acts as both a root barrier and a waterproofing layer, and was installed over the insulation. The same protection layer (which is a three-layer material with a non-woven fabric on either side of a plastic mesh) was also used to protect the waterproofing membrane against being punctured or damaged. This protection layer is installed directly on top of the waterproofing layer.

Table 1: Water Budget Parameters of Interest. Source: Hardin 2006

Parameter	Anticipated value
P' [in/GR Area]	62.51¥
I' [in/GR Area]	1 in/week or 2 in/week
ET' [in/GR Area]	0.14¤
Z' [in/GR Area]	Will vary with storm event
O' [in/GR Area]	-
Ms [in/GR Area]	-
F' [in/GR Area]	Will vary with storm event
S' [in/GR Area]	-

www.cityoforlando.net/public_works/stormwater/
¥ Based on 2004 data, Inches per year
¤ Monthly average, Inches per day

The drainage media used was also consistent with that used for the full size roof, not just in material type but also at the same depth of 2 inches. The drainage media, which is installed directly onto the protection layer, creates additional pore space allowing water to flow more freely to the point of discharge while maintaining a low flow rate. The same separation fabric, which is installed directly on top of the drainage media, was also used. The purpose of the separation fabric is to keep the fine particles associated with the growing media out of the drainage media and prevent clogging.

The species of plants, which also were held constant for this experiment, include; Helianthus debilis (Dune sunflower), Gaillardia pulchella or aristata (Blanket flower), Lonicera sempervirens (Coral honeysuckle), Myricanthes fragrans (Simpson's stopper), Clytostoma callistegioides (Argentine trumpet vine), Tecomeria capensis (Cape honeysuckle), and Trachelospermum jasminoides (Confederate jasmine). The plants were selected based on hardiness, drought tolerance, the aesthetically pleasing aspects of the plant and whether or not they are native to Florida. The first four plant species are Florida natives while the last three are not.

There were two different types of growing media mixes studied; an expanded clay mix and a tire crumb mix (Black & Gold™). It should be noted at this time that the experimental chambers with the tire crumb mix were notated as both T and B&G. The expanded clay mix consists of 60% expanded clay, 15% peat moss, 15% perlite and 10% vermiculite. The tire crumb mix consists of 40% tire crumb from recycled automobile tires, 20% expanded clay, 15% peat moss, 15% perlite and 10% vermiculite. All of the preceding percentages are percent by volume.

The 1600 ft^2 green roof located on the University of Central Florida's Student Union building consists of a 4-6 inch deep growing media made up of the expanded clay composite mix, and is irrigated twice a week totaling 1 inch of water per week. The growing media, use of plants and irrigation rates are the variables of interest for this project.

Two different irrigation rates were studied to determine the effects on water quantity. The two different irrigation rates used for this experiment are regular irrigation and over irrigation. The regular irrigation consisted of two weekly irrigation events that totaled 1.0 inch of water per week while over irrigation consisted of two weekly irrigation events that totaled 2.0 inches of water per week. Irrigation occurred whenever the precipitation for the last 24 hours was less than the volume to be irrigated.

The added benefit of the biological processes associated with the use of plants was also examined. This was determined by constructing some of the chambers with only growing media and no plants and some with both growing media and plants. The purpose of this aspect of the experiment is to qualify which set-up (plants or no plants, regular irrigation vs. over-irrigation, etc.) will most efficiently reduce the volume of stormwater runoff.

The water quality analyses were preformed weekly with sampling occurring from the cistern. The water quality parameters studied were the following: ortho-phosphorus, total phosphorus, nitrate + nitrite, ammonia, TKN, total nitrogen, total suspended solids, total dissolved solids, total solids, pH, and alkalinity.

The testing procedures used for the determination of ortho-phosphorus was the Hach method for the low range concentration detection which was adopted from the Standard Methods 4500-P E ascorbic acid method, the Hach DR 5000 spectrophotometer was used for this procedure. The testing procedures used for the determination of total phosphorus was the Standard Methods 4500-P B 5 persulfate digestion method for the conversion of organic phosphorus to ortho-phosphorus and the previously mentioned Hach method for the final concentration determination.

The testing procedure for the determination of nitrate+nitrite was the Hach method for the low range concentration detection which was adopted from the Standard Methods 4500-NO_3^- E cadmium reduction method, the Hach DR 5000 spectrophotometer was used for this procedure.

The testing procedure for the determination of ammonia was the Standard Methods 4500-NH_3 D using the Accumet™ AR50 Dual Channel pH/Ion/Conductivity Meter with the Thermo Electron Corporation Orion 9512 Ammonia selective probe. The testing procedure for the determination of TKN was the Standard Methods procedure 4500-N_{org} B Macro-kjideal method. The total nitrogen was determined by adding up the nitrogen species. The total suspended and dissolved solids were determined using the Standard Methods 2540 D and C respectively.

The total solids were determined by summing the total suspended and dissolved solids. The pH was determined using the Accumet™ AR50 dual channel pH/Ion/Conductivity Meter with the AccutupH^{+}™ selective probe. The alkalinity was determined using the Standard Methods titration method 2320 B. Each sample was collected weekly and stored according to EPA Test Methods Technical Additions to Methods for Chemical Analysis of Water and Wastes. All of the analysis was preformed in a timely manner, according to proper analyses and within 36 hours of sampling.

RESULTS

Water Budget:

ET and Filtrate Factor Determination:

The average monthly ET rates as well as the average monthly filtrate factor for an irrigated green roof in central Florida were estimated from actual measurements for the green roof schematic shown in Figure 1. The monthly ET rates were calculated using a mass balance approach. The filtrate factor was calculated as the fraction of water collected per water added from both precipitation and irrigation. The ET rates were calculated daily and then averaged for each month. The inputs into the system are the precipitation and irrigation volumes. The outputs to the system are ET and filtrate volumes. The monthly estimated ET and calculated filtrate factors from the experimental data are shown in Tables 2 and 3 respectively.

It can be seen from Tables 2 and 3 that both the evapotranspiration rates and the filtrate factors change with the season. As would be expected, the evapotranspiration rates increased during the summer months and decreased during the winter months. The filtrate factor did the opposite, decreased during the summer months and increased during the winter months. With closer examination of Table 2 it can be seen that the evapotranspiration rates for both the vegetated and non-vegetated chambers are essentially the same during the winter months. This calculation shows that while necessary during the summer months the irrigation rates can be reduced during the winter months.

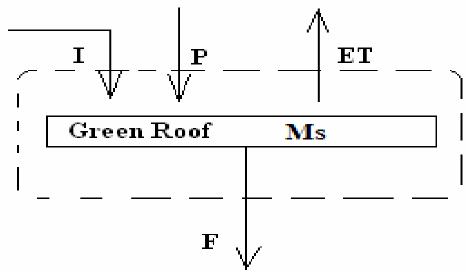


Figure 1: Green Roof System Boundaries. Source: Hardin 2006

Table 2: ET Monthly Average Comparison

ET Monthly Average Comparison of all the Chambers [in/day]																		
Da[illegible]	[illegible]	[illegible]VO2	TVR1	TVR2	TO1	TO2	C1	C2	TR1	TR2	EO1	EO2	ER1	ER2	EVO1	EVO2	EVR1	EVR2
Jul[illegible]	[illegible]	[illegible].25	0.24	0.24	0.22	0.21	0.02	0.00	0.14	0.13	0.14	0.15	0.14	0.13	0.17	0.17	0.17	0.16
Aug[illegible]	[illegible]	[illegible].22	0.17	0.18	0.17	0.17	0.00	0.02	0.16	0.16	0.15	0.15	0.14	0.14	0.14	0.14	0.14	0.14
Sep[illegible]	[illegible]	[illegible].22	0.16	0.17	0.14	0.14	0.00	0.00	0.12	0.13	0.10	0.10	0.09	0.09	0.17	0.15	0.14	0.13
Oct-05	0.11	0.14	0.10	0.10	0.09	0.10	0.00	0.01	0.09	0.09	0.07	0.08	0.07	0.08	0.11	0.13	0.10	0.09
Nov-05	0.10	0.10	0.08	0.09	0.09	0.09	0.00	0.00	0.07	0.08	0.07	0.08	0.08	0.07	0.11	0.11	0.09	0.09
Dec-05	0.09	0.09	0.08	0.09	0.09	0.08	0.00	0.00	0.07	0.08	0.08	0.08	0.07	0.07	0.09	0.09	0.08	0.08
Jan-06	0.10	0.09	0.08	0.09	0.09	0.09	0.00	0.01	0.09	0.08	0.08	0.08	0.08	0.08	0.11	0.10	0.09	0.10
Feb-06	0.11	0.10	0.08	0.12	0.11	0.12	0.00	0.00	0.09	0.10	0.09	0.09	0.09	0.09	0.12	0.10	0.10	0.10
Mar-06	0.13	0.14	0.12	0.13	0.15	0.15	0.00	0.00	0.11	0.12	0.11	0.11	0.11	0.11	0.14	0.13	0.12	0.12
Apr-06	0.17	0.19	0.13	0.16	0.16	0.17	0.00	0.00	0.13	0.13	0.12	0.12	0.12	0.12	0.17	0.16	0.15	0.14
May-06	0.16	0.18	0.14	0.15	0.13	0.14	0.00	0.02	0.11	0.12	0.11	0.12	0.10	0.10	0.16	0.15	0.13	0.13
Jun-06	0.20	0.20	0.18	0.19	0.17	0.18	0.00	0.03	0.16	0.15	0.16	0.16	0.14	0.14	0.17	0.18	0.17	0.17

Table 3: f Factor Monthly Average Comparison

F Factor Monthly Average Comparison of all the Chambers																		
Date	TVO1	TVO2	TVR1	TVR2	TO1	TO2	C1	C2	TR1	TR2	EO1	EO2	ER1	ER2	EVO1	EVO2	EVR1	EVR2
Jul-05	0.54	0.53	0.42	0.38	0.61	0.61	0.96	0.91	0.50	0.50	0.70	0.67	0.50	0.53	0.64	0.65	0.52	0.56
Aug-05	0.46	0.41	0.24	0.21	0.52	0.51	0.94	0.88	0.35	0.27	0.67	0.65	0.39	0.40	0.62	0.62	0.39	0.40
Sep-05	0.58	0.50	0.44	0.41	0.69	0.68	0.98	1.01	0.50	0.55	0.70	0.68	0.56	0.56	0.63	0.68	0.52	0.55
Oct-05	0.71	0.68	0.60	0.55	0.75	0.74	0.97	0.94	0.60	0.61	0.81	0.79	0.67	0.64	0.71	0.71	0.55	0.59
Nov-05	0.67	0.65	0.46	0.40	0.70	0.69	0.94	0.78	0.49	0.45	0.76	0.74	0.51	0.52	0.62	0.63	0.40	0.38
Dec-05	0.74	0.72	0.59	0.54	0.74	0.75	0.98	0.82	0.61	0.57	0.77	0.77	0.61	0.61	0.73	0.73	0.58	0.57
Jan-06	0.70	0.70	0.49	0.49	0.72	0.72	0.86	0.71	0.47	0.49	0.75	0.73	0.52	0.51	0.65	0.67	0.45	0.42
Feb-06	0.65	0.68	0.51	0.42	0.68	0.67	0.98	0.87	0.46	0.45	0.72	0.70	0.48	0.49	0.62	0.67	0.45	0.44
Mar-06	0.54	0.51	0.19	0.15	0.49	0.48	-	-	0.24	0.21	0.62	0.60	0.25	0.26	0.54	0.54	0.19	0.17
Apr-06	0.47	0.41	0.25	0.10	0.50	0.46	0.97	0.83	0.26	0.21	0.62	0.60	0.28	0.28	0.49	0.50	0.14	0.16
May-06	0.50	0.45	0.26	0.20	0.58	0.57	0.99	0.81	0.37	0.36	0.66	0.64	0.41	0.43	0.52	0.54	0.27	0.30
Jun-06	0.56	0.57	0.42	0.37	0.62	0.62	0.99	0.84	0.48	0.52	0.65	0.65	0.55	0.56	0.62	0.61	0.44	0.47

Hydrograph Results:

Hydrograph analysis was also performed on the green roof chambers. The results show that use of a green roof will result in a reduced peak flow and an increased time to peak when compared to the control roof. The peak flow for the vegetated chambers was approximately half of that for the control chambers. Figure 2 below shows a comparison of the control chamber hydrograph with the expanded clay hydrograph, both of which has an input rate of 6 inches per hour for a 10 minute duration. This translates to a volume of 37.71 liters of rainfall. For the control chamber 36.51 liters of discharge were collected while for the vegetated expanded clay chamber only 16.8 liters of discharge was collected. This shows a filtrate factor of about 0.45 for the expanded clay chamber as apposed to 0.97 for the control chamber. This hydrograph analysis shows a green roof's ability to store and attenuate the peak flow from storm events.

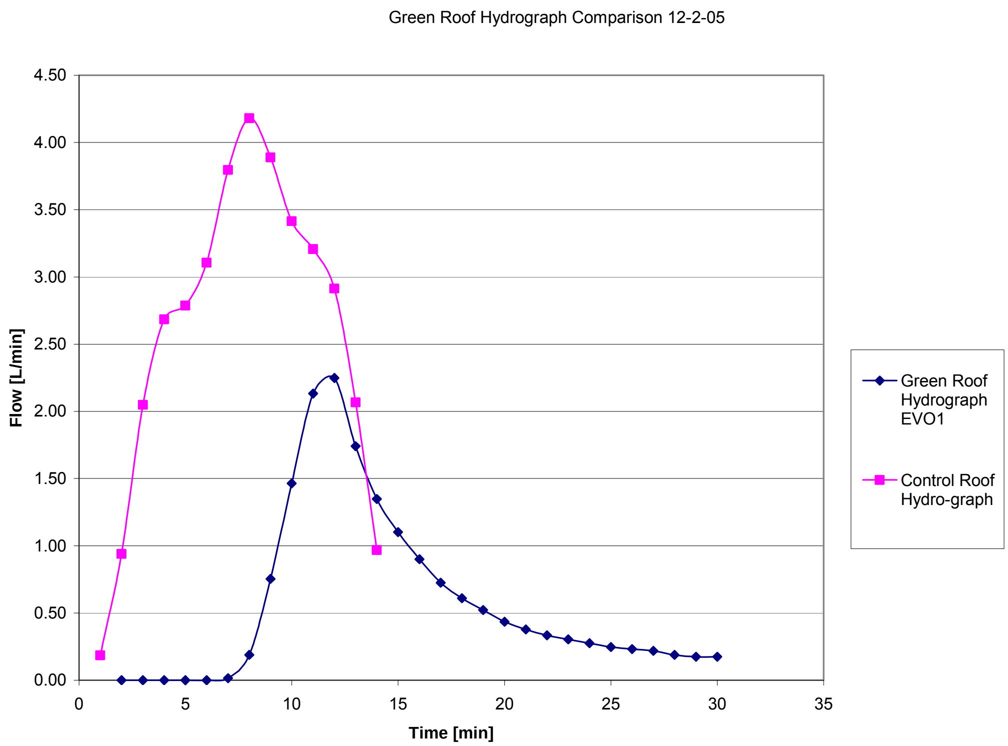


Figure 2: Hydrograph Comparison Control vs. Expanded Clay. Source: Hardin 2006

Irrigation Rates per Week:

Based on the hypothesis testing statistics presented in Table 4 the irrigation rates per week had no significant affect on the evapotranspiration rates, $\alpha = 0.05$. It should be noted that this conclusion is due to the fact that some, not all, of the experimental chambers accepted the null hypothesis. The z scores were however, high for over irrigation suggesting that evapotranspiration rates are higher just not significantly higher. The results from the hypothesis testing on the filtrate factor, which appears in Table 5, show that the irrigation regime does have a significant effect, $\alpha = 0.05$. That is, the filtrate factor is higher for over irrigation and lower for regular irrigation. This shows that the higher the soil moisture the higher the 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.

Vegetated vs. Non-vegetated:

The use of vegetation to increase evapotranspiration rates and decrease the filtrate factor was also examined. From the hypothesis tests presented in Table 4 it is shown that vegetation significantly increases evapotranspiration rates, $\alpha = 0.05$. All the null hypotheses were rejected except one, but that one had a large positive z score. It should be noted that the one accepted hypothesis test would also be rejected if using a lower α. All eight of the hypothesis tests suggest that all chambers with vegetation have higher evapotranspiration rates than chambers without vegetation.

The hypothesis tests in Table 5 shows that vegetation significantly lowers the filtrate factor, $\alpha = 0.05$. All the null hypotheses for this test were rejected except one, but that one had a large negative z score. All eight of the hypothesis tests suggest that all chambers with vegetation have lower filtrate factor than chambers without vegetation. The overall results for this set of hypothesis tests show that vegetation increases evapotranspiration rates and lowers the filtrate factor.

Media Types:

The choice of media types between the Black & Gold™ mix and the expanded clay mix has no significant affect on evapotranspiration rates, $\alpha = 0.05$. While five of the hypothesis tests rejected the null hypothesis, three did not. It should be noted, however, all z scores were large positive numbers indicating that the Black & Gold™ mix did increase the evapotranspiration rates, just not significantly. The filtrate factor also is not affected by the media selection, $\alpha = 0.05$. Only three of the eight chambers rejected the null hypothesis, although, all but one chamber had a rather large negative z score. This indicates that the Black & Gold™ mix did reduce the filtrate factor when compared to the expanded clay mix, just not a statistically significant reduction.

Table 4: ET Hypothesis Tests. Source: Hardin 2006

ET Hypothesis Tests

H_{O1}	Media and vegetation are held constant, ET Rates for Over irrigation = ET Rates for Regular irrigation
H_{a1}	Media and vegetation are held constant, ET Rates for Over irrigation > ET Rates for Regular irrigation
H_{O2}	Media and irrigation rates are held constant, ET Rates for Vegetated boxes = ET Rates for Non Vegetated boxes
H_{a2}	Media and irrigation rates are held constant, ET Rates for Vegetated boxes > ET Rates for Non Vegetated boxes
H_{O3}	Irrigation rates and vegetation is held constant, ET Rates for Black & Gold = ET Rates for Expanded Clay
H_{a3}	Irrigation rates and vegetation is held constant, ET Rates for Black & Gold > ET Rates for Expanded Clay

$\alpha =$ 0.05 $z_\alpha =$ 1.645

Note: R = Reject H_O & A = Accept H_O

	TVO1	TVO2	TVR1	TVR2	TO1	TO2	TR1	TR2	EO1	EO2	ER1	ER2	EVO1	EVO2	EVR1	EVR2
Average	0.15	0.16	0.13	0.14	0.13	0.14	0.11	0.12	0.11	0.11	0.10	0.10	0.14	0.14	0.13	0.12
s	0.086	0.087	0.081	0.081	0.072	0.076	0.058	0.055	0.056	0.056	0.052	0.052	0.062	0.064	0.057	0.057
s^2	0.007	0.008	0.007	0.007	0.005	0.006	0.003	0.003	0.003	0.003	0.003	0.003	0.004	0.004	0.003	0.003
n	103	103	103	103	103	103	102	102	102	102	102	102	103	103	103	103
z_1	1.693	1.577			2.195	2.309			0.537	1.249			1.701	1.497		
H_{O1}	**R**	**A**			**R**	**R**			**A**	**A**			**A**	**A**		
z_2	1.532	2.016	1.757	2.654									4.030	2.872	3.025	2.819
H_{O2}	**A**	**R**	**R**	**R**									**R**	**R**	**R**	**R**
z_3	0.856	2.352	0.382	1.924	2.861	2.773	1.281	1.873								
H_{O3}	**A**	**R**	**A**	**R**	**R**	**R**	**A**	**R**								

Table 5: Filtrate Factor Hypothesis Tests. Source: Hardin 2006

Filtrate Factor Hypothesis Tests

H_{O1}	When media and vegetation is held constant, The f Factor for Over irrigation = f Factor for Regular irrigation
H_{a1}	When media and vegetation is held constant, f Factor for Over irrigation > f Factor for Regular irrigation
H_{O2}	When media and irrigation rates are held constant, f Factor for Vegetated boxes = f Factor for Non Vegetated boxes
H_{a2}	When media and irrigation rates are held constant, f Factor for Vegetated boxes < f Factor for Non Vegetated boxes
H_{O3}	When irrigation rates and vegetation is held constant, f Factor for Black & Gold = f Factor for Expanded Clay
H_{a3}	When irrigation rates and vegetation is held constant, f Factor for Black & Gold < f Factor for Expanded Clay

α = 0.05 z_α = 1.645 $-z_\alpha$ = -1.65

Note: R = Reject H_O & A = Accept H_O

	TVO1	TVO2	TVR1	TVR2	TO1	TO2	TR1	TR2	EO1	EO2	ER1	ER2	EVO1	EVO2	EVR1	EVR2
Average	0.59	0.57	0.41	0.35	0.63	0.62	0.45	0.43	0.70	0.68	0.48	0.49	0.61	0.63	0.41	0.42
s	0.159	0.175	0.228	0.240	0.156	0.169	0.231	0.225	0.133	0.129	0.236	0.231	0.150	0.138	0.239	0.239
s^2	0.025	0.031	0.052	0.058	0.024	0.029	0.053	0.051	0.018	0.017	0.056	0.054	0.023	0.019	0.057	0.057
n	104	104	104	104	104	104	103	103	103	103	103	103	102	101	101	102
z_1	6.793	7.330			6.689	6.839			8.105	7.538			7.319	7.568		
H_{O1}	**R**	**R**			**R**	**R**			**R**	**R**			**R**	**R**		
z_2	-1.861	-2.327	-1.320	-2.467									-4.242	-2.925	-2.212	-1.985
H_{O2}	**R**	**R**	**A**	**R**									**R**	**R**	**R**	**R**
z_3	-1.111	-2.709	-0.113	-1.981	-3.342	-2.825	-1.078	-1.619								
H_{O3}	**A**	**R**	**A**	**R**	**R**	**R**	**A**	**A**								

Water Quality:

The use of a green roof for the improvement of stormwater runoff quality is examined in this study. The results for the water quality analysis are presented in Appendix D. The tables in Appendix D show the average, standard deviation, and number of sampling events for each water quality parameter and chamber. Also shown in these tables are the relative percent difference of each of the duplicate chambers and the relative percent difference between each chamber and the control chamber. As expected, there was no temperature differential among the chambers, and thus fewer measurements were recorded after this was obvious. However, it was postulated that the Black & Gold™ media may have a higher temperature. Appendix D also shows graphically the average concentration of each chamber and the mass that leaves the system for each chamber. This is done for each water quality parameter. The mass out of the system was calculated based on average concentration and total volume of cistern overflow. From the average concentration graphs presented in Appendix D it can be seen that, with the exception of nitrate and ammonia, all the chambers have either comparable or higher concentrations than the control chambers. However, from the mass comparison graphs in Appendix D, chambers with media or media and plants have lower mass leaving than a control chamber. This reduction is seen with all water quality parameters except total dissolved solids, total solids, and alkalinity. Figure 3 and Figure 4 shows the nitrate concentration and mass comparisons, respectively and Table 6 shows the nitrate hypothesis tests. Hypothesis test results for the water quality data is presented in Appendix E and discussed below.

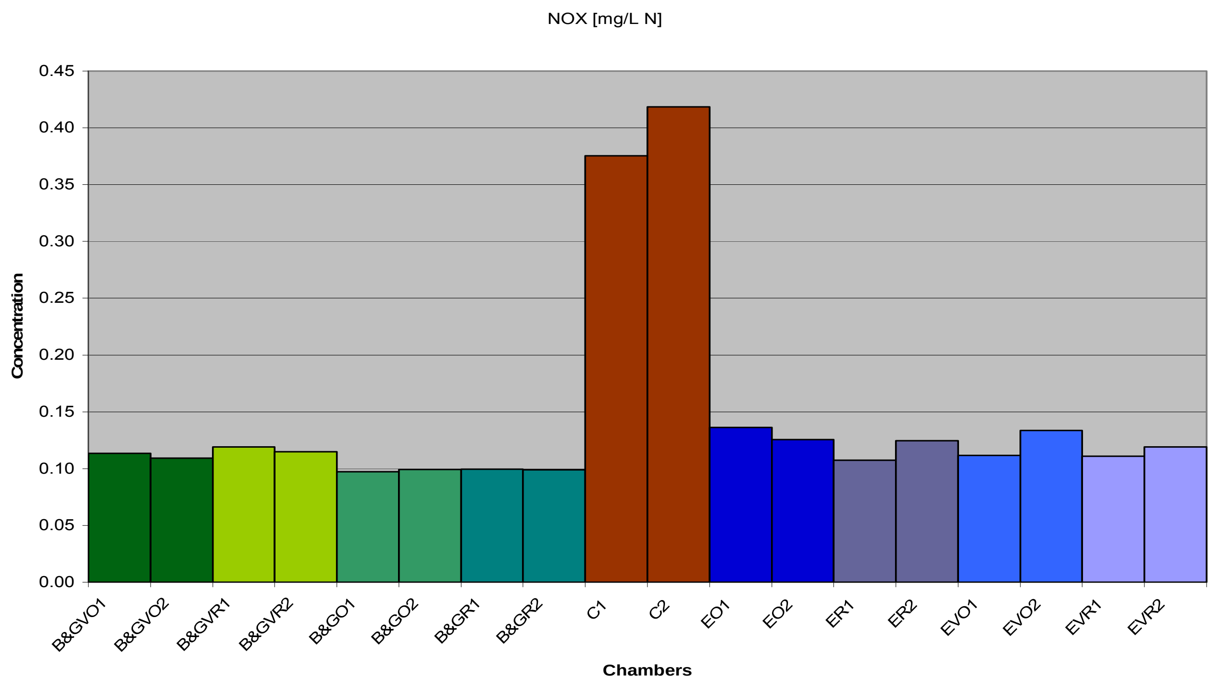


Figure 3: Nitrate Concentration Comparison

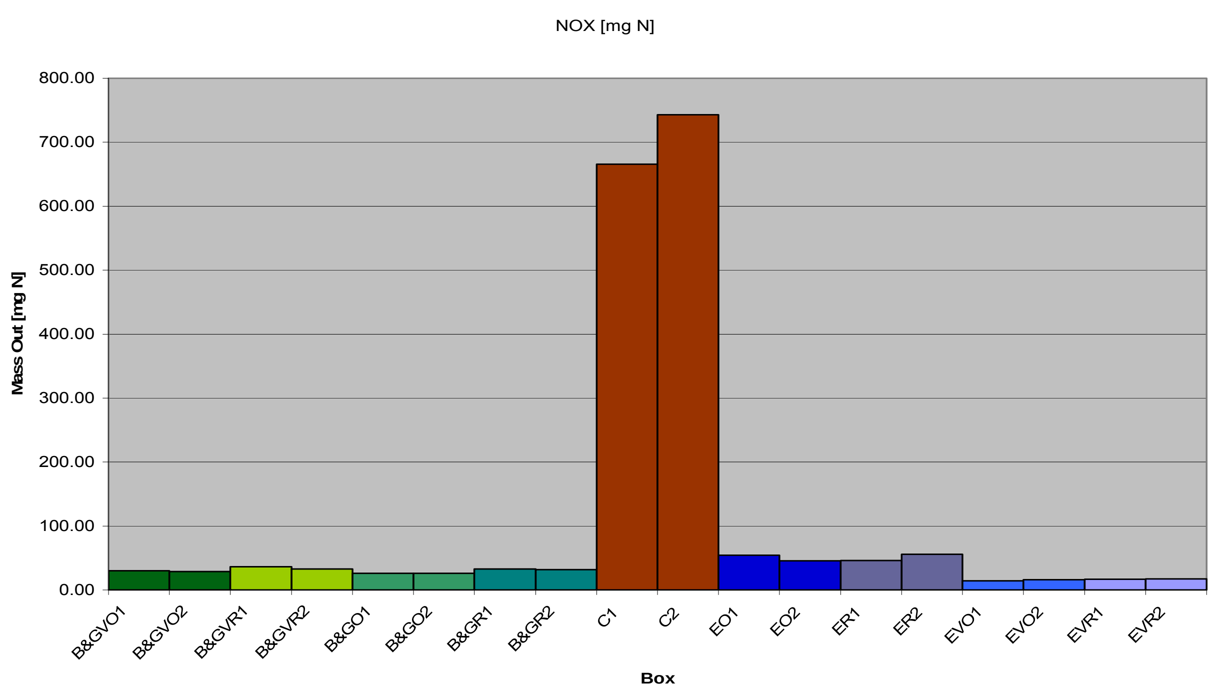


Figure 4: Nitrate Mass Comparison

Table 6: Nitrate Concentration Hypothesis Tests

NOx Hypothesis Tests

H_{O1}	Media and vegetation are held constant, NOx Concentration for Over irrigation = NOx Concentration for Regular irrigation
H_{a1}	Media and vegetation are held constant, NOx Concentration for Over irrigation < NOx Concentration for Regular irrigation
H_{O2}	Media and irrigation rates are held constant, NOx Concentration for Vegetated boxes = NOx Concentration for Non Vegetated boxes
H_{a2}	Media and irrigation rates are held constant, NOx Concentration for Vegetated boxes < NOx Concentration for Non Vegetated boxes
H_{O3}	Irrigation rates and vegetation are held constant, NOx Concentration for Black & Gold = NOx Concentration for Expanded Clay
H_{a3}	Irrigation rates and vegetation are held constant, NOx Concentration for Black & Gold < NOx Concentration for Expanded Clay
H_{O4}	NOx for a vegetated box = NOx for a control box
H_{a4}	NOx for a vegetated box < NOx for a control box
H_{O5}	NOx for a non-vegetated box = NOx for a control box
H_{a5}	NOx for a non-vegetated box < NOx for a control box

α =	0.05	z_α =	1.645	$-z_\alpha$ =	-1.645

Note: R = Reject H_O & A = Accept H_O

	TVO1	TVO2	TVR1	TVR2	TO1	TO2	C1	C2	TR1	TR2	EO1	EO2	ER1	ER2	EVO1	EVO2	EVR1	EVR2
Average	0.11	0.11	0.12	0.11	0.10	0.10	0.32	0.35	0.10	0.10	0.14	0.13	0.11	0.12	0.11	0.13	0.11	0.12
s	0.06	0.05	0.05	0.05	0.04	0.04	0.24	0.29	0.04	0.03	0.10	0.09	0.04	0.08	0.05	0.09	0.03	0.03
Var	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.09	0.00	0.00	0.01	0.01	0.00	0.01	0.00	0.01	0.00	0.00
n	37	37	35	36	34	36	28	28	37	36	37	38	33	35	42	42	36	35
z_1	-0.414	-0.473			-0.288	0.035					1.580	0.049			-0.111	0.772		
H_{O1}	**A**	**A**			**A**	**A**					**A**	**A**			**A**	**A**		
z_2	1.437	0.951	1.807	1.586											-1.351	0.239	0.558	-0.386
H_{O2}	**A**	**A**	**R**	**A**											**A**	**A**	**A**	**A**
z_3	0.204	-1.317	0.674	-0.441	-2.172	-1.683			-0.799	-1.796								
H_{O3}	**A**	**A**	**A**	**A**	**R**	**R**			**A**	**R**								
z_4	-4.362	-4.294	-4.266	-4.194											-4.457	-3.852	-4.463	-4.149
H_{O4}	**R**	**R**	**R**	**R**											**R**	**R**	**R**	**R**
z_5					-4.785	-4.497			-4.725	-4.509	-3.715	-3.921	-4.551	-3.957				
H_{O5}					**R**	**R**			**R**	**R**	**R**	**R**	**R**	**R**				

Irrigation Rates per Week:

The affect of irrigation amount on green roof cistern water quality was examined to determine the benefit, if any. From the hypothesis testing statistics in Appendix E it can be seen that irrigation amount had no significant affect, $\alpha = 0.05$, on any water quality parameter. The results of the hypothesis tests show that a majority, fifty three out of eighty, of the null hypotheses were accepted and when the null hypothesis was not accepted the rejection rate was not consistent.

Vegetated vs. Non-vegetated:

The affect of vegetation on the cistern water quality was also studied. Based on the hypothesis test statistics presented in Appendix E it can be seen that for pH, alkalinity, total solids, total dissolved solids, turbidity, total nitrogen, TKN, total phosphorus, and ortho-phosphorus, vegetation makes a significant difference, $\alpha = 0.05$. Specifically, vegetation neutralized the pH and increased the alkalinity concentration of the green roof filtrate. Vegetation was also shown to increase the concentration of total solids and total dissolved solids although it should be noted that the increase was more significant in the Black & Gold™ growing media than the expanded clay growing media. The results of the turbidity analysis showed that when vegetation was used with the expanded clay growth media the turbidity was reduced while when used with the Black & Gold™ growth media the turbidity was increased. This is probably due to the fact that the plants did not grow as well in the Black & Gold™ growth media. The total nitrogen and TKN results were very similar showing that the addition of vegetation to the expanded clay growing media reduced the concentration of both while the vegetated Black & Gold™ chambers showed no significant difference. This is again probably due to the poor plant growth observed in the Black & Gold™ chambers. Vegetation was also shown to significantly reduce the concentration of both total and ortho-phosphorus. There is no significant difference, $\alpha = 0.05$, in the other water quality parameters due to acceptance of the null hypothesis, or inconsistent rejection of the null hypothesis.

Media Types:

There were two different growing media examined for water quality, Black & Gold™ and an expanded clay mix. Both media had the same components with the exception of the Black & Gold™ which had an addition of recycled ground up automobile tires. Hypothesis tests which examine the affect of growing media selection on different water quality parameters are presented in Appendix E. From these hypothesis test statistics it can be seen that growing media selection significantly affects, $\alpha = 0.05$, the following water quality parameters: pH, alkalinity, total solids, total dissolved solids, total phosphorus and ortho-phosphorus. Specifically, the Black & GoldTM growing media was shown to neutralize the pH, increase the alkalinity, total solids, and total dissolved solids concentration, and reduce the total phosphorus and ortho-phosphorus concentrations. There was no significant effect, $\alpha = 0.05$, on the other water quality parameters, again due to acceptance of the null hypothesis or inconsistent rejection of the null hypothesis.

Green Roof Stormwater Treatment System vs. Control Roof:

An important comparison is the green roof stormwater treatment system versus the control roof. Tables which show the relative percent difference between each experimental chamber and the control chamber are presented in Appendix D. The results show that for each water quality parameter, there exists a significant difference between the control chambers and each experimental chamber, vegetated or not. Further analysis is presented in Appendix E in the form of hypothesis testing. The results for the comparisons of the vegetated chambers and control chambers show that most of the water quality parameters are significantly different, $\alpha = 0.05$. The parameters that show a significant difference are pH, alkalinity, total solids, total dissolved solids, nitrate+nitrite, ammonia, and total phosphorus. This analysis showed that the green roof chambers were effective at increasing the pH to neutral levels as well as increasing the buffering capacity (alkalinity) of the green roof filtrate. The hypothesis tests showed that the total solids, total dissolved solids, and total phosphorus concentrations were increased when compared to a conventional roof. The green roof was shown to significantly reduce the concentration of nitrate+nitrite and ammonia when compared to a conventional roof. The following parameters showed no significant difference between the Black & Gold™ media and the control roof while showing a significant difference between the expanded clay media and the control roof. These parameters are turbidity and ortho-phosphorus. The turbidity showed a reduction while the ortho-phosphorus showed an increase in concentration. The other water quality parameters showed no significant difference from the control chamber concentration.

The hypothesis testing for non-vegetated chambers verses control chambers shows similar results as above. Specifically, pH, alkalinity, total solids, total dissolved solids, total nitrogen, TKN, ammonia, nitrate+nitrite, total phosphorus, and ortho-phosphorus all are significantly different, $\alpha = 0.05$, for a chamber with growing media and no plants when compared with a control chamber. As shown with the vegetated chambers, the media only chambers are effective at neutralizing the pH and increasing the buffering capacity of the green roof filtrate when compared to the control roof. The non-vegetated chambers also significantly increased the total solids, total dissolved solids, total nitrogen, TKN, total phosphorus and ortho-phosphorus concentration when compared to the control roof. As with the vegetated chambers the non-vegetated chambers reduced the ammonia and nitrate concentration compared to the control roof. The other water quality parameters show no significant difference from the control chambers.

<u>CSTORM Model Development</u>

Mass Balance

Green roof stormwater treatment systems are an acceptable way to treat and store stormwater. Modern green roofs have been used for three decades or more in Europe. Despite this longevity there have been little or no equations developed for the design of cisterns intended to store green roof runoff for irrigation. There have been models developed to predict the runoff from a green roof using historical precipitation and evapotranspiration data. Hoffman (2006) and Miller (2000 & 2006) have both developed models for the purpose of green roof stormwater retention, but did not include the addition of a cistern to store and reuse stormwater for green roof irrigation. Both Hoffman (2006) and Miller (2000 & 2006) have identified the important factors that determine green roof efficiency without a cistern. These factors are soil moisture, soil water holding capacity, plant water holding capacity, precipitation, evapotranspiration, temperature, and humidity to name a few. While Miller (2000 & 2006) discusses the different approaches used to develop a green roof model he uses a modified groundwater modeling program for the development of the model. The models proposed by Hoffman (2006) and Miller (2000 & 2006) are a representation of the actual findings from several working green roofs. However, the mass balance across the green roof boundary may not be preserved. Further, by using groundwater modeling variables that are not easy to measure or describe with equations probably introduces more error into the model rather than the desired result of a fine tuned model. The development of a logical model resulted using a mass balance approach to preserve a hydrologic balance.

Similar to the design of a reuse pond, a mass balance approach can be used for the design of a green roof stormwater treatment system. To design a green roof stormwater treatment system, the inputs and outputs for a mass balance must be preserved (see Figure 3). The main system inputs and outputs are precipitation, evapotranspiration, makeup water, and overflow.

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. The overflow rate will be a function of the maximum cistern storage volume and the rate at which makeup water is added will be a function of available storage water and irrigation rate. The irrigation rate is not to exceed 1 inch per week (St. John's Water Management District) in the summer months and half that for the winter months. It should be noted that irrigation will not occur if, in the twenty four hours previous to the irrigation event, the precipitation volume is greater than or equal to the irrigation volume. From this it can be seen that filtrate from the green roof is the only variable that is not known.

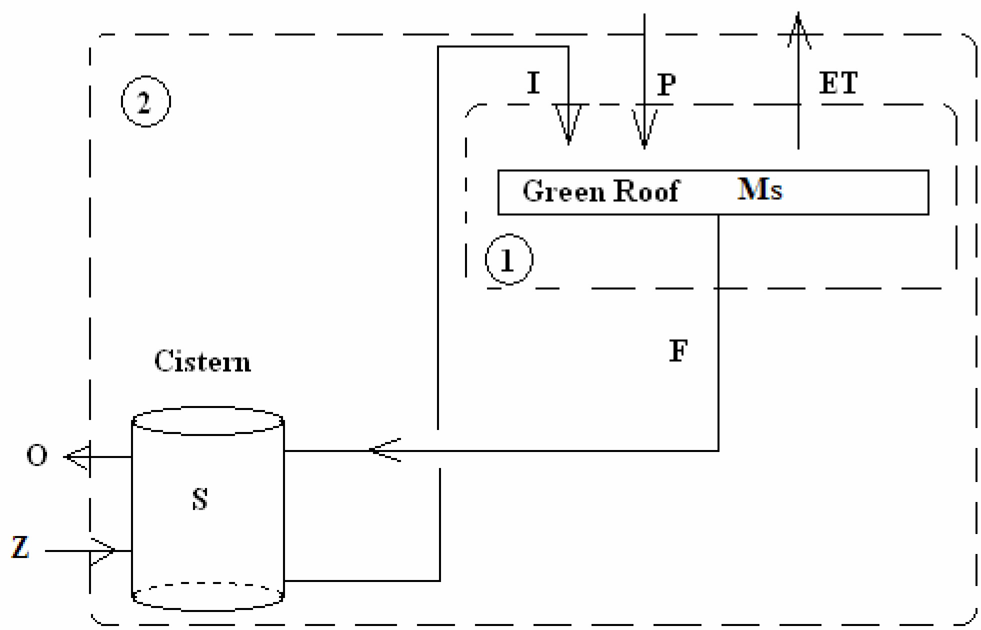


Figure 3: Green Roof Stormwater Treatment System Boundaries. Source: Hardin 2006

The variables of Figure 4 are as follows:
M_S = Media storage [in/ft^2 of green roof]
P' = Precipitation [in/ ft^2 of green roof*time]
I' = Irrigation [in/ ft^2 of green roof*time]
ET' = Evapotranspiration [in/ ft^2 of green roof*time]
F' = Filtrate [in/ ft^2 of green roof*time]
S = Cistern storage [in/ ft^2 of green roof]
Z' = Makeup Water [in/ ft^2 of green roof*time]
O' = Overflow [in/ ft^2 of green roof*time]

Isolating the green roof stormwater treatment system into mass balances as shown in Figure 3 is necessary in order to determine the filtrate, or the filtrate coefficient. Using the system boundaries for system one in Figure 3, an expression for the filtrate factor as it varies with soil conditions, precipitation, evapotranspiration, and irrigation amount can be derived.

$$\frac{dMs}{dt} = P + I - ET - F$$

Making the assumption of a finite difference the following simplification can be made:

$$\frac{\Delta Ms}{\Delta t} = P + I - ET - F \qquad \textbf{(1)}$$

This equation is in terms of volume per unit time and needs to be multiplied through by the time step to get volume. This equation then simplifies as follows:

$$\Delta Ms = P' + I' - ET' - F' \qquad \textbf{(2)}$$

where the prime nomenclature is indicative of volume. Solving for the filtrate gives:

$$F' = P' + I' - ET' - \Delta Ms \qquad \textbf{(3)}$$

But:

$$F' = f * (P' + I')$$

Where f = Filtrate coefficient, the fractional volume of precipitation and irrigation which becomes filtrate.

Therefore,

$$f = \frac{P' + I' - ET' - \Delta Ms}{P' + I'} \qquad \textbf{(4)}$$

It can be seen from equation 4 that the filtrate will vary depending on the soil conditions and therefore with time. Since green roofs need to be irrigated more frequently when first installed to ensure the health of the plants (FLL, 2002) the assumption that the initial soil storage is equal to the soil saturation is made. All other variables needed to solve this equation are known with the exception of the final soil storage and the filtrate coefficient.

To solve for the filtrate coefficient several more assumptions must be made. First, precipitation and irrigation contribute to the soil storage up until the point of saturation. For this equation, assume that media saturation is at a volume of 20% of the growing media depth. Also, assume that any precipitation and irrigation past the point of saturation will contribute to runoff, or the filtrate equals input for any additional water past the saturation point of the soil. Therefore, for saturated conditions the equation that describes the final soil storage term, M_{S2}, is as follows:

$$M_{S2} = M_{Ssat} - ET' \quad \textbf{(5)}$$

That is, whenever runoff occurs, equation 5 is used to determine the soil storage at the end of the time step. If runoff does not occur, or the soil does not get saturated, then the soil storage at the end of the time step can be found from the following equation:

$$M_{S2} = M_{S1} + P' + I' - ET' \quad \textbf{(6)}$$

Using these assumptions every variable in equation 4 is known except for the filtrate coefficient. From this information “f” can be solved for any location provided average monthly ET data and daily precipitation data are available.

Now that the filtrate has been quantified an equation needs to be developed that describes how the cistern behaves. An equation for the change in soil storage between times 1 and 2 needs to be developed using the first system boundaries from Figure 3. This gives the following equation:

$$M_{S1} - M_{S2} = ET' + f(P' + I') - P' - I' \quad \textbf{(7)}$$

Next, using the second system boundaries in Figure 3, an equation is developed to describe the overall system. The equation for this system is as follows:

$$\frac{d(S + M_S)}{dt} = P + Z - ET - O$$

Assuming a finite time step and converting to volume terms gives:

$$\frac{\Delta(S + M_S)}{\Delta t} = P + Z - ET - O$$

This equation further simplifies to:

$$\Delta(S + M_S) = P' + Z' - ET' - O'$$

Rearranging gives:

$$S_1 + (M_{S1} - M_{S2}) + Z' + P' - O' - ET' = S_2 \qquad \textbf{(8)}$$

Finally, an equation needs to be developed for the cistern. This can be done by combining equations 7 and 8 to give:

$$S_1 + f(P' + I') - I' + Z' - O' = S_2 \qquad \textbf{(9)}$$

This equation describes how the water level in the cistern fluctuates over time.

Using the equations previously developed, equations 4, 5, 6, and 9, a green roof model is formulated. The model developed is called the continuous stormwater treatment outflow reduction model, or CSTORM. The equation developed to solve for the filtrate coefficient, equation 4, needs to be solved simultaneously with equation 9 using the entire record of daily precipitation data and monthly average evapotranspiration data for a one day time step. The purpose of using the entire precipitation record is to reduce the introduction of error into the model due to the variability of yearly precipitation for any given area. The equations that describe the soil storage potential, equations 5 and 6, are to be used as stipulations that depend on the current conditions of the system.

Operating assumptions for the cistern need to be made, the first is that the initial storage volume of the cistern is equal to the irrigation volume. This is done so as to provide sufficient water to perform the initial irrigation. If the cistern storage is less than the irrigation volume, and irrigation is to occur, then makeup water is added. The amount of makeup water added is equal to the difference of the irrigation volume and the current cistern storage volume. In addition, if the volume of filtrate plus the initial volume of the cistern is greater than the maximum storage capacity of the cistern, then overflow occurs. The volume of overflow is equal to the difference between the beginning period cistern volume plus the filtrate in that period and the maximum cistern storage capacity.

With the CSTORM model, a green roof and cistern system can be designed to achieve a desired stormwater retention efficiency. The efficiency expressed as a percentage is defined as the volume of stormwater retained divided by the volume of precipitation.

$$Efficiency = [1 - (\frac{O'}{P'})] * 100 \qquad \textbf{(10)}$$

Using the above equations the CSTORM model was developed. This model can produce design curves which can be used for quantification of stormwater efficiency.

CSTORM Model Output

The CSTORM model is a valuable design tool for the consulting and design industry. This model has the ability to design a green roof stormwater treatment system for a desired efficiency, incorporate additional irrigation areas, and include additional impervious area runoff.

The model predicts the expected yearly retention and gives an estimate to the yearly makeup water requirements.

Design curves developed using the above equations can be produced for effective cistern sizing given a desired retention (see Appendix A). Presented in Table 3 is a summary of efficiencies for different cistern storage volumes and locations in the state of Florida. From Table 3 it can be determined that the main factors that affect the efficiency of the system are precipitation, evapotranspiration, and cistern storage volume. Lower precipitation and higher evapotranspiration produces a higher efficiency green roof stormwater treatment system, while the converse yields a lower efficiency for the system. Also from Table 3, it is noted that for an irrigated green roof the roof runoff without a cistern can be reduced by about 33% - 51%. If the no cistern option is used, there are more pollutants (nutrients) from the green roof than from the control roof and an additional stormwater management technique will need to be used to help meet TMDL standards. Another way to increase the efficiency of the system is to irrigate additional areas, such as ground level landscaping.

The results of the CSTORM model as shown below in Table 3 and in Appendix A show that an expected efficiency of 87% can be achieved for the Orlando area when storing five inches over the green roof area. Hardin, 2006 showed from experimental data that the actual efficiency is about 83%. These results show that the CSTORM model can be used to accurately predict, plus or minus 4%, the green roof system performance.

Table 3: Summary of yearly hydrologic efficiencies for different cistern storage volumes and locations in Florida

Location	Cistern Storage Volume [in/sf of GR]					
	0	1	2	3	4	5
Belle Glade	50	72	80	84	87	89
Boca Raton	42	61	69	73	77	79
Brooksville	45	66	74	78	81	83
Daytona Beach	42	66	74	79	82	85
Ft. Myers	44	65	72	76	79	81
Gainesville	42	67	76	80	83	86
Homestead	44	64	71	75	77	79
Jacksonville	40	65	73	77	80	82
Key West	51	72	80	85	88	9
Lakeland	42	67	75	8	83	85
Miami	42	63	69	73	76	78
Niceville	33	57	65	69	71	73
Orlando	43	69	78	82	85	87
Panama City	33	57	66	70	73	76
Tallahassee	35	58	66	70	72	74
Tampa	44	69	77	82	84	86
Venice	47	70	78	83	86	88
West Palm	42	62	69	73	76	78

Source: Hardin 2006

CONCLUSIONS

Stormwater management continues to be a growing problem in urban areas because of limited space and resources. Green roof stormwater treatment systems are a solution to this problem that offers several other benefits. As presented within this report an irrigated green roof with a cistern is an effective way to reduce the volume of stormwater runoff from rooftops. From the results of the CSTORM model and the water budget experiment it can be seen that green roof stormwater treatment systems can effectively reduce the volume of runoff by as much as 87% for the Orlando, Florida region. This efficiency is based on a cistern that stores a volume of five inches over the green roof area. It should be noted that an irrigated green roof without a cistern will achieve a runoff reduction of about 43% for the same region. Examination of Table 3 and Appendix A shows that the expected efficiency is highly dependent on the geographic region. This is due to local climate conditions.

The results from the water budget experiment show that evapotranspiration rates and filtrate factors will vary with design of the green roof. From the hypothesis test results section it can be seen that all the design parameters studied had a significant effect on evapotranspiration rates and filtrate factors. Increasing the irrigation rate increased evapotranspiration rates, although not at a statistically significant level and significantly increased the filtrate factor. Use of vegetation and Black & Gold™ growing media will significantly increase the evapotranspiration rates and decrease the filtrate factor. The increase in evapotranspiration rates is beneficial as it helps maintain the water budget and decrease runoff. A decrease in filtrate factor is also desired as it signifies less runoff from the roof to the cistern and thus increasing the efficiency of the system. Also, hydrograph analysis shows that the volume and peak rate of discharge is reduced by approximately 50% when using the green roof designs of this research and a rainfall of 6 inches per hour for a ten minute duration.

Based on the results of the experiments, the optimal design for a green roof stormwater treatment system is to irrigate 1 inch per week, use vegetation, and use the Black & Gold™ growing media. The plants did not, however, grow as well in the Black & Gold™ growing media. It is for this reason that the authors recommend using the expanded clay growing media to ensure vibrant plant growth, and to use the pollution control media beneath the growth media for water quality benefits. It should be noted at this time that by reducing the irrigation rate during the winter months a decrease in filtrate factor will result. This conclusion is based on the fact 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, as shown in Tables 2 and 3.

The results of the water quality experiment showed that green roof stormwater treatment systems are effective at reducing the mass and sometimes the concentration of pollutants from stormwater runoff. This is when compared to a conventional roof. The water quality parameters studied are pH, alkalinity, total suspended solids, total dissolved solids, total solids, turbidity, nitrate + nitrite, ammonia, total nitrogen, TKN, ortho-phosphorus, and total phosphorus.

The use of vegetation and growing media selection has a significant affect on the pH and alkalinity of the cistern water. From the experimental results, it can be seen that vegetation and the Black & Gold™ growing media will neutralize the pH and increase the alkalinity of the runoff. The runoff from the control chambers had low pH and alkalinity potentially decreasing the buffering capacity of the receiving body. The results of this experiment support the use of green roof stormwater treatment systems as a means to resolve this problem.

Green roofs, due to the solids associated with the growing media, tend to increase the amount of solids released in stormwater runoff. This experiment supported this assertion with the exception of suspended solids, which was equivalent to the control. Examination of the graphs presented in Appendix D show that while the concentration is usually increased for the green roof stormwater treatment system, the mass is equivalent except for suspended solids which is lower.

The results of the turbidity analysis show that vegetation and media selection make a significant difference in the water quality of the cistern water. The vegetated chambers with the expanded clay growing media had significantly lower turbidity than the Black & Gold™ growing media chambers. The difference between the control chambers and the vegetated chambers also showed a reduction for the vegetated expanded clay growing media and an increase for the vegetated Black & Gold™ growing media. This is probably due to the fact that plant growth was much stronger in the expanded clay growing media.

The total nitrogen and TKN results show that when compared to the control chambers there is no significant difference in concentration for green roof stormwater treatment systems. The use of chambers without vegetation showed an increased concentration in both total nitrogen and TKN when compared to the control chambers. With examination of the mass comparison graphs in Appendix D it can be seen that the green roof stormwater treatment system does reduce the mass of both total nitrogen and TKN.

The results of the ammonia and nitrate+nitrite analysis show that neither vegetation nor growing media selection has any significant effect on concentration. When compared to the control chambers, however, the concentrations of all the chambers with and without vegetation were significantly lower. This is presumed to be due to the cistern creating an anaerobic environment facilitating denitrification. From the mass comparison graphs presented in Appendix D, it can be seen that there is a drastic reduction in mass when comparing a green roof stormwater treatment system to a control chamber. This shows that green roof stormwater treatment systems are an effective technique to help achieve mass reductions.

From examination of the ortho-phosphorus and the total phosphorus results, it can be seen that vegetation and growing media selection have a significant affect on the resulting cistern concentration. By adding vegetation, both the ortho-phosphorus and total phosphorus concentration can be significantly reduced. Use of the Black & Gold™ growing media will also produce a concentration reduction when compared to the expanded clay growing media. All of the chambers however, had a significantly higher concentration for both parameters when compared to the control chambers. The only exception is the vegetated Black & Gold™ media chambers which showed no significant increase in concentration. The mass comparison graphs in Appendix D show that the mass released from the vegetated chambers and the Black & Gold™ growing media chambers are less than the mass released from the control chambers.

Green roof stormwater treatment systems as described within this work are an effective way to reduce the volume of runoff leaving a developed site. These systems are also efficient at reducing the mass of pollutants leaving a developed site. It should be noted that to achieve this pollutant reduction a cistern needs to be used to store filtrate from the roof for irrigation.

Based on visual plant appearance during the experiment, it was determined that the plants did not grow well in the Black & Gold™ growing media. The Black & Gold™ growing media did, however, show to be effective at removing both total and ortho-phosphorus. This suggests that a pollution control layer under the growing media will produce the benefits of pollutant removal while maintaining vibrant plant growth.

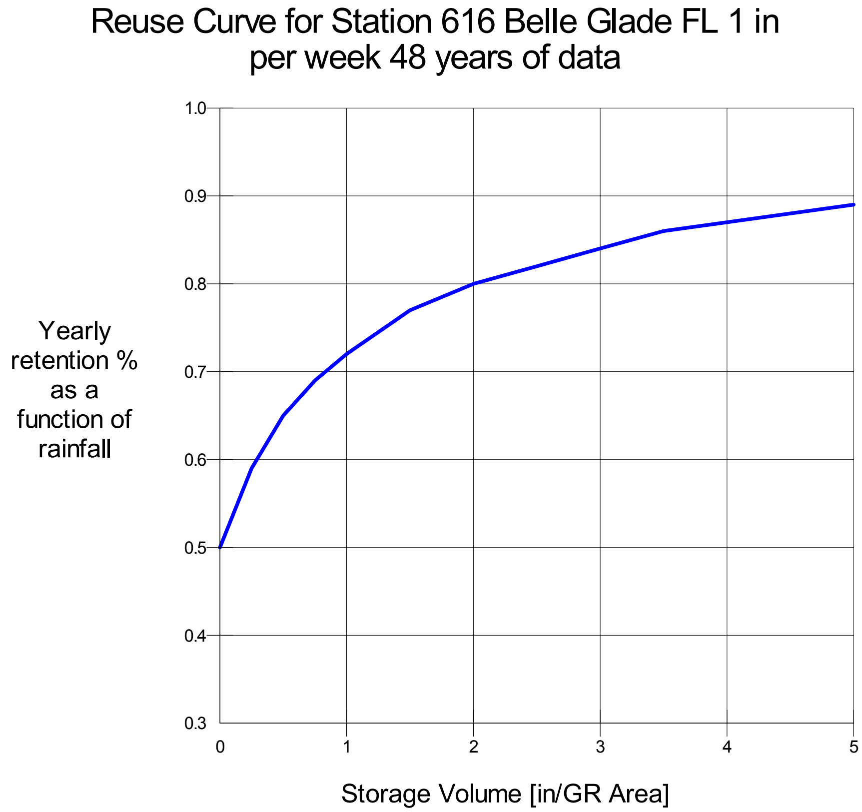
RECOMMENDATIONS FOR FUTURE WORK

This work examined the hydrologic and water quality improvement benefits of a specifically designed green roof stormwater treatment system and a model to predict performance. Throughout the course of this work the authors have noted the following areas needing further work. Research examining the effect of different media depths on stormwater retention efficiency and evapotranspiration rates needs to be done. These results should be checked against the CSTORM model to ensure the model is accurate for different depths. The media water storage capacity should also be examined to develop how it affects storage capacity.

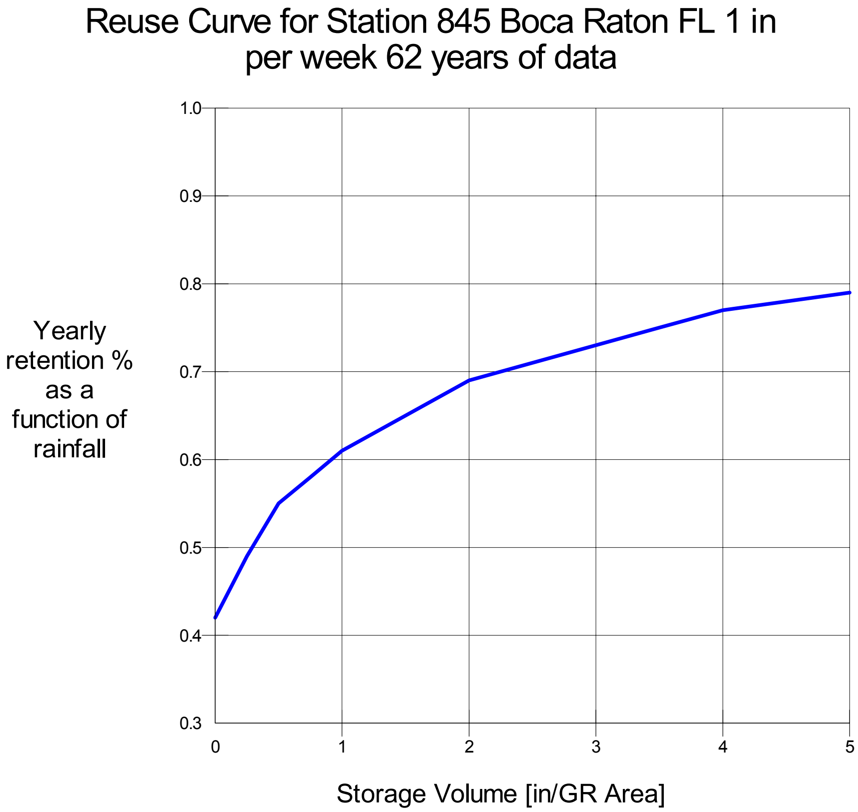
The addition of a pollution control layer should also be examined for additional pollution removal. The water quality results presented within this work as well as the results from the isotherm analysis suggest that phosphorus removal can be achieved with the addition of this layer. The isotherm results presented by Shah (2006) show that significant phosphorus removal is possible with a pollution control mix that consists of recycled tires, sand, and sawdust. This pollution control media mix should be further examined as well as other mixes.

The effect of cistern environment on water quality also needs to be examined. This aspect of the green roof stormwater treatment system needs to be better understood so that it can be maintained for optimal performance. Some specific parameters of interest are BOD, DO, pH and bacteria communities present. The bacterial communities present will give the most insight as to the optimal operating conditions.

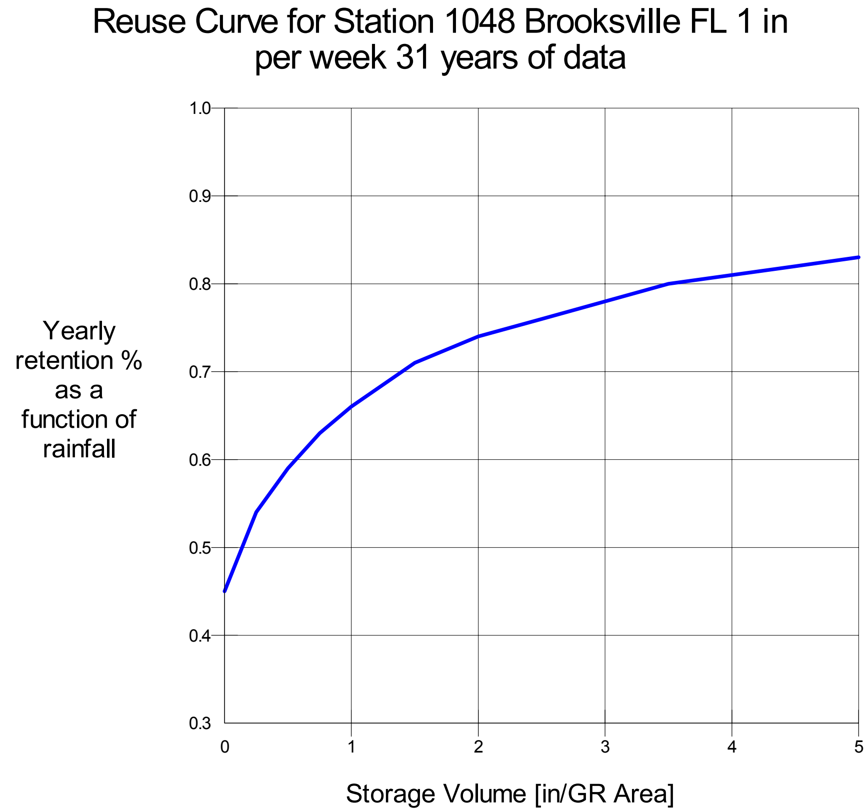
APPENDIX A: CSTORM GREEN ROOF DESIGN CURVES



Storage	Efficiency
0	0.5
0.25	0.59
0.5	0.65
0.75	0.69
1	0.72
1.5	0.77
2	0.8
2.5	0.82
3	0.84
3.5	0.86
4	0.87
4.5	0.88
5	0.89

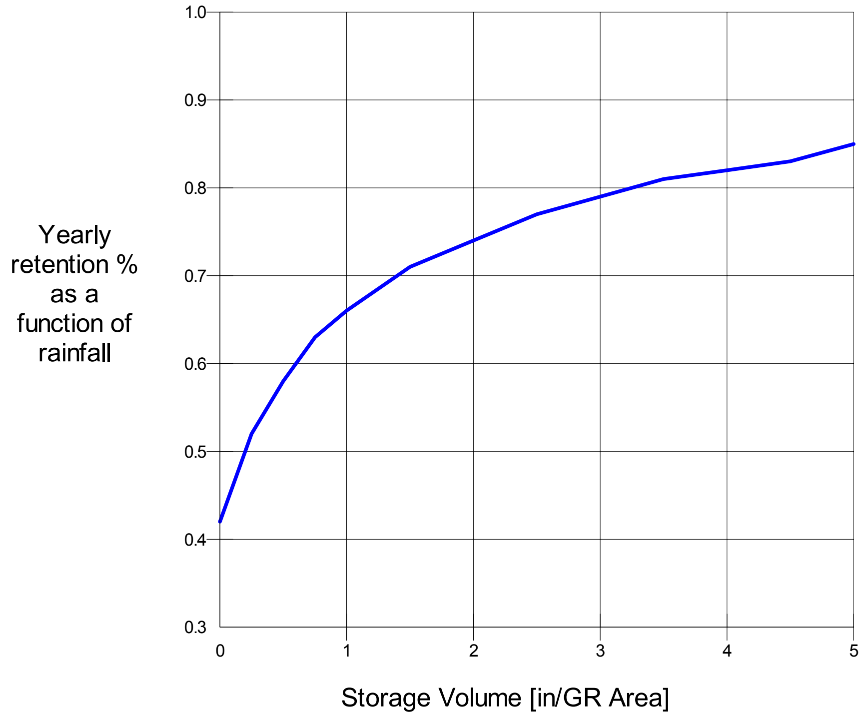


Storage	Efficiency
0	0.42
0.25	0.49
0.5	0.55
0.75	0.58
1	0.61
1.5	0.65
2	0.69
2.5	0.71
3	0.73
3.5	0.75
4	0.77
4.5	0.78
5	0.79



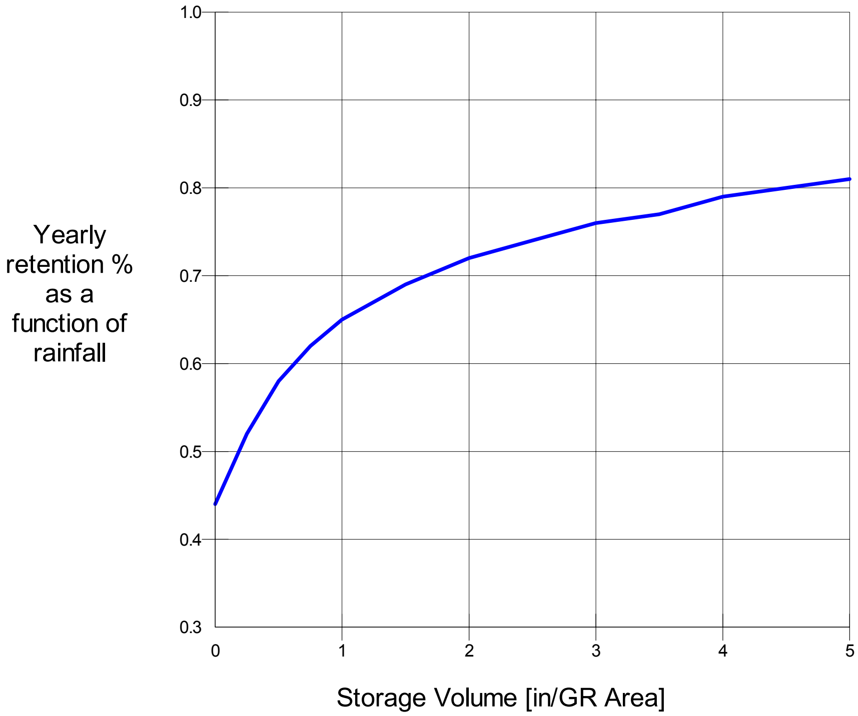
Storage	Efficiency
0	0.45
0.25	0.54
0.5	0.59
0.75	0.63
1	0.66
1.5	0.71
2	0.74
2.5	0.76
3	0.78
3.5	0.8
4	0.81
4.5	0.82
5	0.83

Reuse Curve for Station 2158 Daytona Beach FL 1
in irrigation per week 63 years

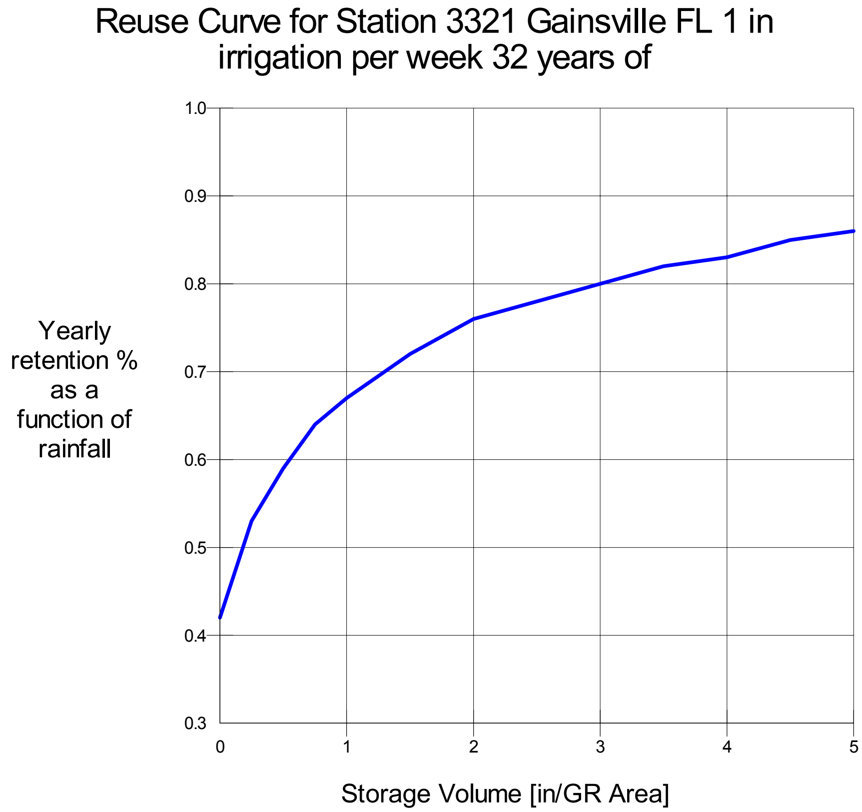


Storage	Efficiency
0	0.42
0.25	0.52
0.5	0.58
0.75	0.63
1	0.66
1.5	0.71
2	0.74
2.5	0.77
3	0.79
3.5	0.81
4	0.82
4.5	0.83
5	0.85

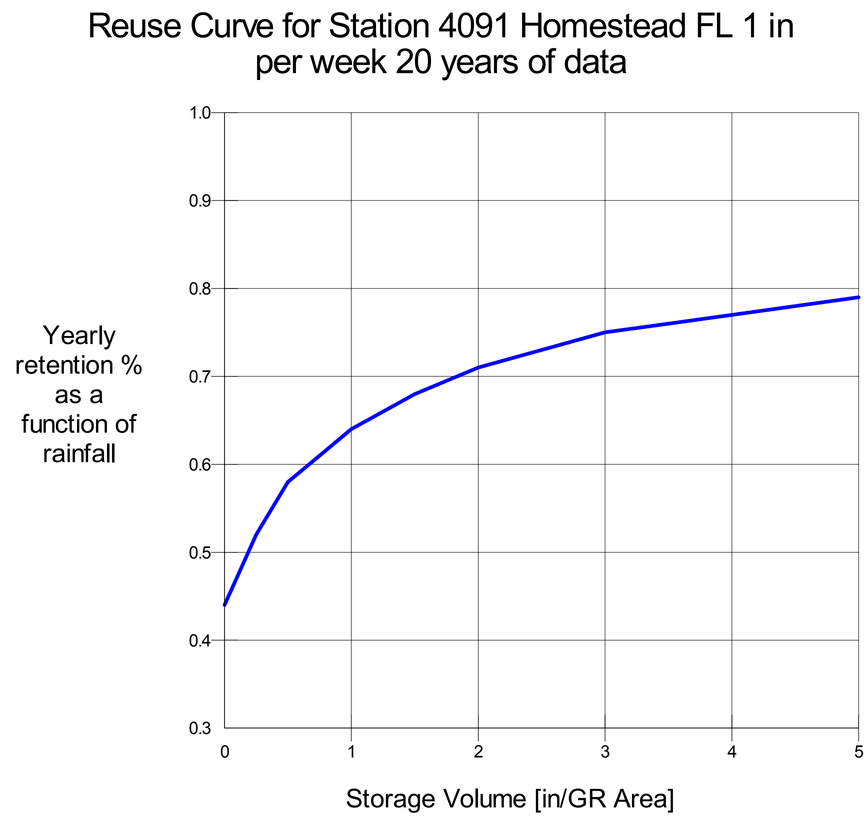
Reuse Curve for Station 3186 Ft. Myers FL 1 in per week 38 years of data



Storage	Efficiency
0	0.44
0.25	0.52
0.5	0.58
0.75	0.62
1	0.65
1.5	0.69
2	0.72
2.5	0.74
3	0.76
3.5	0.77
4	0.79
4.5	0.8
5	0.81

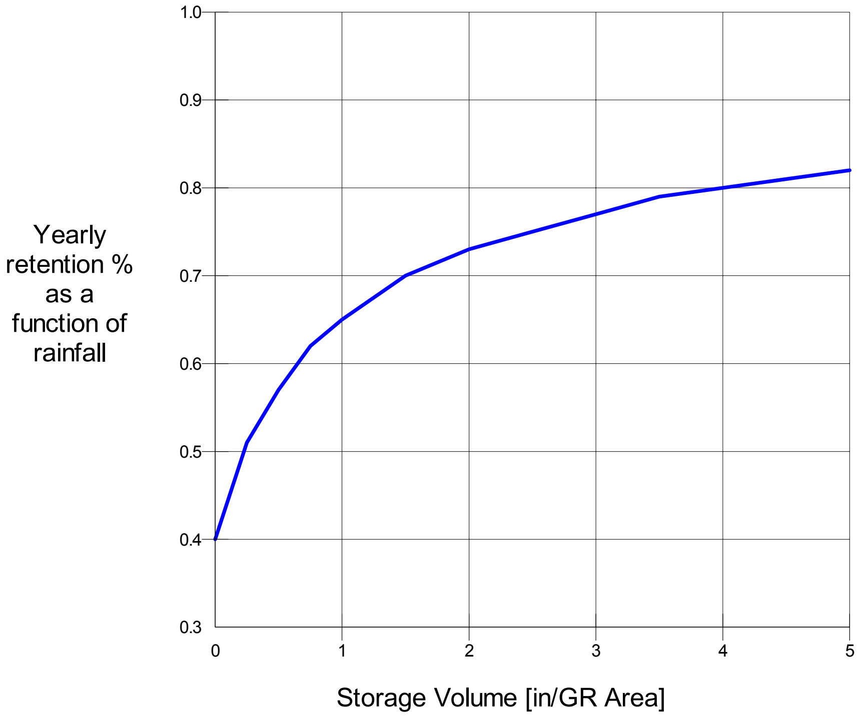


Storage	Efficiency
0.00	0.42
0.25	0.53
0.50	0.59
0.75	0.64
1.00	0.67
1.50	0.72
2.00	0.76
2.50	0.78
3.00	0.80
3.50	0.82
4.00	0.83
4.50	0.85
5.00	0.86

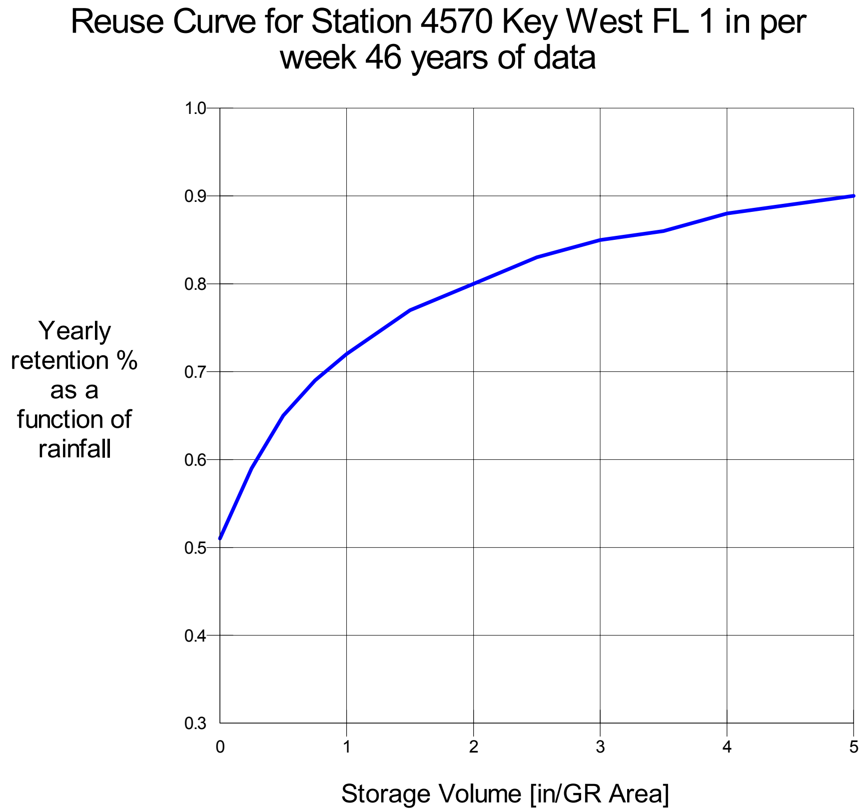


Storage	Efficiency
0	0.44
0.25	0.52
0.5	0.58
0.75	0.61
1	0.64
1.5	0.68
2	0.71
2.5	0.73
3	0.75
3.5	0.76
4	0.77
4.5	0.78
5	0.79

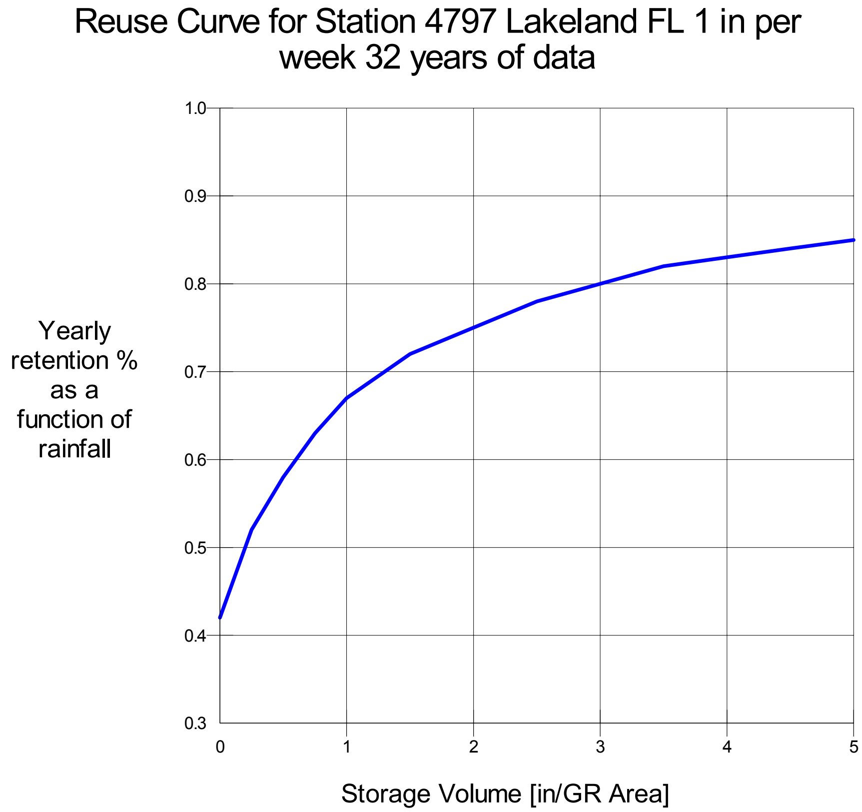
Reuse Curve for Station 4358 Jacksonville FL 1 in irrigation per week 57 years o



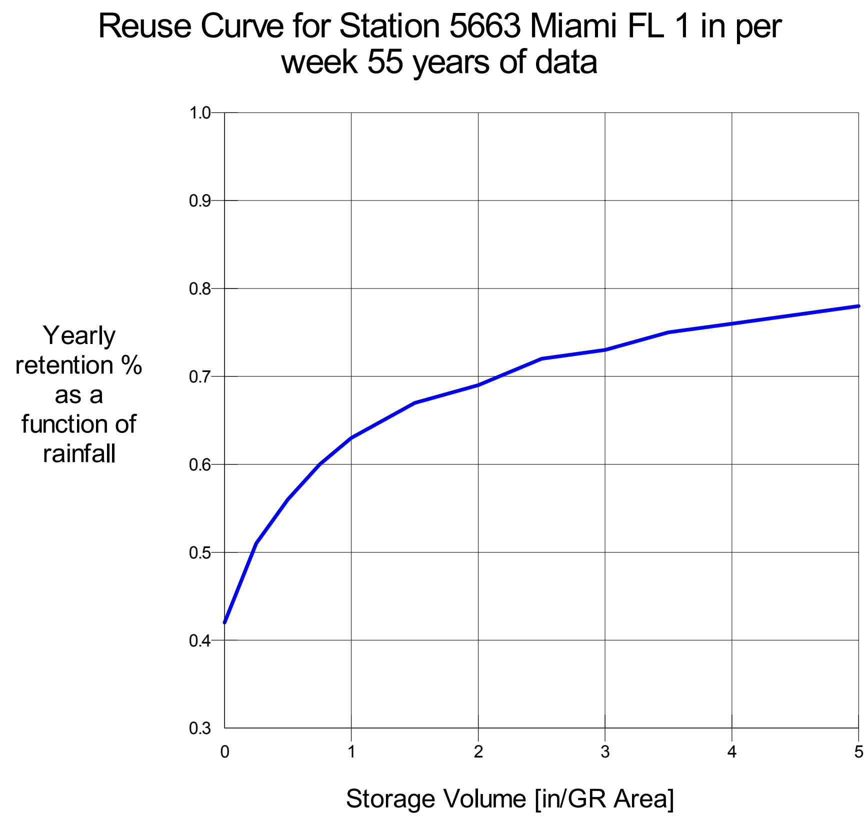
Storage	Efficiency
0	0.4
0.25	0.51
0.5	0.57
0.75	0.62
1	0.65
1.5	0.7
2	0.73
2.5	0.75
3	0.77
3.5	0.79
4	0.8
4.5	0.81
5	0.82



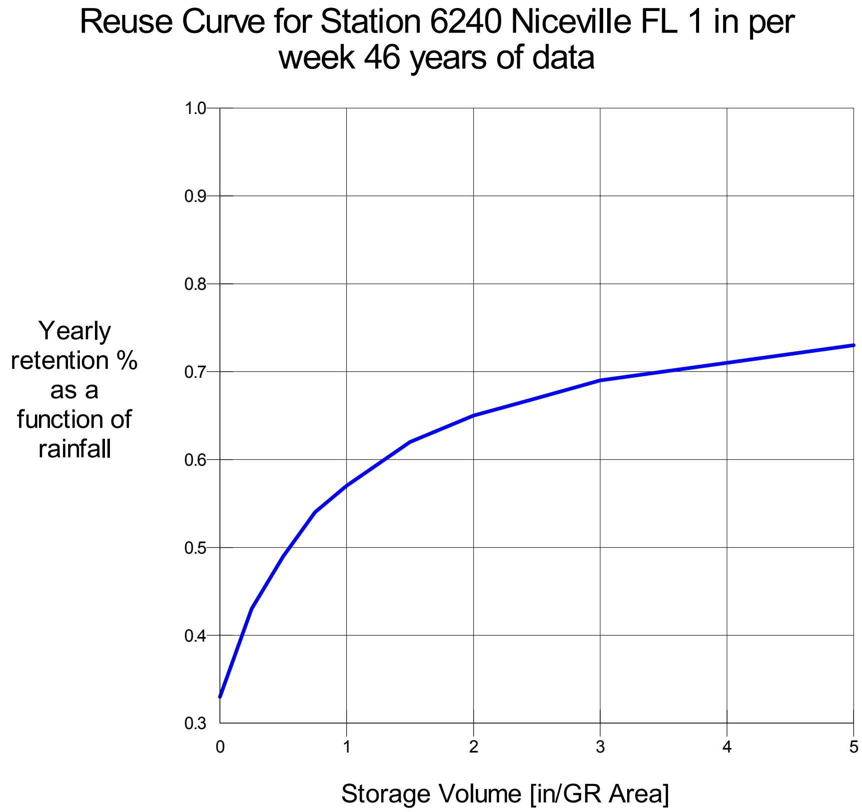
Storage	Efficiency
0	0.51
0.25	0.59
0.5	0.65
0.75	0.69
1	0.72
1.5	0.77
2	0.8
2.5	0.83
3	0.85
3.5	0.86
4	0.88
4.5	0.89
5	0.9



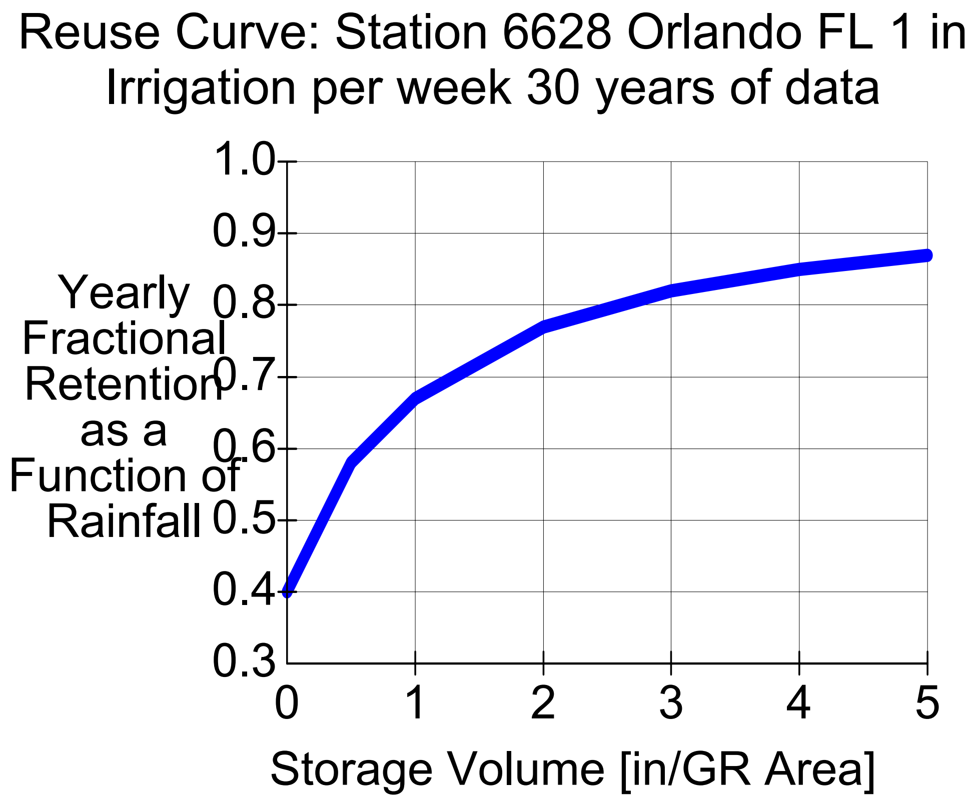
Storage	Efficiency
0	0.42
0.25	0.52
0.5	0.58
0.75	0.63
1	0.67
1.5	0.72
2	0.75
2.5	0.78
3	0.8
3.5	0.82
4	0.83
4.5	0.84
5	0.85



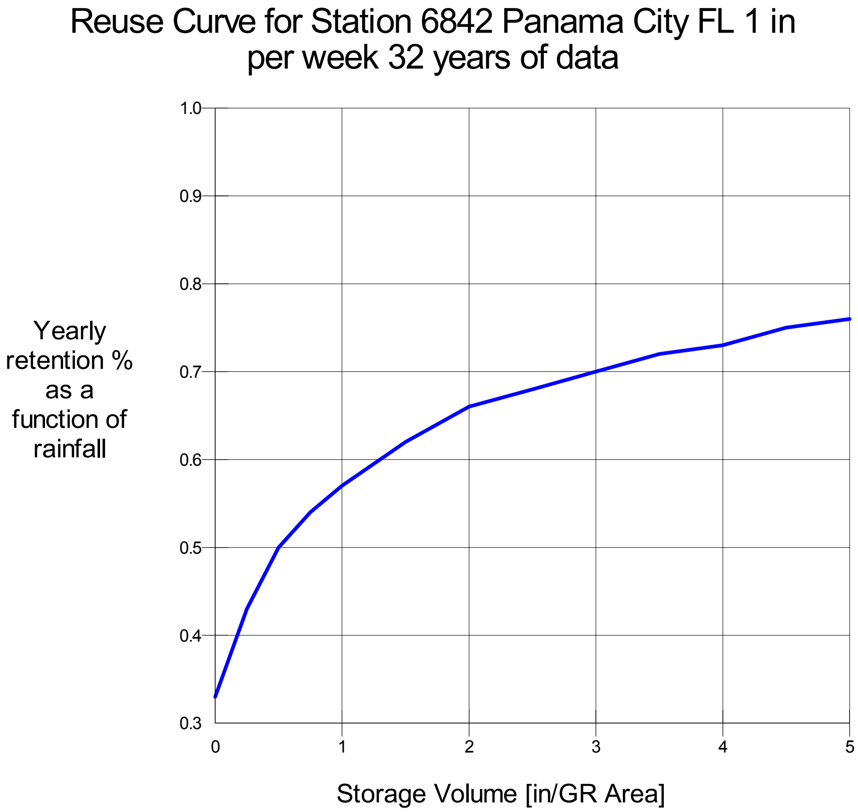
Storage	Efficiency
0	0.42
0.25	0.51
0.5	0.56
0.75	0.6
1	0.63
1.5	0.67
2	0.69
2.5	0.72
3	0.73
3.5	0.75
4	0.76
4.5	0.77
5	0.78



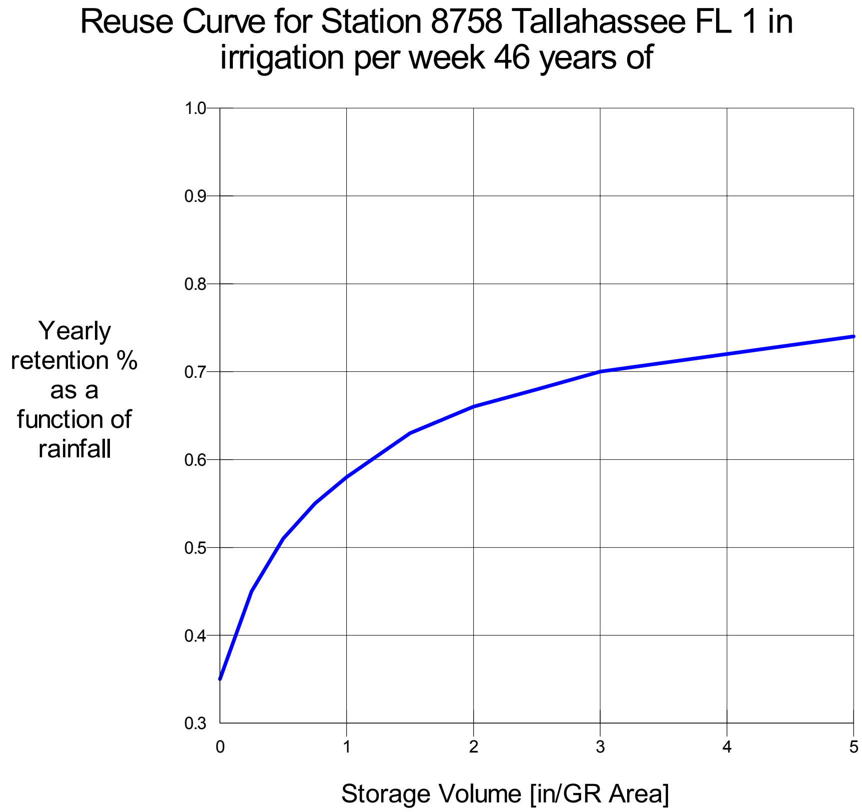
Storage	Efficiency
0	0.33
0.25	0.43
0.5	0.49
0.75	0.54
1	0.57
1.5	0.62
2	0.65
2.5	0.67
3	0.69
3.5	0.7
4	0.71
4.5	0.72
5	0.73



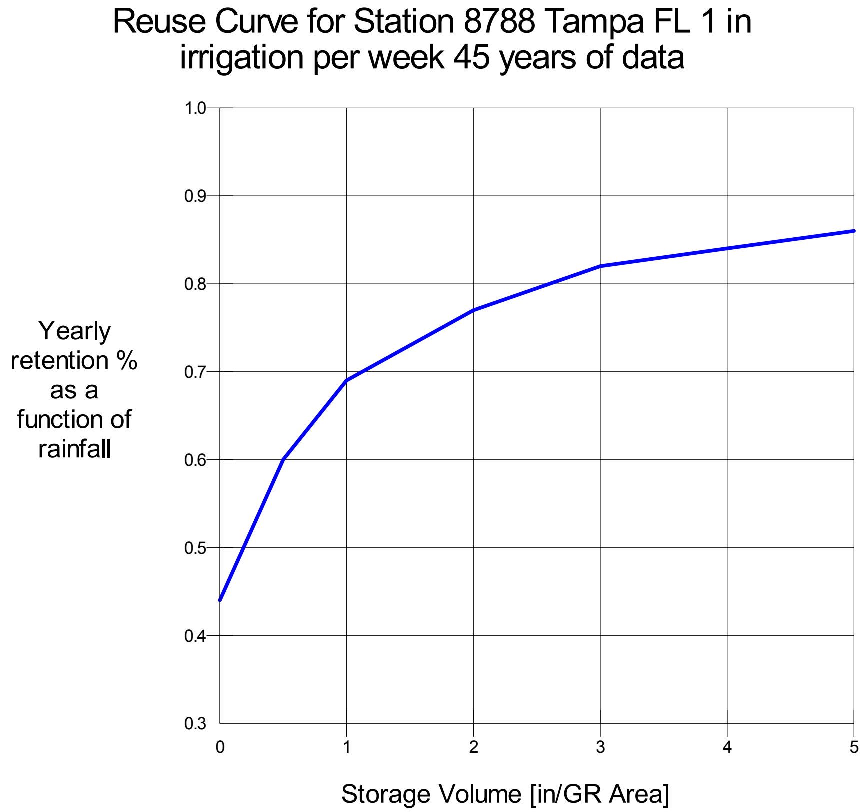
Storage	Efficiency
0	0.40
1	0.67
2	0.77
3	0.82
4	0.85
5	0.87



Storage	Efficiency
0	0.33
0.25	0.43
0.5	0.5
0.75	0.54
1	0.57
1.5	0.62
2	0.66
2.5	0.68
3	0.7
3.5	0.72
4	0.73
4.5	0.75
5	0.76

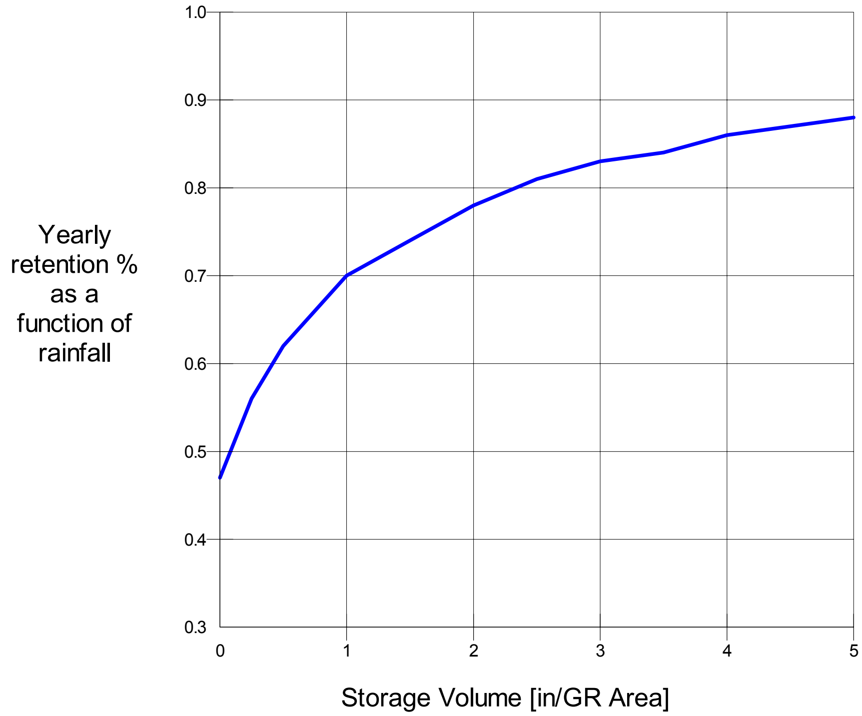


Storage	Efficiency
0	0.35
0.25	0.45
0.5	0.51
0.75	0.55
1	0.58
1.5	0.63
2	0.66
2.5	0.68
3	0.7
3.5	0.71
4	0.72
4.5	0.73
5	0.74

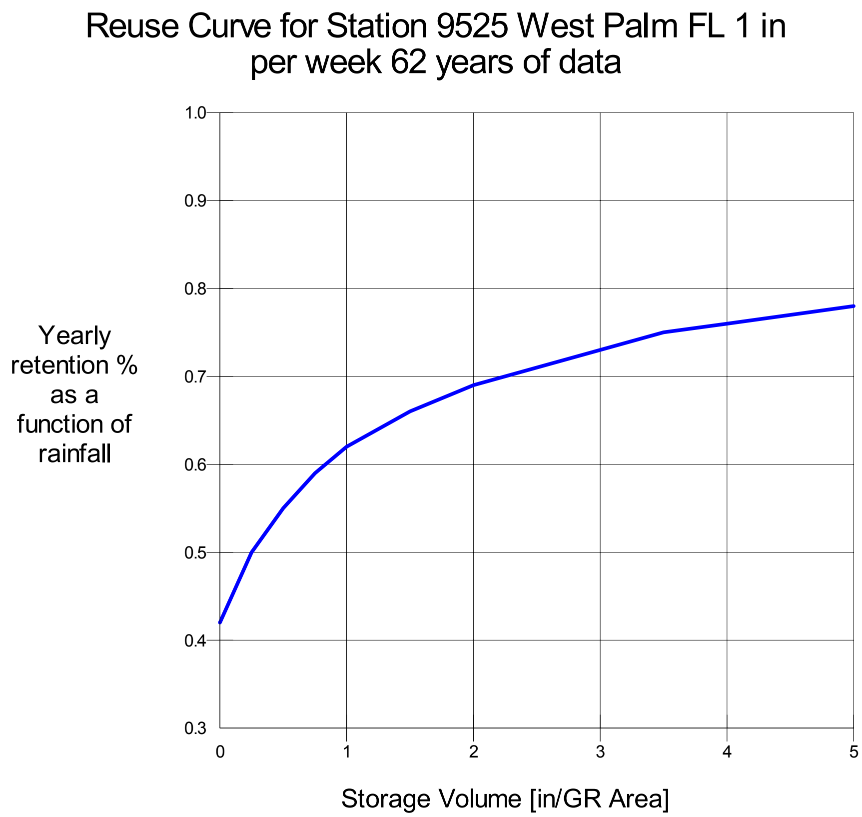


Storage	Efficiency
0.00	0.44
0.50	0.60
1.00	0.69
2.00	0.77
3.00	0.82
4.00	0.84
5.00	0.86

Reuse Curve for Station 9176 Vencie FL 1 in per week 62 years of data

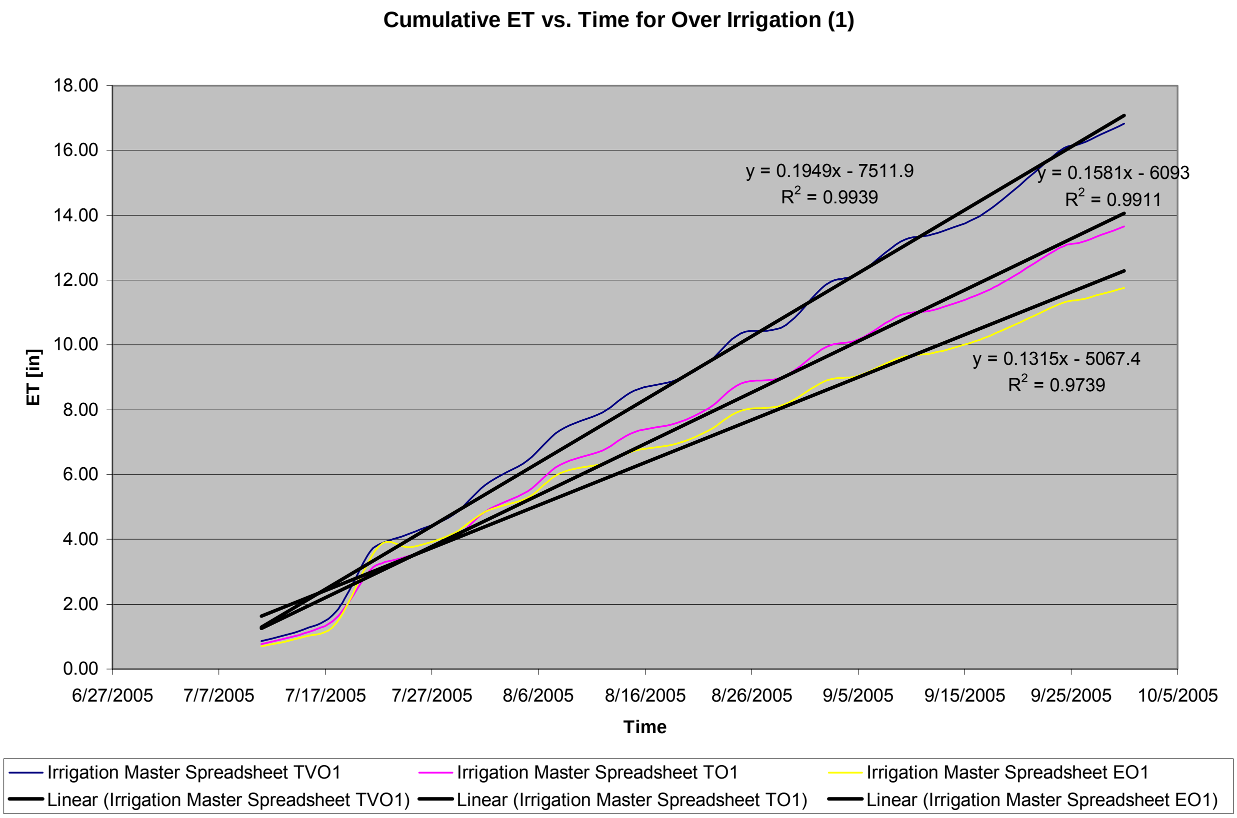


Storage	Efficiency
0	0.47
0.25	0.56
0.5	0.62
0.75	0.66
1	0.7
1.5	0.74
2	0.78
2.5	0.81
3	0.83
3.5	0.84
4	0.86
4.5	0.87
5	0.88

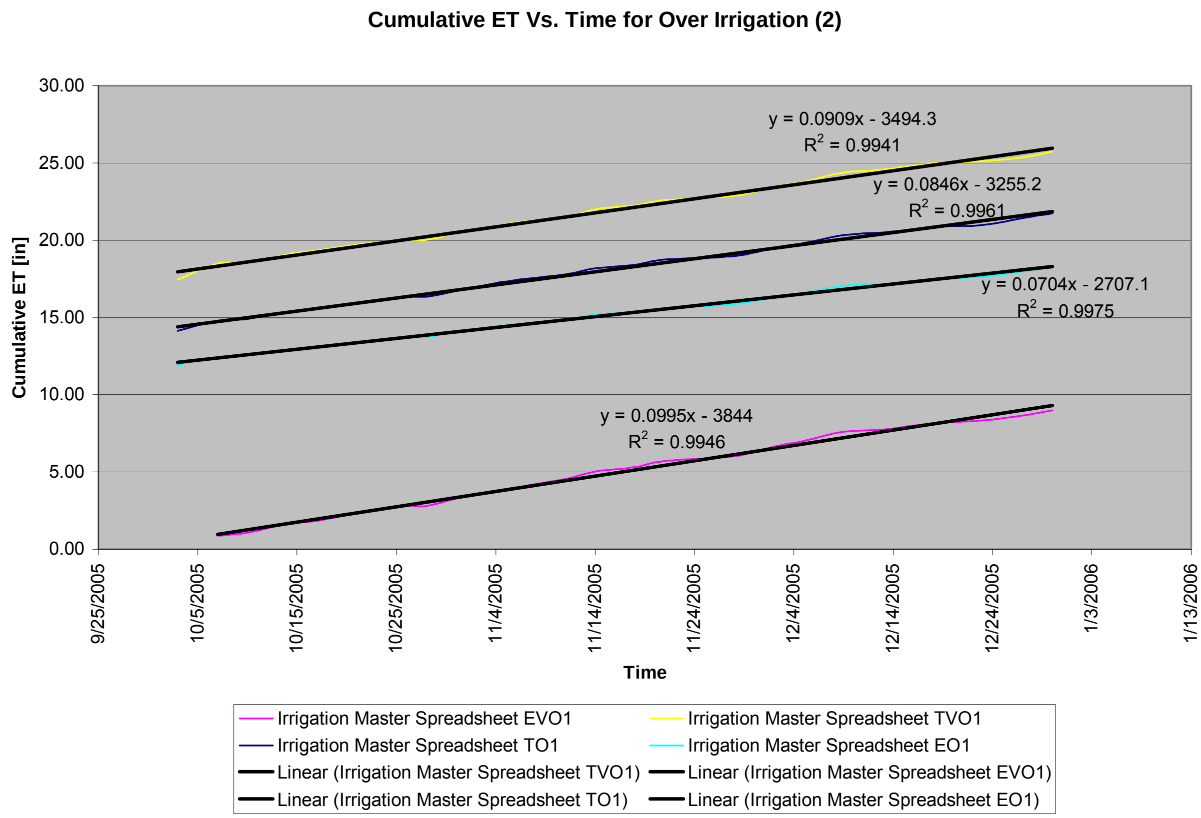


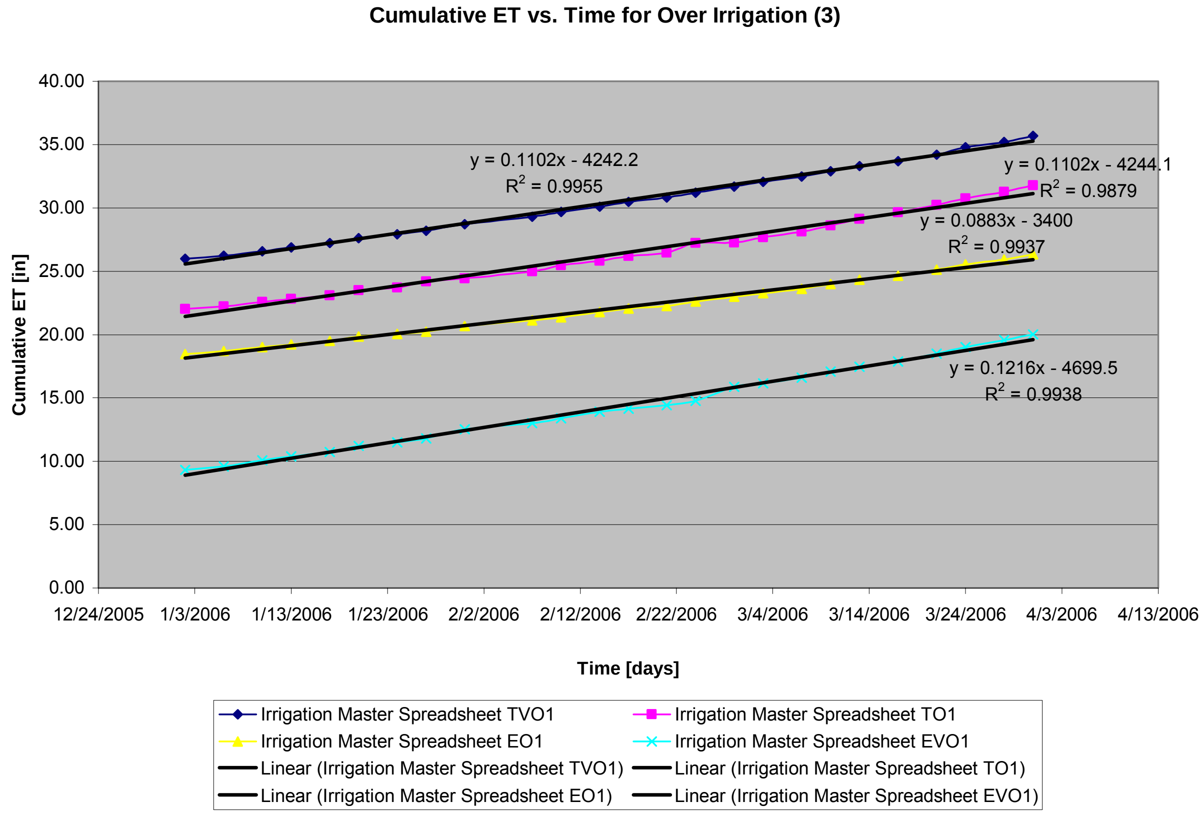
Storage	Efficiency
0	0.42
0.25	0.5
0.5	0.55
0.75	0.59
1	0.62
1.5	0.66
2	0.69
2.5	0.71
3	0.73
3.5	0.75
4	0.76
4.5	0.77
5	0.78

APPENDIX B: WATER BUDGET TABLES AND CHARTS

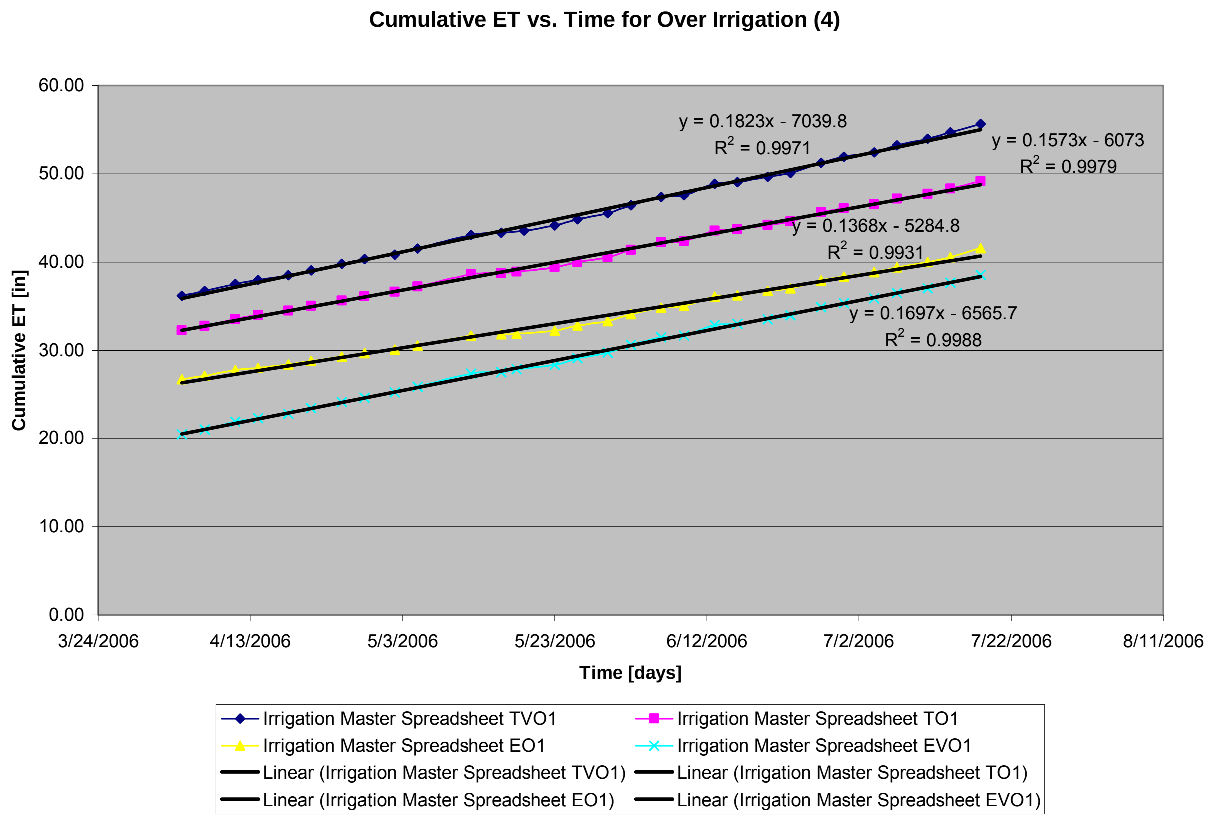


Cumulative ET vs. Time for Over Irrigation (1)
18.00
16.00
14.00
12.00
10.00
8.00
6.00
4.00
2.00
0.00
ET [in]
y = 0.1949x - 7511.9
R2 = 0.9939
y = 0.1581x - 6093
R2 = 0.9911
y = 0.1315x - 5067.4
R2 = 0.9739
6/27/2005
7/7/2005
7/17/2005
7/27/2005
8/6/2005
8/16/2005
8/26/2005
9/5/2005
9/15/2005
9/25/2005
10/5/2005
Time
Irrigation Master Spreadsheet TVO1
Irrigation Master Spreadsheet TO1
Irrigation Master Spreadsheet EO1
Linear (Irrigation Master Spreadsheet TVO1)
Linear (Irrigation Master Spreadsheet TO1)
Linear (Irrigation Master Spreadsheet EO1)

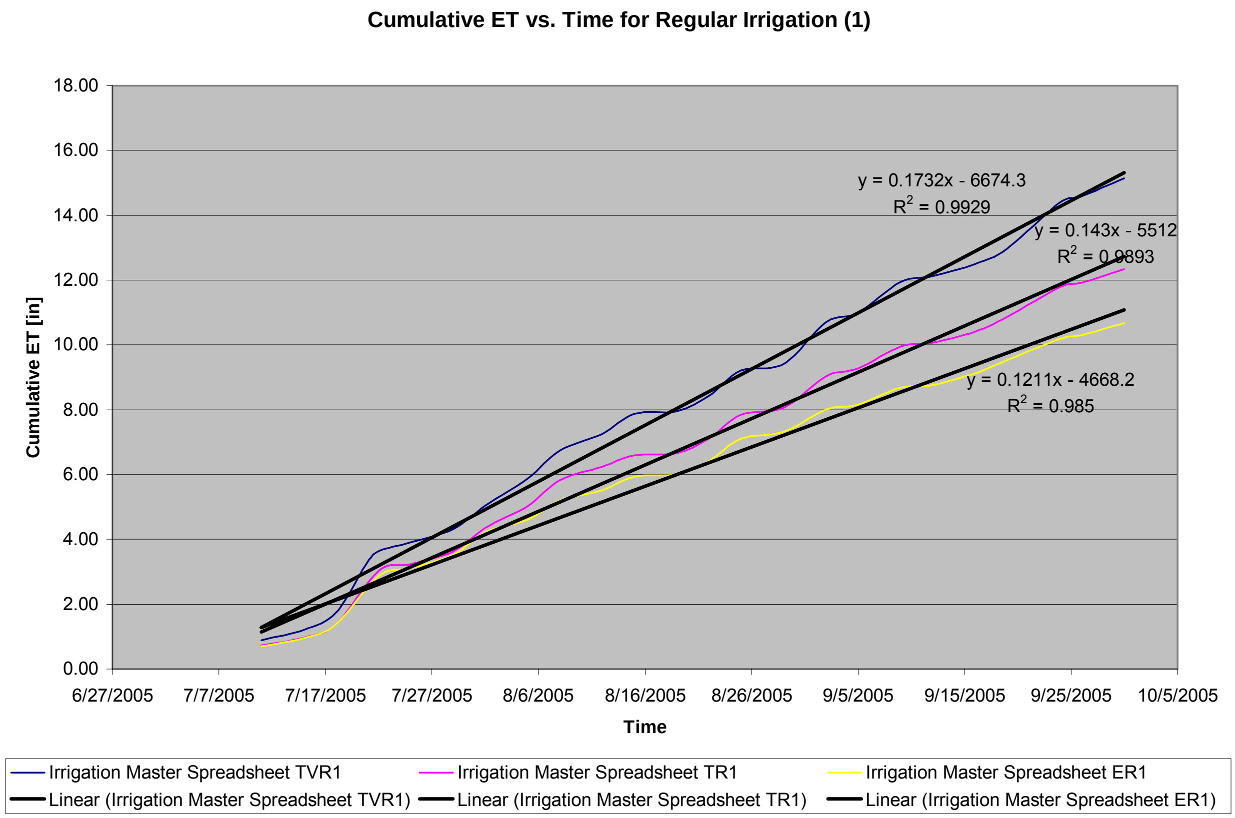

Cumulative ET Vs. Time for Over Irrigation (2)
Cumulative ET [in]
30.00
25.00
20.00
15.00
10.00
5.00
0.00
y = 0.0909x - 3494.3
R2 = 0.9941
y = 0.0846x - 3255.2
R2 = 0.9961
y = 0.0704x - 2707.1
R2 = 0.9975
y = 0.0995x - 3844
R2 = 0.9946
9/25/2005
10/5/2005
10/15/2005
10/25/2005
11/4/2005
11/14/2005
11/24/2005
12/4/2005
12/14/2005
12/24/2005
1/3/2006
1/13/2006
Time
Irrigation Master Spreadsheet EVO1
Irrigation Master Spreadsheet TVO1
Irrigation Master Spreadsheet TO1
Irrigation Master Spreadsheet EO1
Linear (Irrigation Master Spreadsheet TVO1)
Linear (Irrigation Master Spreadsheet EVO1)
Linear (Irrigation Master Spreadsheet TO1)
Linear (Irrigation Master Spreadsheet EO1)

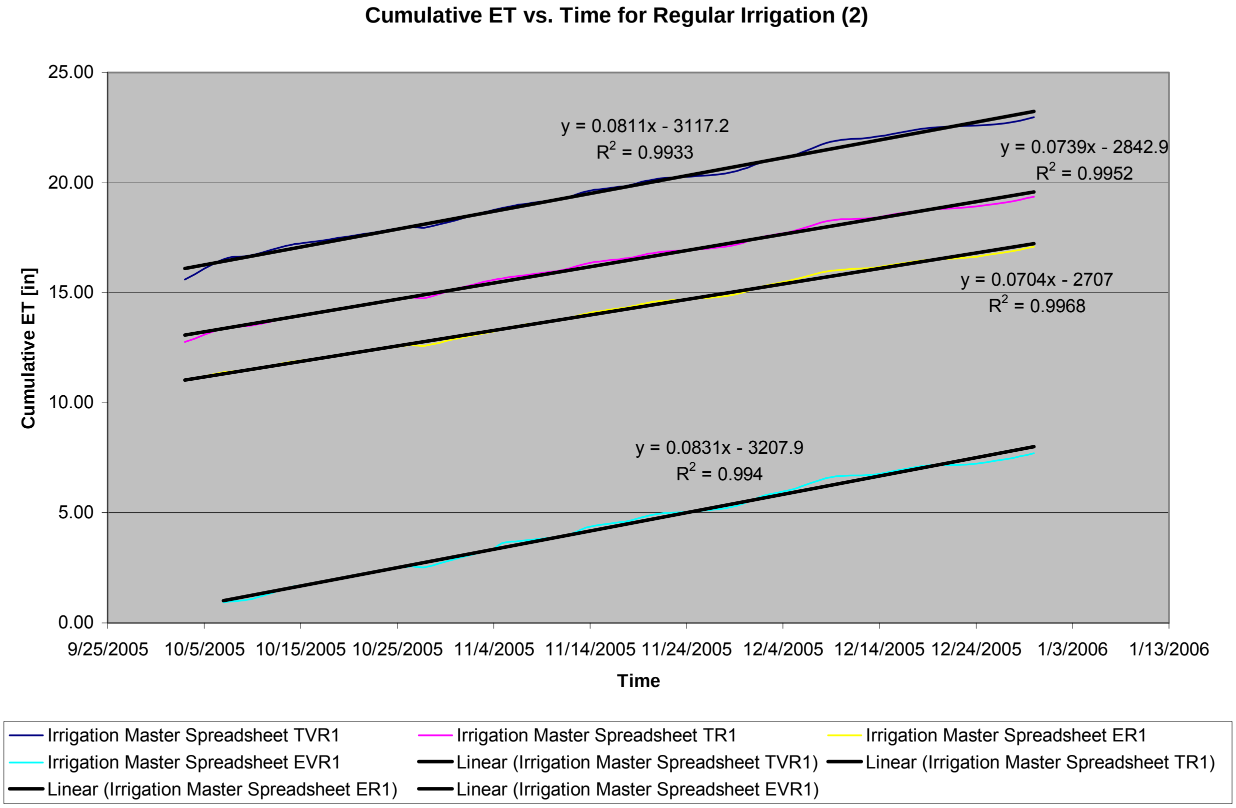


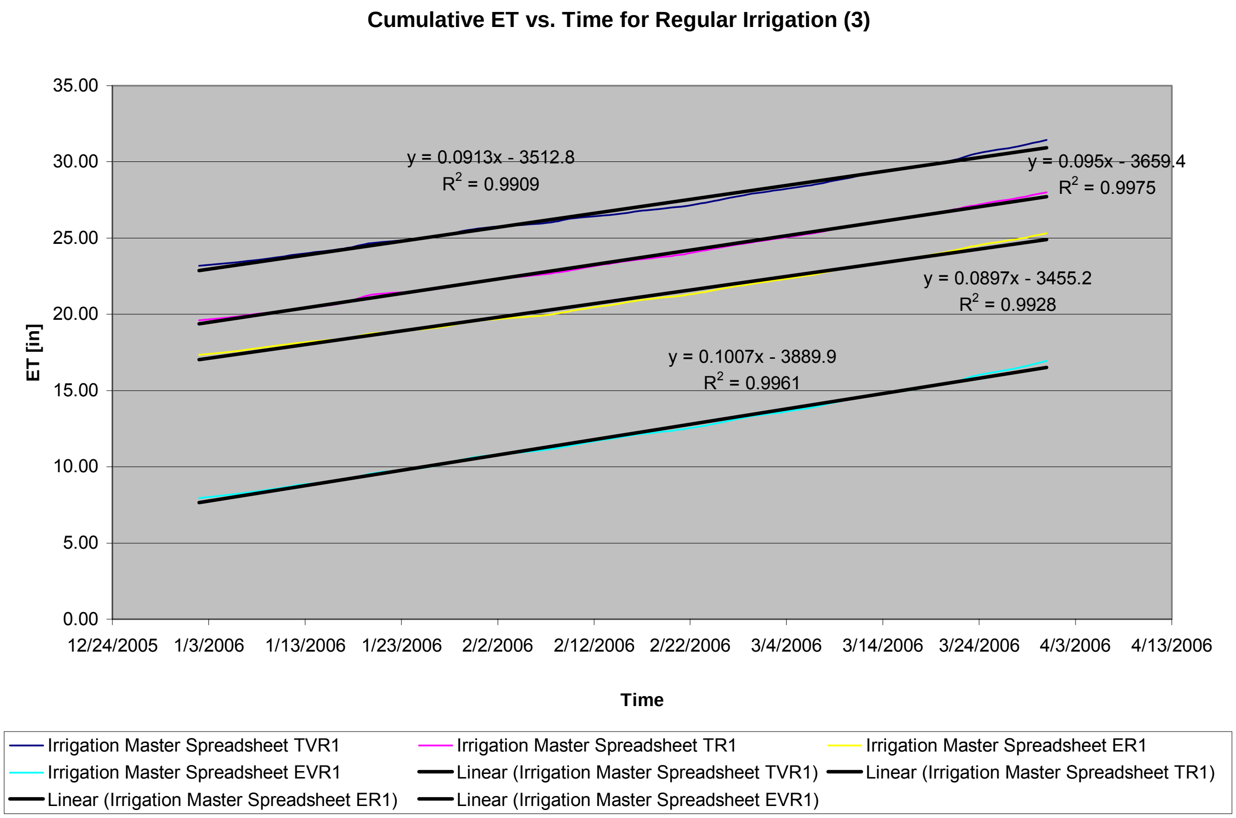
Cumulative ET vs. Time for Over Irrigation (3)
40.00
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
Cumulative ET [in]
y = 0.1102x - 4242.2
R2 = 0.9955
y = 0.1102x - 4244.1
R2 = 0.9879
y = 0.0883x - 3400
R2 = 0.9937
y = 0.1216x - 4699.5
R2 = 0.9938
12/24/2005
1/3/2006
1/13/2006
1/23/2006
2/2/2006
2/12/2006
2/22/2006
3/4/2006
3/14/2006
3/24/2006
4/3/2006
4/13/2006
Time [days]
Irrigation Master Spreadsheet TVO1
Irrigation Master Spreadsheet TO1
Irrigation Master Spreadsheet EO1
Irrigation Master Spreadsheet EVO1
Linear (Irrigation Master Spreadsheet TVO1)
Linear (Irrigation Master Spreadsheet TO1)
Linear (Irrigation Master Spreadsheet EO1)
Linear (Irrigation Master Spreadsheet EVO1)



Cumulative ET vs. Time for Over Irrigation (4)
y = 0.1823x - 7039.8
R2 = 0.9971
y = 0.1573x - 6073
R2 = 0.9979
y = 0.1368x - 5284.8
R2 = 0.9931
y = 0.1697x - 6565.7
R2 = 0.9988
Cumulative ET [in]
60.00
50.00
40.00
30.00
20.00
10.00
0.00
3/24/2006
4/13/2006
5/3/2006
5/23/2006
6/12/2006
7/2/2006
7/22/2006
8/11/2006
Time [days]
Irrigation Master Spreadsheet TVO1
Irrigation Master Spreadsheet TO1
Irrigation Master Spreadsheet EO1
Irrigation Master Spreadsheet EVO1
Linear (Irrigation Master Spreadsheet TVO1)
Linear (Irrigation Master Spreadsheet TO1)
Linear (Irrigation Master Spreadsheet EO1)
Linear (Irrigation Master Spreadsheet EVO1)


Cumulative ET vs. Time for Regular Irrigation (1)
18.00
16.00
14.00
12.00
10.00
8.00
6.00
4.00
2.00
0.00
Cumulative ET [in]
6/27/2005
7/7/2005
7/17/2005
7/27/2005
8/6/2005
8/16/2005
8/26/2005
9/5/2005
9/15/2005
9/25/2005
10/5/2005
Time
y = 0.1732x - 6674.3
R2 = 0.9929
y = 0.143x - 5512
R2 = 0.9893
y = 0.1211x - 4668.2
R2 = 0.985
Irrigation Master Spreadsheet TVR1
Irrigation Master Spreadsheet TR1
Irrigation Master Spreadsheet ER1
Linear (Irrigation Master Spreadsheet TVR1)
Linear (Irrigation Master Spreadsheet TR1)
Linear (Irrigation Master Spreadsheet ER1)


Cumulative ET vs. Time for Regular Irrigation (2)
25.00
20.00
15.00
10.00
5.00
0.00
Cumulative ET [in]
y = 0.0811x - 3117.2
R2 = 0.9933
y = 0.0739x - 2842.9
R2 = 0.9952
y = 0.0704x - 2707
R2 = 0.9968
y = 0.0831x - 3207.9
R2 = 0.994
9/25/2005
10/5/2005
10/15/2005
10/25/2005
11/4/2005
11/14/2005
11/24/2005
12/4/2005
12/14/2005
12/24/2005
1/3/2006
1/13/2006
Time
Irrigation Master Spreadsheet TVR1
Irrigation Master Spreadsheet TR1
Irrigation Master Spreadsheet ER1
Irrigation Master Spreadsheet EVR1
Linear (Irrigation Master Spreadsheet TVR1)
Linear (Irrigation Master Spreadsheet TR1)
Linear (Irrigation Master Spreadsheet ER1)
Linear (Irrigation Master Spreadsheet EVR1)



Cumulative ET vs. Time for Regular Irrigation (3)
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
ET [in]
y = 0.0913x - 3512.8
R2 = 0.9909
y = 0.095x - 3659.4
R2 = 0.9975
y = 0.0897x - 3455.2
R2 = 0.9928
y = 0.1007x - 3889.9
R2 = 0.9961
12/24/2005
1/3/2006
1/13/2006
1/23/2006
2/2/2006
2/12/2006
2/22/2006
3/4/2006
3/14/2006
3/24/2006
4/3/2006
4/13/2006
Time
Irrigation Master Spreadsheet TVR1
Irrigation Master Spreadsheet TR1
Irrigation Master Spreadsheet ER1
Irrigation Master Spreadsheet EVR1
Linear (Irrigation Master Spreadsheet TVR1)
Linear (Irrigation Master Spreadsheet TR1)
Linear (Irrigation Master Spreadsheet ER1)
Linear (Irrigation Master Spreadsheet EVR1)

ET Comparison of all the Chambers																		
Date	TVO1	TVO2	TVR1	TVR2	TO1	TO2	C1	C2	TR1	TR2	EO1	EO2	ER1	ER2	EVO1	EVO2	EVR1	EVR2
7/8/2005	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.21	0.20	0.20	0.21
7/11/2005	0.29	0.35	0.30	0.32	0.26	0.27	-0.01	-0.01	0.24	0.21	0.23	0.27	0.23	0.22	0.13	0.13	0.13	0.11
7/15/2005	0.09	0.10	0.08	0.08	0.09	0.08	0.00	0.00	0.06	0.08	0.07	0.06	0.06	0.06	0.21	0.21	0.19	0.19
7/18/2005	0.19	0.19	0.18	0.19	0.15	0.14	0.00	0.00	0.14	0.14	0.14	0.15	0.14	0.13	0.23	0.22	0.23	0.19
7/21/2005	0.58	0.46	0.52	0.50	0.46	0.44	0.12								0.15	0.15	0.15	0.15
7/22/2005	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.17	0.17	0.19	0.15
7/25/2005	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.16	0.13	0.16	0.13
7/29/2005	0.14	0.15	0.10	0.12	0.12	0.12	0.00	0.00	0.10	0.10	0.10	0.10	0.10	0.10	0.15	0.14	0.16	0.13
8/1/2005	0.31	0.35	0.24	0.25	0.28	0.28	0.00	0.02	0.25	0.25	0.23	0.23	0.23	0.22	0.08	0.09	0.08	0.09
8/5/2005	0.19	0.21	0.21	0.24	0.16	0.15	0.01	0.02	0.17	0.16	0.11	0.09	0.10	0.11	0.17	0.18	0.14	0.14
8/8/2005	0.30	0.31	0.29	0.30	0.27	0.28	-0.02	0.10	0.26	0.26	0.25	0.22	0.20	0.20	0.16	0.16	0.15	0.14
8/12/2005	0.14	0.16	0.13	0.14	0.11	0.17	0.00	0.01	0.11	0.11	0.08	0.09	0.08	0.09	0.23	0.24	0.24	0.23
8/15/2005	0.22	0.26	0.21	0.22	0.19	0.11	0.00	0.03	0.11	0.17	0.13	0.16	0.14	0.14	0.17	0.16	0.17	0.15
8/19/2005	0.09	0.09	0.02	0.02	0.07	0.08	0.00	0.00	0.02	0.02	0.06	0.06	0.02	0.02	0.19	0.18	0.20	0.19
8/22/2005	0.18	0.24	0.15	0.16	0.15	0.16	0.00	0.00	0.15	0.15	0.13	0.13	0.13	0.12	0.14	0.14	0.16	0.14
8/25/2005	0.29	0.34	0.26	0.27	0.25	0.27	0.02	0.02	0.25	0.25	0.21	0.24	0.23	0.22	0.00	0.00	0.00	0.05
8/29/2005	0.05	0.05	0.05	0.05	0.05	0.05	0.01	0.00	0.05	0.05	0.04	0.04	0.05	0.05	0.27	0.19	0.18	0.20
9/2/2005	0.33	0.38	0.32	0.35	0.23	0.24	-0.01	0.01	0.24	0.23	0.19	0.16	0.17	0.15	0.15	0.17	0.17	0.15
9/5/2005	0.11	0.18	0.09	0.11	0.08	0.09	0.00	0.00	0.08	0.08	0.05	0.06	0.05	0.05	0.10	0.10	0.12	0.11
9/9/2005	0.25	0.33	0.24	0.24	0.19	0.20	0.00	0.00	0.17	0.18	0.14	0.15	0.13	0.14	0.07	0.08	0.08	0.07
9/12/2005	0.08	0.09	0.06	0.06	0.05	0.04	0.00	0.00	0.04	0.04	0.04	0.04	0.03	0.04	0.22	0.21	0.22	0.18
9/16/2005	0.12	0.16	0.09	0.11	0.11	0.11	0.00	0.00	0.09	0.09	0.09	0.10	0.09	0.08	0.06	0.06	0.05	0.05
9/19/2005	0.23	0.29	0.16	0.17	0.17	0.17	0.00	0.00	0.15	0.15	0.14	0.15	0.14	0.14	0.22	0.21	0.19	0.19
9/24/2005	0.28	0.29	0.29	0.29	0.20	0.23	0.00	0.00	0.19	0.20	0.15	0.16	0.13	0.14	0.16	0.13	0.12	0.11
9/26/2005	0.11	0.11	0.09	0.10	0.08	0.08	0.00	0.00	0.06	0.07	0.07	0.08	0.06	0.05	0.29	0.17	0.16	0.14
9/30/2005	0.15	0.16	0.14	0.14	0.12	0.12	0.01	-0.01	0.11	0.11	0.08	0.09	0.09	0.09	-	-	-	-
10/3/2005	0.20	0.22	0.15	0.19	0.16	0.17	0.01	0.02	0.14	0.15	0.06	0.13	0.11	0.12	-	-	-	-
10/7/2005	0.26	0.19	0.23	0.20	0.17	0.16	0.00	0.04	0.15	0.15	0.13	0.12	0.09	0.10	0.22	0.40	0.23	0.19
10/10/2005	0.01	0.07	0.07	0.07	0.04	0.06	0.00	0.00	0.05	0.06	0.04	0.06	0.03	0.03	0.07	0.05	0.06	0.05
10/14/2005	0.14	0.12	0.11	0.12	0.12	0.11	0.00	0.01	0.10	0.10	0.09	0.09	0.09	0.10	0.14	0.14	0.14	0.12
10/17/2005	0.08	0.09	0.06	0.06	0.07	0.07	0.00	0.00	0.06	0.06	0.06	0.06	0.05	0.05	0.07	0.08	0.07	0.06
10/21/2005	0.10	0.10	0.07	0.08	0.09	0.10	0.00	0.00	0.08	0.08	0.07	0.08	0.08	0.09	0.12	0.11	0.09	0.09
10/26/2005	0.06	0.31	0.07	0.07	0.08	0.07	0.01	0.00	0.07	0.07	0.10	0.07	0.06	0.07	0.10	0.08	0.07	0.07

Date	TVO1	TVO2	TVR1	TVR2	TO1	TO2	C1	C2	TR1	TR2	EO1	EO2	ER1	ER2	EVO1	EVO2	EVR1	EVR2
10/28/2005	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10/31/2005	0.14	0.14	0.11	0.12	0.13	0.13	0.00	0.00	0.13	0.12	0.11	0.11	0.10	0.10	0.15	0.15	0.12	0.12
11/4/2005	0.12	0.12	0.12	0.12	0.13	0.11	0.00	0.01	0.10	0.11	0.08	0.08	0.08	0.09	0.13	0.12	0.12	0.10
11/7/2005	0.11	0.13	0.09	0.09	0.09	0.08	0.00	0.00	0.07	0.09	0.07	0.08	0.10	0.07	0.11	0.11	0.09	0.09
11/11/2005	0.06	0.07	0.06	0.07	0.07	0.09	0.00	0.00	0.06	0.07	0.05	0.06	0.06	0.06	0.11	0.10	0.07	0.08
11/14/2005	0.17	0.16	0.12	0.13	0.14	0.15	0.00	0.00	0.12	0.14	0.12	0.13	0.11	0.12	0.16	0.18	0.14	0.15
11/18/2005	0.07	0.06	0.06	0.07	0.06	0.06	0.00	0.00	0.05	0.06	0.04	0.05	0.06	0.05	0.07	0.07	0.07	0.07
11/21/2005	0.11	0.12	0.10	0.10	0.11	0.11	0.00	0.00	0.09	0.10	0.09	0.09	0.09	0.09	0.13	0.12	0.11	0.10
11/28/2005	0.04	0.04	0.03	0.04	0.03	0.03	0.00	0.00	0.04	0.03	0.03	0.03	0.03	0.03	0.05	0.04	0.04	0.04
12/2/2005	0.15	0.16	0.14	0.15	0.13	0.13	0.00	0.02	0.11	0.12	0.12	0.12	0.12	0.11	0.16	0.15	0.14	0.14
12/5/2005	0.10	0.14	0.09	0.10	0.10	0.10	0.00	0.00	0.08	0.10	0.09	0.10	0.09	0.09	0.12	0.11	0.09	0.09
12/9/2005	0.15	0.13	0.16	0.15	0.13	0.13	0.01	0.00	0.12	0.13	0.12	0.11	0.11	0.12	0.15	0.15	0.14	0.16
12/13/2005	0.05	0.04	0.05	0.05	0.04	0.00	0.00	0.01	0.02	0.04	0.03	0.03	0.03	0.03	0.03	0.03	0.02	0.03
12/16/2005	0.09	0.08	0.08	0.08	0.07	0.07	0.00	0.00	0.08	0.07	0.07	0.07	0.07	0.06	0.09	0.09	0.07	0.08
12/19/2005	0.07	0.08	0.07	0.07	0.06	0.08	0.00	0.01	0.05	0.07	0.05	0.05	0.06	0.07	0.07	0.07	0.07	0.06
12/23/2005	0.02	0.03	0.03	0.03	0.02	0.02	0.00	0.00	0.03	0.03	0.02	0.03	0.02	0.02	0.03	0.03	0.01	0.02
12/27/2005	0.07	0.07	0.03	0.07	0.11	0.11	0.00	0.00	0.05	0.06	0.09	0.08	0.06	0.06	0.08	0.07	0.06	0.06
12/30/2005	0.12	0.10	0.09	0.09	0.11	0.09	0.00	0.00	0.09	0.10	0.10	0.11	0.08	0.09	0.12	0.12	0.09	0.09
1/2/2006	0.09	0.09	0.08	0.09	0.09	0.08	0.00	0.00	0.08	0.08	0.06	0.07	0.08	0.08	0.11	0.09	0.07	0.08
1/6/2006	0.06	0.07	0.06	0.06	0.05	0.06	0.00	0.01	0.07	0.06	0.06	0.06	0.06	0.06	0.07	0.08	0.07	0.08
1/10/2006	0.09	0.10	0.08	0.08	0.08	0.09	0.00	0.00	0.08	0.08	0.08	0.08	0.08	0.08	0.12	0.10	0.09	0.09
1/13/2006	0.10	0.08	0.08	0.09	0.08	0.08	0.00	0.00	0.07	0.07	0.07	0.07	0.08	0.07	0.11	0.11	0.09	0.09
1/17/2006	0.08	0.07	0.08	0.07	0.07	0.08	0.00	0.03	0.09	0.08	0.07	0.09	0.06	0.06	0.09	0.08	0.07	0.07
1/20/2006	0.13	0.14	0.13	0.13	0.14	0.13	0.00	0.01	0.18	0.13	0.12	0.13	0.11	0.12	0.16	0.15	0.15	0.15
1/24/2009	0.08	0.07	0.06	0.06	0.05	0.05	0.00	0.01	0.05	0.06	0.05	0.05	0.05	0.05	0.07	0.06	0.07	0.07
1/27/2006	0.09	0.09	0.07	0.16	0.16	0.16	0.00	0.00	0.07	0.07	0.06	0.07	0.07	0.06	0.11	0.11	0.09	0.10
1/31/2006	0.13	0.12	0.12	0.06	0.06	0.05	0.00	0.01	0.11	0.12	0.11	0.12	0.11	0.12	0.18	0.14	0.14	0.14
2/7/2006	0.08	0.07	0.05	0.11	0.08	0.07	0.00	0.00	0.07	0.06	0.06	0.07	0.05	0.06	0.07	0.08	0.07	0.08
2/10/2006	0.12	0.12	0.10	0.16	0.16	0.17	0.00	0.00	0.09	0.11	0.09	0.10	0.11	0.09	0.13	0.11	0.10	0.10
2/14/2006	0.11	0.11	0.06	0.10	0.08	0.07	0.00	0.01	0.11	0.11	0.10	0.11	0.10	0.11	0.13	0.14	0.11	0.10
2/17/2006	0.13	0.11	0.08	0.11	0.13	0.13	0.00	0.00	0.09	0.10	0.09	0.09	0.11	0.08	0.08	0.06	0.09	0.11
2/21/2006	0.08	0.07	0.07	0.07	0.07	0.07	0.00	0.00	0.07	0.07	0.06	0.07	0.06	0.06	0.07	0.07	0.07	0.06
2/24/2006	0.13	0.11	0.10	0.24	0.26	0.29	0.00	0.00	0.11	0.11	0.12	0.11	0.11	0.09	0.11	0.12	0.10	0.12
2/28/2006	0.13	0.12	0.12	0.01	0.01	0.03	0.00	0.01	0.11	0.12	0.09	0.10	0.11	0.11	0.28	0.14	0.13	0.13

Date	TVO1	TVO2	TVR1	TVR2	TO1	TO2	C1	C2	TR1	TR2	EO1	EO2	ER1	ER2	EVO1	EVO2	EVR1	EVR2
3/3/2006	0.12	0.13	0.10	0.09	0.13	0.12	0.00	0.00	0.09	0.09	0.09	0.10	0.09	0.09	0.09	0.10	0.09	0.09
3/7/2006	0.10	0.11	0.09	0.10	0.12	0.12	0.00	0.00	0.09	0.09	0.09	0.10	0.09	0.09	0.11	0.11	0.10	0.10
3/10/2006	0.14	0.17	0.13	0.15	0.16	0.18	0.00	0.00	0.13	0.13	0.13	0.13	0.13	0.13	0.16	0.14	0.14	0.14
3/13/2006	0.14	0.15	0.12	0.14	0.17	0.17	0.00	0.00	0.11	0.12	0.11	0.12	0.11	0.10	0.14	0.14	0.12	0.13
3/17/2006	0.09	0.10	0.09	0.11	0.13	0.12	0.00	0.00	0.09	0.09	0.08	0.08	0.09	0.08	0.10	0.10	0.09	0.09
3/21/2006	0.14	0.15	0.11	0.12	0.15	0.16	0.00	0.00	0.11	0.11	0.12	0.12	0.11	0.11	0.15	0.15	0.12	0.11
3/24/2006	0.19	0.19	0.17	0.18	0.17	0.20	0.00	0.00	0.13	0.15	0.13	0.13	0.13	0.14	0.18	0.18	0.17	0.17
3/28/2006	0.11	0.14	0.11	0.12	0.13	0.13	0.00	0.00	0.10	0.11	0.09	0.11	0.10	0.10	0.13	0.13	0.12	0.12
3/31/2006	0.16	0.18	0.15	0.16	0.17	0.19	0.00	0.00	0.13	0.14	0.13	0.13	0.13	0.13	0.15	0.15	0.15	0.14
4/4/2006	0.12	0.17	0.10	0.12	0.12	0.13	0.00	0.00	0.09	0.09	0.10	0.10	0.10	0.10	0.12	0.11	0.11	0.10
4/7/2006	0.18	0.20	0.02	0.16	0.16	0.17	0.00	0.00	0.13	0.14	0.13	0.13	0.13	0.13	0.17	0.18	0.16	0.15
4/11/2006	0.20	0.20	0.21	0.21	0.20	0.20	0.00	0.01	0.16	0.17	0.15	0.16	0.16	0.16	0.22	0.21	0.21	0.21
4/14/2006	0.15	0.18	0.12	0.15	0.15	0.15	0.00	0.00	0.11	0.12	0.08	0.10	0.10	0.10	0.14	0.13	0.12	0.12
4/18/2006	0.13	0.13	0.10	0.12	0.12	0.13	0.00	0.00	0.10	0.12	0.10	0.10	0.09	0.10	0.13	0.12	0.11	0.11
4/21/2006	0.19	0.25	0.16	0.17	0.19	0.19	0.00	0.00	0.14	0.14	0.13	0.14	0.13	0.13	0.21	0.15	0.16	0.15
4/25/2006	0.18	0.19	0.17	0.18	0.15	0.17	0.00	0.02	0.13	0.14	0.13	0.12	0.13	0.13	0.17	0.17	0.16	0.16
4/28/2006	0.18	0.20	0.15	0.16	0.17	0.22	0.00	0.00	0.14	0.15	0.13	0.14	0.13	0.13	0.17	0.17	0.16	0.15
5/2/2006	0.13	0.16	0.12	0.13	0.12	0.12	0.00	0.00	0.11	0.11	0.10	0.09	0.10	0.11	0.15	0.14	0.12	0.12
5/5/2006	0.22	0.22	0.14	0.16	0.19	0.21	0.00	0.00	0.15	0.17	0.14	0.18	0.15	0.13	0.21	0.18	0.16	0.15
5/12/2006	0.22	0.23	0.21	0.22	0.20	0.19	0.00	0.02	0.18	0.18	0.16	0.16	0.16	0.16	0.21	0.21	0.20	0.20
5/16/2006	0.07	0.08	0.06	0.07	0.04	0.03	0.00	0.00	0.04	0.05	0.04	0.04	0.04	0.04	0.04	0.05	0.03	0.03
5/19/2006	0.09	0.13	0.08	0.09	0.05	0.07	0.00	0.00	0.04	0.04	0.01	0.03	0.02	0.02	0.11	0.08	0.08	0.07
5/23/2006	0.14	0.14	0.11	0.11	0.12	0.12	0.00	0.00	0.09	0.10	0.09	0.09	0.10	0.07	0.13	0.12	0.12	0.11
5/26/2006	0.24	0.27	0.18	0.20	0.20	0.22	0.00	0.00	0.18	0.17	0.20	0.19	0.18	0.16	0.24	0.24	0.20	0.21
5/30/2006	0.16	0.18	0.18	0.19	0.14	0.14	0.00	0.16	0.12	0.13	0.11	0.13	0.07	0.08	0.16	0.14	0.16	0.14
6/2/2006	0.31	0.33	0.27	0.29	0.27	0.28	0.00	0.03	0.23	0.19	0.27	0.26	0.26	0.24	0.30	0.28	0.28	0.31
6/6/2006	0.23	0.23	0.23	0.23	0.21	0.24	0.00	0.00	0.18	0.18	0.19	0.19	0.15	0.15	0.21	0.22	0.21	0.20
6/9/2006	0.07	0.09	0.06	0.07	0.06	0.07	0.00	0.01	0.07	0.05	0.06	0.06	0.06	0.05	0.06	0.09	0.05	0.05
6/13/2006	0.33	0.31	0.30	0.31	0.29	0.29	0.00	0.00	0.25	0.21	0.26	0.25	0.20	0.21	0.30	0.30	0.28	0.28
6/16/2006	0.06	0.06	0.08	0.08	0.05	0.02	0.00	0.16	0.03	0.06	0.05	0.05	0.05	0.04	0.05	0.06	0.07	0.06
6/20/2006	0.14	0.15	0.12	0.13	0.13	0.15	0.00	0.02	0.16	0.11	0.12	0.12	0.11	0.11	0.13	0.12	0.12	0.12
6/23/2006	0.15	0.15	0.11	0.14	0.13	0.15	0.00	0.03	0.12	0.11	0.11	0.11	0.10	0.09	0.14	0.13	0.13	0.10
6/27/2006	0.29	0.28	0.28	0.28	0.25	0.26	0.00	0.00	0.23	0.24	0.23	0.23	0.19	0.20	0.25	0.25	0.25	0.25
6/30/2006	0.23	0.16	0.17	0.18	0.15	0.17	0.00	0.03	0.15	0.16	0.15	0.15	0.12	0.13	0.14	0.14	0.17	0.15

Date	TVO1	TVO2	TVR1	TVR2	TO1	TO2	C1	C2	TR1	TR2	EO1	EO2	ER1	ER2	EVO1	EVO2	EVR1	EVR2
7/4/2006	0.13	0.11	0.11	0.10	0.11	0.11	0.00	0.02	0.10	0.10	0.11	0.09	0.08	0.07	0.14	0.12	0.11	0.12
7/7/2006	0.26	0.23	0.22	0.22	0.22	0.23	0.00	0.01	0.22	0.20	0.18	0.22	0.18	0.18	0.21	0.20	0.20	0.21
7/11/2006	0.19	0.15	0.14	0.15	0.14	0.15	0.00	0.00	0.13	0.18	0.15	0.12	0.09	0.08	0.13	0.13	0.13	0.11
7/14/2006	0.25	0.25	0.22	0.23	0.20	0.22	0.00	0.02	0.19	0.20	0.19	0.17	0.16	0.14	0.21	0.21	0.19	0.19
7/18/2006	0.23	0.22	0.21	0.22	0.21	0.23	0.00	0.11	0.20	0.19	0.26	0.29	0.27	0.30	0.23	0.22	0.23	0.19
Average	0.15	0.16	0.13	0.14	0.13	0.14	0.00	0.01	0.11	0.12	0.11	0.11	0.10	0.10	0.14	0.14	0.13	0.12
RPD	6.56		8.34		3.10		134.32		2.53		3.80		1.19		4.07		2.81	
s	0.086	0.087	0.081	0.081	0.072	0.076	0.012	0.027	0.058	0.055	0.056	0.056	0.052	0.052	0.062	0.064	0.057	0.057
s^2	0.007	0.008	0.007	0.007	0.005	0.006	0.000	0.001	0.003	0.003	0.003	0.003	0.003	0.003	0.004	0.004	0.003	0.003
n	103	103	103	103	103	103	103	102	102	102	102	102	102	102	103	103	103	103
Average	0.16		0.14		0.14		0.01		0.11		0.11		0.10		0.14		0.13	
RPD (Plants no plants)	13.69		17.10												23.22		19.50	
RPD (Tire crumb vs EC)	11.52		8.56		21.07				10.94									

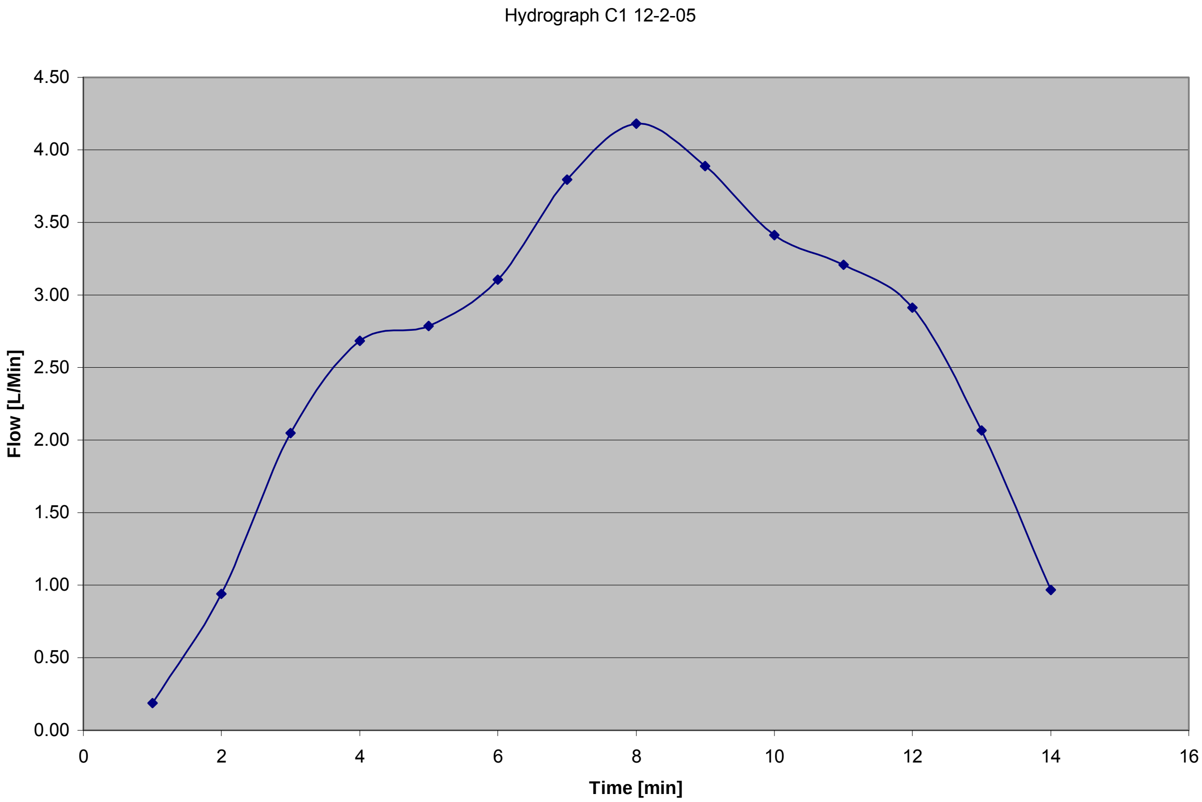
f Factor Comparison of all the Chambers																		
Date	TVO1	TVO2	TVR1	TVR2	TO1	TO2	C1	C2	TR1	TR2	EO1	EO2	ER1	ER2	EVO1	EVO2	EVR1	EVR2
7/8/2005	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.58	0.58	0.41	0.40
7/11/2005	0.49	0.41	0.32	0.27	0.57	0.57	1.04	1.04	0.47	0.50	0.60	0.57	0.46	0.50	0.69	0.70	0.58	0.64
7/15/2005	0.65	0.59	0.42	0.39	0.66	0.67	0.87	0.88	0.52	0.45	0.71	0.75	0.53	0.54	0.59	0.58	0.45	0.47
7/18/2005	0.65	0.64	0.52	0.51	0.71	0.73	1.00	0.99	0.62	0.62	0.73	0.73	0.62	0.66	0.59	0.61	0.47	0.55
7/21/2005	0.62	0.70	0.62	0.64	0.69	0.71	0.90								0.63	0.62	0.62	0.63
7/22/2005	0.33	0.31	0.33	0.31	0.44	0.44	1.00	0.72	0.64	0.64	0.53	0.60	0.68	0.68	0.69	0.69	0.55	0.65
7/25/2005	0.64	0.64	0.57	0.51	0.71	0.71	-	-	0.57	0.64	1.04	0.78	0.56	0.60	0.74	0.78	0.64	0.71
7/29/2005	0.42	0.40	0.15	0.04	0.48	0.48	-	-	0.20	0.17	0.57	0.56	0.17	0.20	0.69	0.70	0.54	0.61
8/1/2005	0.23	0.14	0.00	0.00	0.28	0.31	0.98	0.70	0.00	0.00	0.43	0.41	0.04	0.10	0.74	0.72	0.49	0.47
8/5/2005	0.70	0.68	0.60	0.53	0.75	0.76	0.98	0.96	0.67	0.68	0.83	0.85	0.81	0.79	0.37	0.37	0.10	0.09
8/8/2005	0.66	0.65	0.60	0.58	0.70	0.68	1.03	0.82	0.64	0.64	0.72	0.75	0.73	0.72	0.49	0.49	0.07	0.11
8/12/2005	0.64	0.59	0.48	0.41	0.63	0.50	1.02	0.88	0.49	0.45	0.72	0.69	0.58	0.58	0.36	0.32	0.02	0.07
8/15/2005	0.58	0.52	0.45	0.40	0.65	0.77	0.99	0.86	0.70	0.54	0.75	0.70	0.63	0.63	0.56	0.58	0.25	0.28
8/19/2005	0.67	0.64	0.00	0.00	0.72	0.69	0.91	1.04	0.13	0.00	0.79	0.77	0.00	0.00	0.54	0.57	0.33	0.35
8/22/2005	0.40	0.26	0.00	0.00	0.52	0.49	-	-	0.09	0.09	0.58	0.58	0.17	0.19	0.80	0.81	0.72	0.75
8/25/2005	0.30	0.21	0.00	0.00	0.40	0.36	0.78	0.81	0.05	0.05	0.53	0.44	0.13	0.16	0.99	0.99	0.99	0.88
8/29/2005	0.00	0.00	0.00	0.00	0.00	0.00	0.81	0.96	0.00	0.00	0.15	0.15	0.00	0.00	0.64	0.76	0.70	0.68
9/2/2005	0.49	0.41	0.38	0.33	0.64	0.62	1.03	0.96	0.52	0.56	0.71	0.75	0.66	0.71	0.74	0.72	0.63	0.67
9/5/2005	0.77	0.59	0.70	0.65	0.83	0.82	1.00	1.03	0.75	0.74	0.89	0.88	0.85	0.82	0.87	0.87	0.85	0.86
9/9/2005	0.54	0.39	0.44	0.43	0.65	0.64	0.99	1.00	0.59	0.57	0.74	0.72	0.69	0.66	0.77	0.72	0.47	0.57
9/12/2005	0.78	0.74	0.70	0.68	0.86	0.87	0.92	1.00	0.81	0.79	0.88	0.89	0.85	0.80	0.49	0.51	0.24	0.30
9/16/2005	0.47	0.39	0.20	0.09	0.54	0.54	-	-	0.27	0.27	0.64	0.58	0.28	0.30	0.73	0.76	0.59	0.57
9/19/2005	0.26	0.13	0.00	0.00	0.47	0.47	-	-	0.07	0.11	0.58	0.53	0.15	0.13	0.56	0.57	0.41	0.42
9/24/2005	0.62	0.61	0.56	0.55	0.72	0.69	1.00	1.00	0.71	0.70	0.80	0.79	0.80	0.78	0.38	0.52	0.21	0.27
9/26/2005	0.76	0.77	0.62	0.59	0.82	0.83	-	-	0.74	0.72	0.86	0.83	0.77	0.78	0.46	0.68	0.56	0.60
9/30/2005	0.54	0.52	0.36	0.35	0.64	0.65	0.92	1.07	0.51	0.49	0.75	0.74	0.58	0.59	-	-	-	-
10/3/2005	0.52	0.50	0.44	0.32	0.64	0.62	0.90	0.84	0.49	0.47	0.86	0.71	0.59	0.56	-	-	-	-
10/7/2005	0.70	0.78	0.70	0.73	0.81	0.82	1.00	0.94	0.80	0.80	0.86	0.87	0.88	0.86	0.75	-	-	0.76
10/10/2005	0.96	0.84	0.77	0.77	0.92	0.88	1.00	0.96	0.85	0.82	0.92	0.88	0.89	0.90	0.85	0.90	0.81	0.84
10/14/2005	0.63	0.67	0.55	0.50	0.69	0.73	0.98	0.94	0.62	0.59	0.75	0.78	0.61	0.61	0.61	0.61	0.46	0.51
10/17/2005	0.74	0.72	0.62	0.59	0.78	0.77	-	-	0.63	0.64	0.83	0.83	0.72	0.70	0.79	0.74	0.58	0.64

Date	TVO1	TVO2	TVR1	TVR2	TO1	TO2	C1	C2	TR1	TR2	EO1	EO2	ER1	ER2	EVO1	EVO2	EVR1	EVR2
10/21/2005	0.59	0.57	0.40	0.30	0.62	0.60	-	-	0.38	0.40	0.71	0.66	0.38	0.22	0.51	0.53	0.22	0.22
10/26/2005	0.95	0.79	0.94	0.94	0.93	0.95	1.00	1.00	0.93	0.94	0.94	0.94	0.95	0.94	0.92	0.93	0.94	0.93
10/28/2005	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
10/31/2005	0.56	0.56	0.35	0.28	0.60	0.59	-	-	0.17	0.26	0.66	0.66	0.39	0.37	0.52	0.53	0.28	0.24
11/4/2005	0.68	0.68	0.54	0.52	0.69	0.70	1.00	0.91	0.61	0.60	0.80	0.78	0.67	0.66	0.68	0.67	0.54	0.61
11/7/2005	0.66	0.60	0.44	0.39	0.72	0.75	-	-	0.52	0.43	0.79	0.76	0.48	0.58	0.65	0.66	0.43	0.41
11/11/2005	0.74	0.67	0.49	0.39	0.70	0.64	-	-	0.51	0.44	0.79	0.75	0.49	0.53	0.55	0.58	0.38	0.33
11/14/2005	0.50	0.52	0.30	0.23	0.59	0.56	0.83	0.69	0.33	0.22	0.64	0.61	0.38	0.30	0.48	0.47	0.15	0.14
11/18/2005	0.71	0.74	0.49	0.44	0.76	0.75	-	-	0.56	0.52	0.81	0.79	0.51	0.60	0.70	0.70	0.44	0.38
11/21/2005	0.66	0.63	0.41	0.39	0.66	0.67	1.00	0.74	0.49	0.43	0.74	0.73	0.48	0.45	0.61	0.65	0.36	0.36
11/28/2005	0.71	0.73	0.52	0.47	0.77	0.75	-	-	0.44	0.50	0.76	0.74	0.52	0.52	0.67	0.68	0.48	0.46
12/2/2005	0.53	0.51	0.33	0.25	0.61	0.59	1.00	0.81	0.45	0.39	0.64	0.62	0.43	0.43	0.54	0.52	0.30	0.31
12/5/2005	0.69	0.58	0.41	0.38	0.67	0.68	-	-	0.45	0.36	0.73	0.69	0.43	0.43	0.65	0.67	0.42	0.42
12/9/2005	0.76	0.79	0.68	0.70	0.79	0.80	0.97	0.99	0.75	0.74	0.81	0.82	0.79	0.77	0.76	0.76	0.72	0.68
12/13/2005	0.82	0.84	0.71	0.69	0.86	1.00	0.95	0.79	0.86	0.75	0.90	0.90	0.83	0.81	0.88	0.90	0.84	0.82
12/16/2005	0.74	0.78	0.56	0.54	0.78	0.79	0.98	0.75	0.56	0.58	0.80	0.80	0.61	0.67	0.73	0.73	0.58	0.56
12/19/2005	0.81	0.78	0.62	0.62	0.82	0.77	0.99	0.77	0.72	0.63	0.84	0.84	0.68	0.61	0.81	0.79	0.60	0.66
12/23/2005	0.91	0.86	0.78	0.78	0.91	0.90	-	-	0.73	0.78	0.90	0.89	0.81	0.86	0.86	0.86	0.91	0.80
12/27/2005	0.73	0.69	0.76	0.47	0.53	0.54	-	-	0.57	0.52	0.63	0.68	0.48	0.48	0.69	0.71	0.47	0.48
12/30/2005	0.65	0.69	0.43	0.42	0.67	0.71	-	-	0.42	0.41	0.70	0.68	0.45	0.44	0.65	0.63	0.41	0.40
1/2/2006	0.72	0.72	0.51	0.47	0.72	0.74	-	-	0.51	0.48	0.80	0.77	0.49	0.50	0.68	0.71	0.51	0.47
1/6/2006	0.77	0.75	0.58	0.53	0.78	0.77	0.93	0.65	0.50	0.57	0.77	0.75	0.53	0.54	0.75	0.71	0.49	0.45
1/10/2006	0.63	0.59	0.36	0.35	0.66	0.62	-	-	0.32	0.30	0.67	0.66	0.31	0.31	0.53	0.59	0.28	0.25
1/13/2006	0.69	0.75	0.48	0.48	0.74	0.75	-	-	0.53	0.53	0.78	0.77	0.51	0.53	0.68	0.68	0.44	0.43
1/17/2006	0.80	0.84	0.74	0.78	0.83	0.81	0.99	0.85	0.69	0.74	0.84	0.79	0.79	0.78	0.80	0.80	0.76	0.75
1/20/2006	0.64	0.61	0.36	0.38	0.62	0.64	0.99	0.78	0.07	0.36	0.66	0.65	0.42	0.40	0.57	0.58	0.30	0.29
1/24/2009	0.71	0.74	0.54	0.56	0.79	0.79	0.87	0.47	0.66	0.53	0.81	0.79	0.64	0.59	0.74	0.76	0.53	0.51
1/27/2006	0.72	0.72	0.55	0.35	0.60	0.60	0.38	0.61	0.55	0.56	0.81	0.79	0.60	0.61	0.66	0.68	0.44	0.42
1/31/2006	0.57	0.60	0.32	0.49	0.75	0.78	0.99	0.88	0.40	0.37	0.63	0.62	0.39	0.36	0.42	0.53	0.27	0.24
2/7/2006	0.77	0.80	0.81	0.62	0.78	0.80	1.00	0.98	0.75	0.78	0.83	0.82	0.82	0.79	0.80	0.79	0.76	0.74
2/10/2006	0.62	0.64	0.39	0.27	0.57	0.54	-	-	0.41	0.36	0.72	0.69	0.38	0.43	0.63	0.67	0.39	0.37
2/14/2006	0.63	0.63	0.64	0.17	0.67	0.73	0.96	0.72	0.34	0.36	0.63	0.62	0.42	0.34	0.55	0.49	0.33	0.39
2/17/2006	0.61	0.68	0.48	0.36	0.59	0.59	-	-	0.43	0.38	0.71	0.71	0.38	0.45	0.76	0.81	0.46	0.37
2/21/2006	0.67	0.71	0.44	0.45	0.72	0.72	-	-	0.44	0.46	0.77	0.72	0.49	0.47	0.72	0.72	0.42	0.50

Date	TVO1	TVO2	TVR1	TVR2	TO1	TO2	C1	C2	TR1	TR2	EO1	EO2	ER1	ER2	EVO1	EVO2	EVR1	EVR2
2/24/2006	0.61	0.65	0.39	0.20	0.43	0.40	-	-	0.33	0.33	0.66	0.67	0.36	0.41	0.66	0.64	0.37	0.30
2/28/2006	0.63	0.66	0.44	0.90	0.97	0.88	0.99	0.92	0.52	0.49	0.73	0.71	0.53	0.52	0.23	0.60	0.43	0.41
3/3/2006	0.65	0.63	0.43	0.44	0.62	0.63	-	-	0.43	0.41	0.73	0.70	0.48	0.45	0.73	0.71	0.49	0.47
3/7/2006	0.59	0.57	0.26	0.24	0.53	0.54	-	-	0.29	0.25	0.64	0.60	0.27	0.30	0.58	0.56	0.24	0.19
3/10/2006	0.55	0.49	0.18	0.13	0.49	0.46	-	-	0.20	0.17	0.60	0.58	0.20	0.22	0.51	0.55	0.15	0.13
3/13/2006	0.59	0.55	0.26	0.20	0.50	0.50	-	-	0.35	0.27	0.65	0.64	0.35	0.38	0.59	0.59	0.30	0.23
3/17/2006	0.63	0.60	0.22	0.24	0.50	0.53	-	-	0.28	0.28	0.66	0.64	0.29	0.30	0.58	0.60	0.28	0.22
3/21/2006	0.43	0.39	0.07	0.04	0.40	0.36	-	-	0.09	0.07	0.49	0.49	0.09	0.11	0.40	0.41	0.07	0.04
3/24/2006	0.42	0.42	0.04	0.00	0.48	0.40	-	-	0.20	0.13	0.59	0.58	0.16	0.15	0.45	0.45	0.04	0.02
3/28/2006	0.53	0.44	0.13	0.02	0.46	0.46	-	-	0.17	0.18	0.62	0.55	0.17	0.21	0.47	0.49	0.06	0.10
3/31/2006	0.49	0.46	0.11	0.02	0.46	0.41	-	-	0.20	0.17	0.59	0.59	0.22	0.21	0.52	0.51	0.07	0.11
4/4/2006	0.51	0.30	0.17	0.08	0.50	0.48	-	-	0.26	0.25	0.60	0.59	0.21	0.24	0.53	0.53	0.15	0.17
4/7/2006	0.45	0.39	0.85	0.02	0.51	0.47	-	-	0.17	0.15	0.58	0.57	0.17	0.17	0.48	0.43	0.02	0.04
4/11/2006	0.54	0.55	0.34	0.37	0.56	0.55	1.00	0.97	0.49	0.46	0.65	0.63	0.50	0.52	0.51	0.53	0.37	0.36
4/14/2006	0.55	0.49	0.27	0.16	0.54	0.54	-	-	0.34	0.31	0.75	0.69	0.41	0.39	0.59	0.61	0.30	0.28
4/18/2006	0.46	0.48	0.18	0.06	0.51	0.46	-	-	0.19	0.04	0.61	0.60	0.23	0.21	0.49	0.49	0.11	0.15
4/21/2006	0.40	0.28	0.02	0.00	0.43	0.44	-	-	0.17	0.11	0.59	0.57	0.20	0.19	0.38	0.52	0.04	0.06
4/25/2006	0.41	0.39	0.08	0.04	0.49	0.46	1.00	0.70	0.27	0.23	0.57	0.59	0.30	0.32	0.44	0.43	0.06	0.13
4/28/2006	0.43	0.41	0.09	0.02	0.47	0.32	0.92	-	0.15	0.10	0.60	0.56	0.22	0.17	0.47	0.47	0.06	0.09
5/2/2006	0.45	0.35	0.04	0.00	0.49	0.49	-	-	0.13	0.13	0.58	0.60	0.17	0.09	0.42	0.43	0.02	0.02
5/5/2006	0.32	0.28	0.05	0.00	0.40	0.36	-	-	0.07	0.08	0.58	0.47	0.12	0.14	0.35	0.45	0.00	0.00
5/12/2006	0.27	0.23	0.12	0.05	0.34	0.36	1.00	0.90	0.25	0.24	0.47	0.45	0.31	0.33	0.30	0.29	0.12	0.12
5/16/2006	0.73	0.69	0.53	0.43	0.81	0.89	-	-	0.69	0.63	0.82	0.81	0.67	0.65	0.84	0.79	0.70	0.74
5/19/2006	0.73	0.62	0.52	0.43	0.86	0.79	-	-	0.75	0.77	0.96	0.90	0.87	0.87	0.69	0.74	0.51	0.59
5/23/2006	0.45	0.42	0.13	0.05	0.51	0.52	-	-	0.22	0.16	0.62	0.62	0.21	0.34	0.45	0.53	0.12	0.16
5/26/2006	0.32	0.27	0.05	0.00	0.42	0.38	0.97	0.91	0.12	0.16	0.44	0.45	0.09	0.15	0.32	0.33	0.02	0.02
5/30/2006	0.75	0.73	0.66	0.63	0.79	0.78	1.00	0.61	0.77	0.76	0.83	0.80	0.86	0.85	0.76	0.78	0.70	0.74
6/2/2006	0.33	0.31	0.14	0.06	0.41	0.40	0.98	0.79	0.26	0.38	0.44	0.45	0.21	0.28	0.34	0.41	0.08	0.07
6/6/2006	0.43	0.43	0.19	0.14	0.47	0.40	0.99	1.00	0.37	0.37	0.51	0.53	0.46	0.44	0.50	0.47	0.26	0.28
6/9/2006	0.77	0.70	0.61	0.53	0.81	0.78	0.99	0.93	0.60	0.69	0.81	0.80	0.65	0.70	0.82	0.74	0.70	0.68
6/13/2006	0.57	0.59	0.52	0.51	0.62	0.62	-	-	0.60	0.66	0.66	0.67	0.68	0.67	0.61	0.60	0.57	0.56
6/16/2006	0.66	0.70	0.58	0.58	0.73	0.90	1.00	0.76	0.85	0.66	0.72	0.73	0.73	0.77	0.73	0.68	0.64	0.70
6/20/2006	0.48	0.47	0.25	0.17	0.52	0.48	1.00	0.86	0.00	0.30	0.58	0.56	0.33	0.32	0.54	0.54	0.22	0.24
6/23/2006	0.51	0.52	0.26	0.07	0.58	0.53	0.95	0.45	0.24	0.32	0.66	0.66	0.39	0.41	0.56	0.58	0.18	0.34

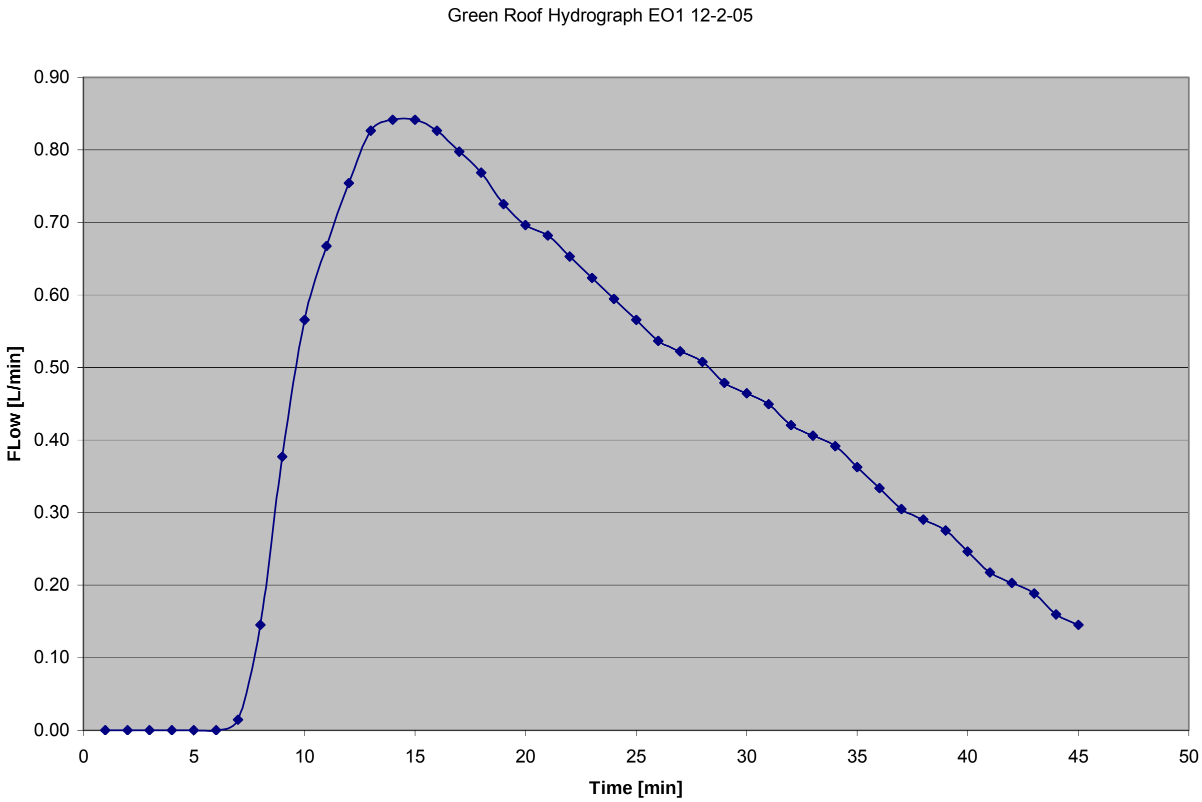
Date	TVO1	TVO2	TVR1	TVR2	TO1	TO2	C1	C2	TR1	TR2	EO1	EO2	ER1	ER2	EVO1	EVO2	EVR1	EVR2
6/27/2006	0.64	0.65	0.59	0.59	0.68	0.67	-	-	0.66	0.65	0.72	0.71	0.72	0.70	0.69	0.69	0.64	0.64
6/30/2006	0.66	0.75	0.66	0.65	0.77	0.75	1.00	0.95	0.71	0.69	0.78	0.78	0.76	0.74	0.80	0.79	0.67	0.70
7/4/2006	0.64	0.65	0.45	0.44	0.66	0.66	1.00	0.93	0.52	0.49	0.66	0.71	0.60	0.61	0.60	0.62	0.45	0.40
7/7/2006	0.48	0.53	0.37	0.35	0.56	0.55	0.98	0.90	0.36	0.40	0.63	0.58	0.48	0.48	0.58	0.58	0.41	0.40
7/11/2006	0.55	0.66	0.56	0.53	0.68	0.64	0.99	0.99	0.59	0.40	0.66	0.73	0.73	0.75	0.69	0.70	0.58	0.64
7/14/2006	0.51	0.52	0.39	0.36	0.60	0.57	0.99	0.88	0.48	0.45	0.63	0.67	0.56	0.61	0.59	0.58	0.45	0.47
7/18/2006	0.57	0.60	0.50	0.49	0.62	0.59	1.00	0.65	0.53	0.56	0.54	0.49	0.38	0.32	0.59	0.61	0.47	0.55
Average	0.59	0.57	0.41	0.35	0.63	0.62	0.96	0.86	0.45	0.43	0.70	0.68	0.48	0.49	0.61	0.63	0.41	0.42
RPD	3.85		13.38		1.19		11.09		2.98		2.30		0.69		2.16		2.80	
s	0.159	0.175	0.228	0.240	0.156	0.169	0.093	0.141	0.231	0.225	0.133	0.129	0.236	0.231	0.150	0.138	0.239	0.239
s^2	0.025	0.031	0.052	0.058	0.024	0.029	0.009	0.020	0.053	0.051	0.018	0.017	0.056	0.054	0.023	0.019	0.057	0.057
n	104	104	104	104	104	104	59	57	103	103	103	103	103	103	102	101	101	102
Average	0.58		0.38		0.63		0.91		0.44		0.69		0.48		0.62		0.41	
RPD (Plants no plants)	-7.97		-14.86												-10.60		-15.43	
RPD (Tire crumb vs EC)	-6.96		-8.79		-9.59				-9.34									

Date: 12/2/05				Chamber: C1	Irr. Amount: 37.71 L		
Irrigation is to take 10 minutes from start to finish							
Control Chamber Hydrograph Data							
Time [min]	In. Collected	Volume Collected [L]	Average	Average	Average	Average	Average
0	0	0.00					
1	10.25	2.97	1.49	0.74	0.37	0.19	0.09
2	10.8	3.13	3.05	2.27	1.51	0.94	0.56
3	8.25	2.39	2.76	2.91	2.59	2.05	1.49
4	9.25	2.68	2.54	2.65	2.78	2.68	2.37
5	13.75	3.99	3.34	2.94	2.79	2.79	2.74
6	17	4.93	4.46	3.90	3.42	3.11	2.95
7	13.6	3.95	4.44	4.45	4.17	3.80	3.45
8	9.9	2.87	3.41	3.92	4.19	4.18	3.99
9	11.5	3.34	3.10	3.26	3.59	3.89	4.03
10	11.5	3.34	3.34	3.22	3.24	3.41	3.65
11	8.7	2.52	2.93	3.13	3.18	3.21	3.31
12	1	0.29	1.41	2.17	2.65	2.91	3.06
13	0.25	0.07	0.18	0.79	1.48	2.07	2.49
14	0.1	0.03	0.05	0.12	0.46	0.97	1.52
Total Volume		36.51	36.49				
% Returned	96.82	0.97	0.97				
i= (liters/min)	3.771						
equivalent in/hr	6						


Hydrograph C1 12-2-05
Flow [L/Min]
Time [min]
4.50
4.00
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
0
2
4
6
8
10
12
14
16

Date: 12/2/05	Chamber: EO1	Irr. Amount: 37.71 L	
Irrigation is to take 10 minutes from start to finish			
Green Roof Hydrograph EO1			
Time [min]	In. Collected	Volume Collected [L]	Average
0	0	0.00	
1	0	0.00	0.00
2	0	0.00	0.00
3	0	0.00	0.00
4	0	0.00	0.00
5	0	0.00	0.00
6	0	0.00	0.00
7	0.1	0.03	0.01
8	0.9	0.26	0.15
9	1.7	0.49	0.38
10	2.2	0.64	0.57
11	2.4	0.70	0.67
12	2.8	0.81	0.75
13	2.9	0.84	0.83
14	2.9	0.84	0.84
15	2.9	0.84	0.84
16	2.8	0.81	0.83
17	2.7	0.78	0.80
18	2.6	0.75	0.77
19	2.4	0.70	0.73
20	2.4	0.70	0.70
21	2.3	0.67	0.68
22	2.2	0.64	0.65
23	2.1	0.61	0.62
24	2	0.58	0.59
25	1.9	0.55	0.57
26	1.8	0.52	0.54

Time [min]	In. Collected	Volume Collected [L]	Average
27	1.8	0.52	0.52
28	1.7	0.49	0.51
29	1.6	0.46	0.48
30	1.6	0.46	0.46
31	1.5	0.44	0.45
32	1.4	0.41	0.42
33	1.4	0.41	0.41
34	1.3	0.38	0.39
35	1.2	0.35	0.36
36	1.1	0.32	0.33
37	1	0.29	0.30
38	1	0.29	0.29
39	0.9	0.26	0.28
40	0.8	0.23	0.25
41	0.7	0.20	0.22
42	0.7	0.20	0.20
43	0.6	0.17	0.19
44	0.5	0.15	0.16
45	0.5	0.15	0.15
Total Volume		18.94	18.87
% Returned	50.24	0.50	0.50
i= (liters/min)	3.771		
equivalent in/hr	6		



Green Roof Hydrograph EO1 12-2-05
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
FLow [L/min]
0
5
10
15
20
25
30
35
40
45
50
Time [min]

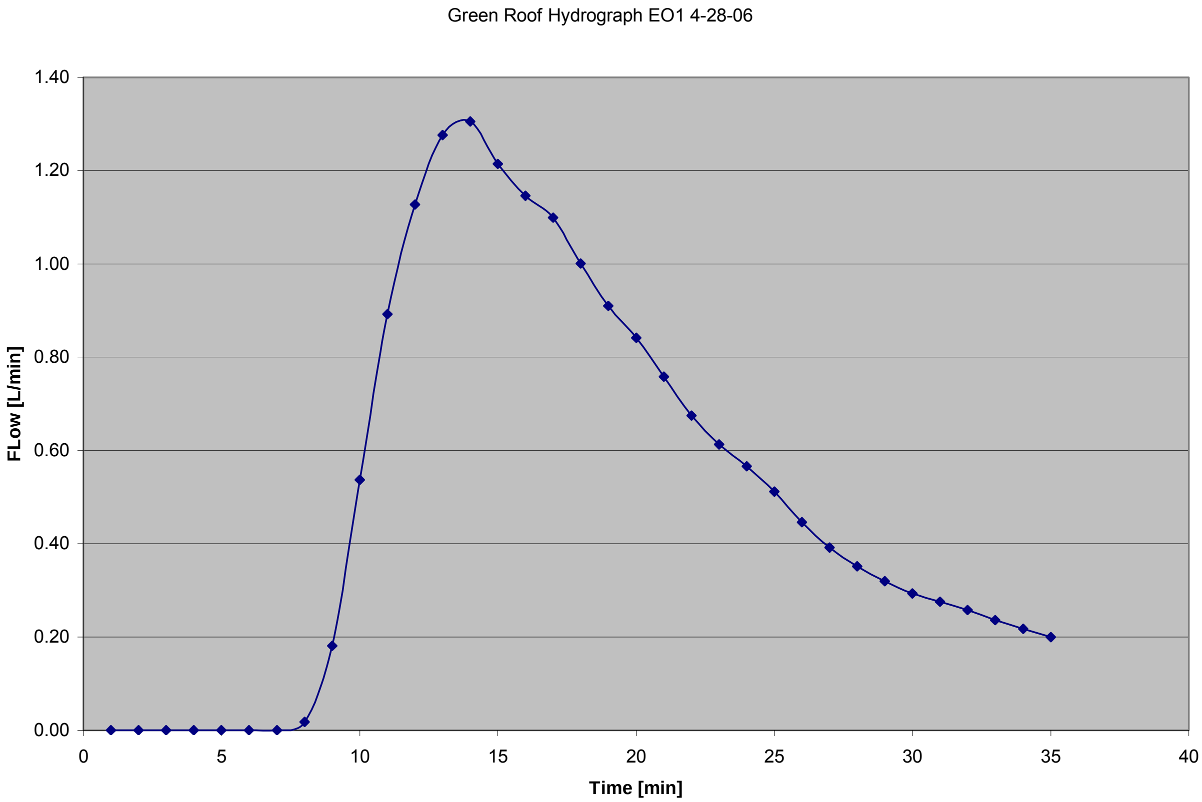
Date: 1/27/06		Chamber: EO1	Irr. Amount: 37.71 L	
Irrigation is to take 10 minutes from start to finish				
Green Roof Hydrograph EO1				
Time [min]	In. Collected	Volume Collected [L]	Average	Average
0	0	0.00		
1	0	0.00	0.00	0.00
2	0	0.00	0.00	0.00
3	0	0.00	0.00	0.00
4	0	0.00	0.00	0.00
5	0.1	0.03	0.01	0.01
6	0.4	0.12	0.07	0.04
7	0.5	0.15	0.13	0.10
8	1.2	0.35	0.25	0.19
9	2.1	0.61	0.48	0.36
10	2.9	0.84	0.73	0.60
11	3.3	0.96	0.90	0.81
12	3.4	0.99	0.97	0.94
13	3.4	0.99	0.99	0.98
14	3.4	0.99	0.99	0.99
15	3.1	0.90	0.94	0.96
16	3.4	0.99	0.94	0.94
17	2.2	0.64	0.81	0.88
18	2.6	0.75	0.70	0.75
19	2.5	0.73	0.74	0.72
20	2.4	0.70	0.71	0.73
21	2.4	0.70	0.70	0.70
22	2.2	0.64	0.67	0.68
23	2.2	0.64	0.64	0.65
24	2.2	0.64	0.64	0.64
Time [min]	In. Collected	Volume Collected [L]	Average	Average

25	1.96	0.57	0.60	0.62
26	1.9	0.55	0.56	0.58
27	1.9	0.55	0.55	0.56
28	1.8	0.52	0.54	0.54
29	1.7	0.49	0.51	0.52
30	1.6	0.46	0.48	0.49
31	1.5	0.44	0.45	0.46
32	1.7	0.49	0.46	0.46
33	1.1	0.32	0.41	0.44
34	1.3	0.38	0.35	0.38
35	1.2	0.35	0.36	0.36
36	1.2	0.35	0.35	0.36
37	0.9	0.26	0.30	0.33
38	1	0.29	0.28	0.29
39	1	0.29	0.29	0.28
40	1	0.29	0.29	0.29
41	0.9	0.26	0.28	0.28
42	0.8	0.23	0.25	0.26
43	0.8	0.23	0.23	0.24
44	0.7	0.20	0.22	0.22
45	0.6	0.17	0.19	0.20
Total Volume		21.02	20.93	20.84
% Returned	55.74	0.56	0.56	0.55
i= (liters/min)	3.771			
equivalent in/hr	6			


Green Roof Hydrograph EO1 1-27-06
FLow [L/min]
Time [min]
1.20
1.00
0.80
0.60
0.40
0.20
0.00
0
5
10
15
20
25
30
35
40
45
50

Date: 4/28/06		Chamber: EO1	Irr. Amount: 37.71 L	
Irrigation is to take 10 minutes from start to finish				
Green Roof Hydrograph EO1				
Time [min]	In. Collected	Volume Collected [L]	Average	Average
0	0	0.00		
1	0	0.00	0.00	0.00
2	0	0.00	0.00	0.00
3	0	0.00	0.00	0.00
4	0	0.00	0.00	0.00
5	0	0.00	0.00	0.00
6	0	0.00	0.00	0.00
7	0	0.00	0.00	0.00
8	0.25	0.07	0.04	0.02
9	2	0.58	0.33	0.18
10	3.15	0.91	0.75	0.54
11	4	1.16	1.04	0.89
12	4.4	1.28	1.22	1.13
13	4.8	1.39	1.33	1.28
14	4	1.16	1.28	1.31
15	3.95	1.15	1.15	1.21
16	3.9	1.13	1.14	1.15
17	3.4	0.99	1.06	1.10
18	3.1	0.90	0.94	1.00
19	2.95	0.86	0.88	0.91
20	2.6	0.75	0.81	0.84
21	2.3	0.67	0.71	0.76
22	2.1	0.61	0.64	0.67
23	1.95	0.57	0.59	0.61
24	1.8	0.52	0.54	0.57
25	1.5	0.44	0.48	0.51
26	1.35	0.39	0.41	0.45

Time [min]	In. Collected	Volume Collected [L]	Average	Average
27	1.2	0.35	0.37	0.39
28	1.1	0.32	0.33	0.35
29	1	0.29	0.30	0.32
30	0.95	0.28	0.28	0.29
31	0.9	0.26	0.27	0.28
32	0.8	0.23	0.25	0.26
33	0.75	0.22	0.22	0.24
34	0.7	0.20	0.21	0.22
35	0.6	0.17	0.19	0.20
Total Volume		17.84	17.75	17.66
% Returned	47.31	0.47	0.47	0.47
i= (liters/min)	3.771			
equivalent in/hr	6			


Green Roof Hydrograph EO1 4-28-06
FLow [L/min]
Time [min]
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
0
5
10
15
20
25
30
35
40

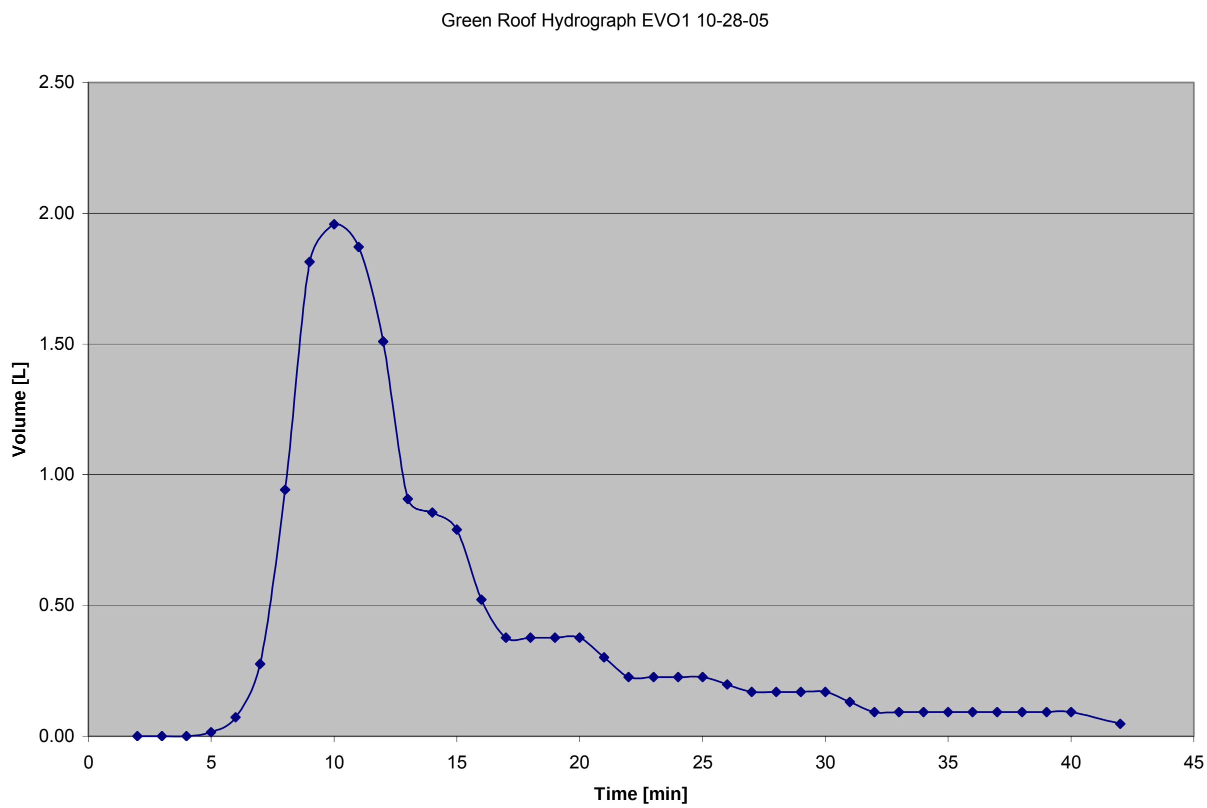
Date: 7/18/06		Chamber: EO1	Irr. Amount: 37.71 L
Irrigation is to take 10 minutes from start to finish			
Green Roof Hydrograph EO1			
Time [min]	In. Collected	Volume Collected [L]	Average
0	0	0.00	
1	0	0.00	0.00
2	0	0.00	0.00
3	0	0.00	0.00
4	0.2	0.06	0.03
5	0.9	0.26	0.16
6	1.2	0.35	0.30
7	1.4	0.41	0.38
8	1.8	0.52	0.46
9	2.1	0.61	0.57
10	2.3	0.67	0.64
11	2.5	0.73	0.70
12	2.8	0.81	0.77
13	2.8	0.81	0.81
14	2.7	0.78	0.80
15	2.6	0.75	0.77
16	2.6	0.75	0.75
17	2.5	0.73	0.74
18	2.4	0.70	0.71
19	2.4	0.70	0.70
20	2.4	0.70	0.70
21	2.2	0.64	0.67
22	2.1	0.61	0.62
23	2.1	0.61	0.61
24	2.1	0.61	0.61
25	2	0.58	0.59
26	2	0.58	0.58

Time [min]	In. Collected	Volume Collected [L]	Average
27	2	0.58	0.58
28	2	0.58	0.58
29	1.9	0.55	0.57
30	1.9	0.55	0.55
31	1.9	0.55	0.55
32	1.7	0.49	0.52
33	1.7	0.49	0.49
34	1.7	0.49	0.49
35	1.7	0.49	0.49
36	1.5	0.44	0.46
37	1.4	0.41	0.42
38	1.4	0.41	0.41
39	1.4	0.41	0.41
40	1.3	0.38	0.39
41	1.3	0.38	0.38
42	1.3	0.38	0.38
43	1.2	0.35	0.36
44	1.2	0.35	0.35
45	1.1	0.32	0.33
46	1.1	0.32	0.32
47	1.1	0.32	0.32
48	1	0.29	0.30
49	1	0.29	0.29
50	1	0.29	0.29
51	0.9	0.26	0.28
52	0.9	0.26	0.26
53	0.8	0.23	0.25
Total Volume		24.80	22.38
% Returned	65.78	0.66	0.59
i= (liters/min)	3.771		
equivalent in/hr	6		


Green Roof Hydrograph EO1 7-18-06
FLow [L/min]
0.00
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
0.90
Time [min]
0
10
20
30
40
50
60

Date: 10/28/05				Chamber: EVO1	Irr. Amount: 37.71 L		
Irrigation is to take 10 minutes from start to finish							
Green Roof Hydrograph EVO1							
Time [min]	In. Collected	Volume Collected [L]	Average	Time [min]	In. Collected	Volume Collected [L]	Average
0	0	0.00		31	0.32	0.09	0.13
1	0	0.00		32	0.32	0.09	0.09
2	0	0.00	0.00	33	0.32	0.09	0.09
3	0	0.00	0.00	34	0.32	0.09	0.09
4	0	0.00	0.00	35	0.32	0.09	0.09
5	0.1	0.03	0.01	36	0.32	0.09	0.09
6	0.4	0.12	0.07	37	0.32	0.09	0.09
7	1.5	0.44	0.28	38	0.32	0.09	0.09
8	5	1.45	0.94	39	0.32	0.09	0.09
9	7.5	2.18	1.81	40	0.32	0.09	0.09
10	6	1.74	1.96				0.05
11	6.9	2.00	1.87	Total Volume		16.13	16.13
12	3.5	1.02	1.51	% Returned	42.77	C=0.43	0.43
13	2.75	0.80	0.91	i= (liters/min)	3.771		
14	3.15	0.91	0.86	equivalent in/hr	6		
15	2.3	0.67	0.79				
16	1.3	0.38	0.52				
17	1.3	0.38	0.38				
18	1.3	0.38	0.38				
19	1.3	0.38	0.38				
20	1.3	0.38	0.38				
21	0.78	0.23	0.30				
22	0.78	0.23	0.23				
23	0.78	0.23	0.23				
24	0.78	0.23	0.23				
25	0.78	0.23	0.23				

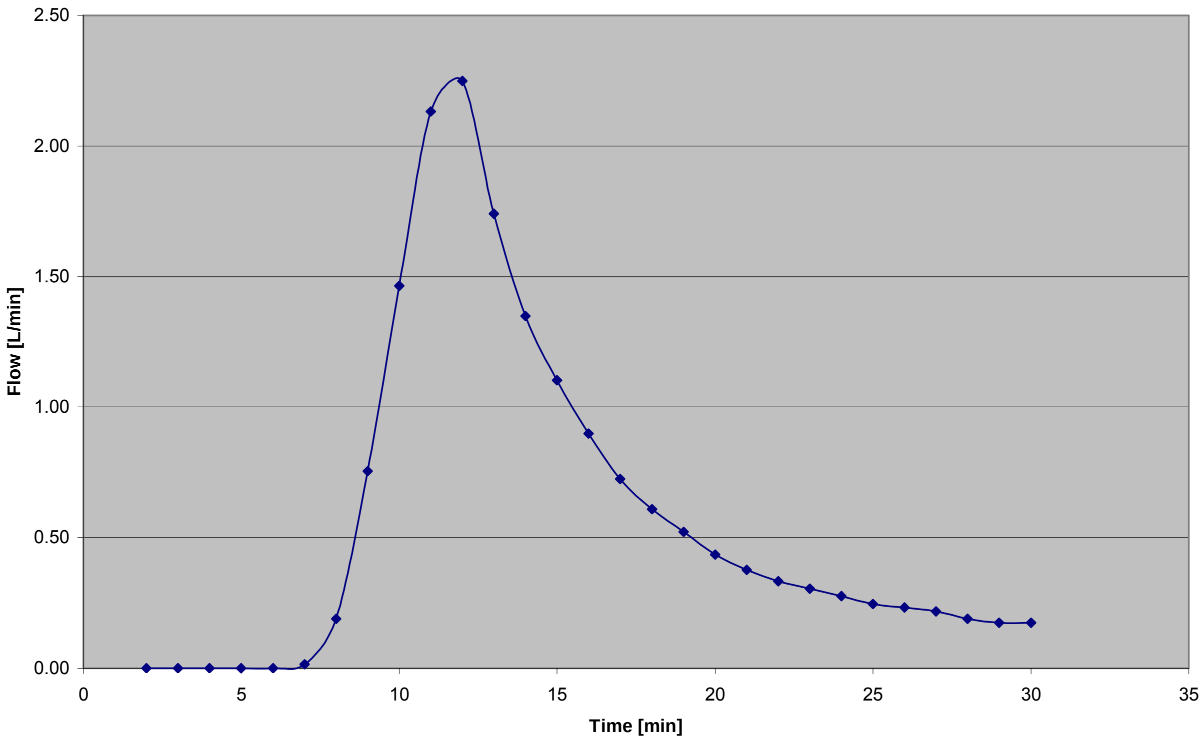
Time [min]	In. Collected	Volume Collected [L]	Average	Time [min]	In. Collected	Volume Collected [L]	Average
26	0.58	0.17	0.20				
27	0.58	0.17	0.17				
28	0.58	0.17	0.17				
29	0.58	0.17	0.17				
30	0.58	0.17	0.17				


Green Roof Hydrograph EVO1 10-28-05
Volume [L]
2.50
2.00
1.50
1.00
0.50
0.00
0
5
10
15
20
25
30
35
40
45
Time [min]

Date: 12/2/05		Chamber: EVO1	Irr. Amount: 37.71 L
Irrigation is to take 10 minutes from start to finish			
Green Roof Hydrograph EVO1			
Time [min]	In. Collected	Volume Collected [L]	Average
0	0	0.00	
1	0	0.00	
2	0	0.00	0.00
3	0	0.00	0.00
4	0	0.00	0.00
5	0	0.00	0.00
6	0	0.00	0.00
7	0.1	0.03	0.01
8	1.2	0.35	0.19
9	4	1.16	0.75
10	6.1	1.77	1.47
11	8.6	2.49	2.13
12	6.9	2.00	2.25
13	5.1	1.48	1.74
14	4.2	1.22	1.35
15	3.4	0.99	1.10
16	2.8	0.81	0.90
17	2.2	0.64	0.73
18	2	0.58	0.61
19	1.6	0.46	0.52
20	1.4	0.41	0.44
21	1.2	0.35	0.38
22	1.1	0.32	0.33
23	1	0.29	0.30
24	0.9	0.26	0.28
25	0.8	0.23	0.25

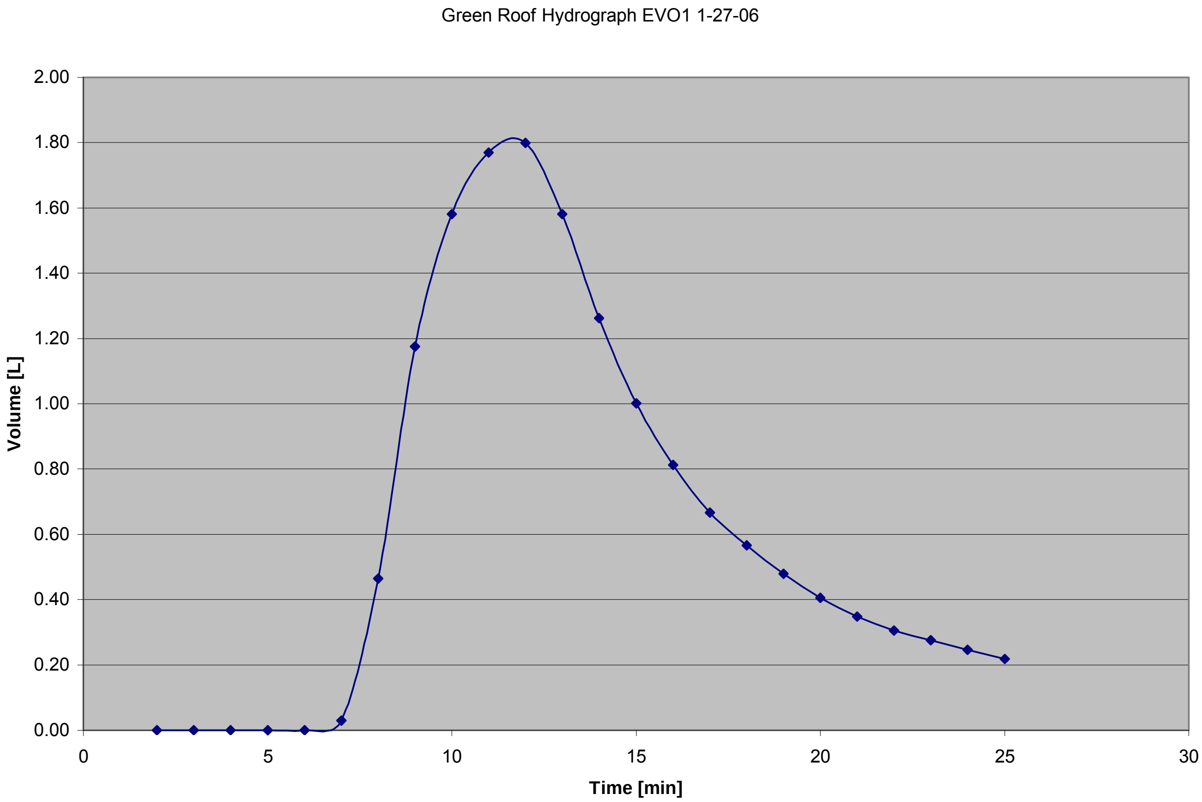
Time [min]	In. Collected	Volume Collected [L]	Average
26	0.8	0.23	0.23
27	0.7	0.20	0.22
28	0.6	0.17	0.19
29	0.6	0.17	0.17
30	0.6	0.17	0.17
Total Volume		16.80	16.71
% Returned	44.54	C=0.45	0.44
i= (liters/min)	3.771		
equivalent in/hr	6		

Green Roof Hydrograph EVO1 12-2-05



Date: 1/27/06		Chamber: EVO1	Irr. Amount: 37.71 L
Irrigation is to take 10 minutes from start to finish			
Green Roof Hydrograph EVO1			
Time [min]	In. Collected	Volume Collected [L]	Average
0	0	0.00	
1	0	0.00	
2	0	0.00	0.00
3	0	0.00	0.00
4	0	0.00	0.00
5	0	0.00	0.00
6	0	0.00	0.00
7	0.2	0.06	0.03
8	3	0.87	0.46
9	5.1	1.48	1.17
10	5.8	1.68	1.58
11	6.4	1.86	1.77
12	6	1.74	1.80
13	4.9	1.42	1.58
14	3.8	1.10	1.26
15	3.1	0.90	1.00
16	2.5	0.73	0.81
17	2.1	0.61	0.67
18	1.8	0.52	0.57
19	1.5	0.44	0.48
20	1.3	0.38	0.41
21	1.1	0.32	0.35
22	1	0.29	0.30
23	0.9	0.26	0.28
24	0.8	0.23	0.25
25	0.7	0.20	0.22

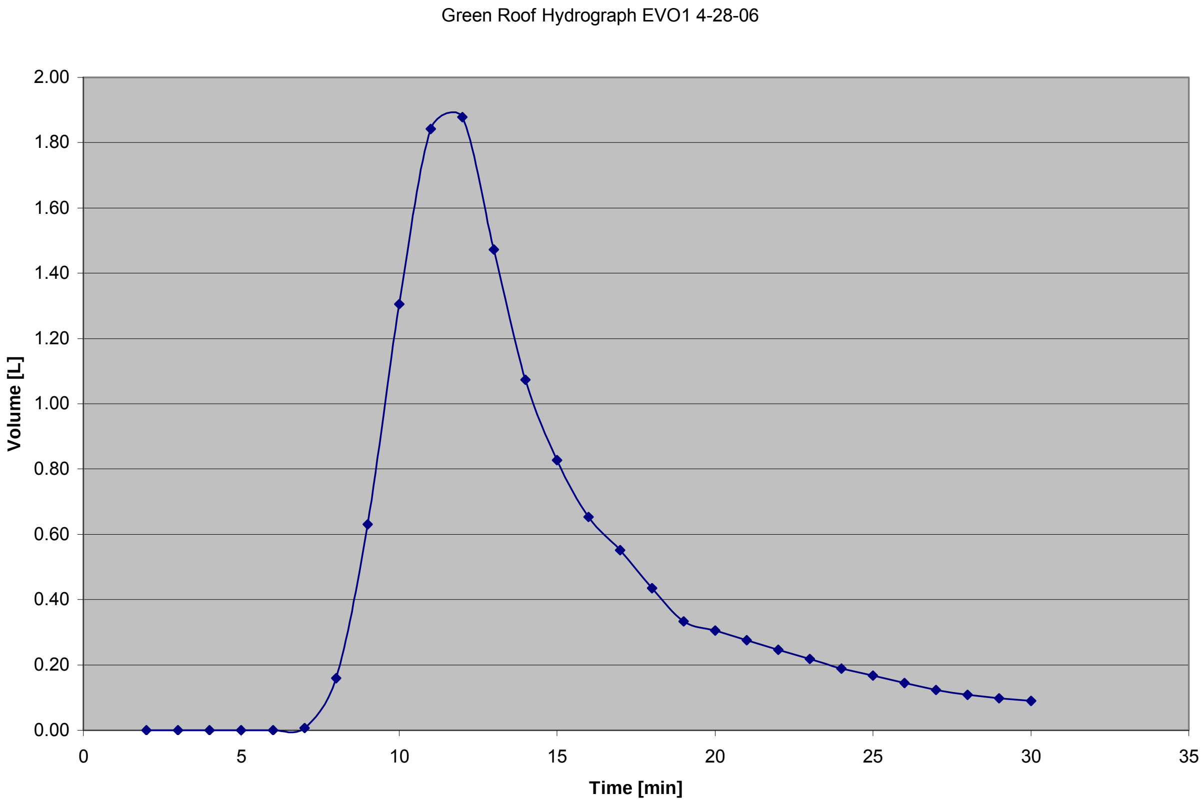
Time [min]	In. Collected	Volume Collected [L]	Average
Total Volume		15.09	14.98
% Returned	40.00	0.40	0.40
i= (liters/min)	3.771		
equivalent in/hr	6		



Green Roof Hydrograph EVO1 1-27-06
Volume [L]
2.00
1.80
1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
0
5
10
15
20
25
30
Time [min]

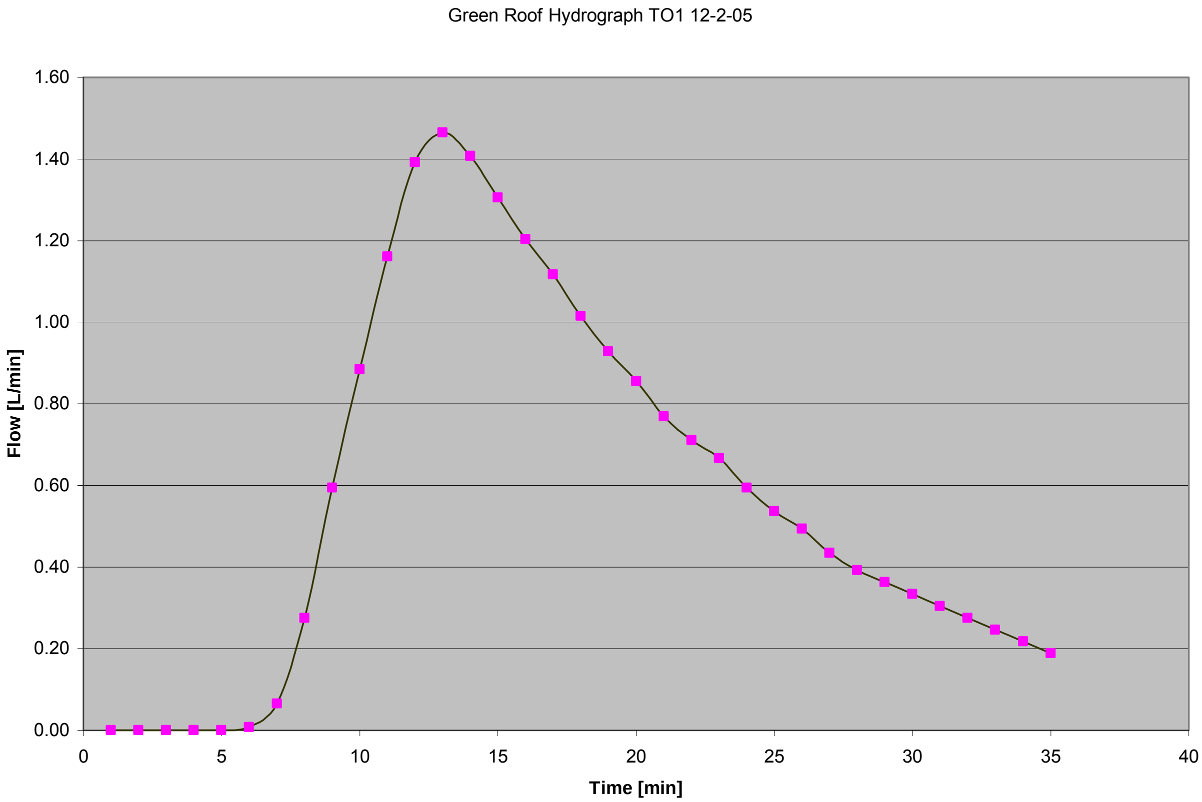
Date: 4/28/06		Chamber: EVO1	Irr. Amount: 37.71 L
Irrigation is to take 10 minutes from start to finish			
Green Roof Hydrograph EVO1			
Time [min]	In. Collected	Volume Collected [L]	Average
0	0	0.00	
1	0	0.00	
2	0	0.00	0.00
3	0	0.00	0.00
4	0	0.00	0.00
5	0	0.00	0.00
6	0	0.00	0.00
7	0.05	0.01	0.01
8	1.05	0.30	0.16
9	3.3	0.96	0.63
10	5.7	1.65	1.31
11	7	2.03	1.84
12	5.95	1.73	1.88
13	4.2	1.22	1.47
14	3.2	0.93	1.07
15	2.5	0.73	0.83
16	2	0.58	0.65
17	1.8	0.52	0.55
18	1.2	0.35	0.44
19	1.1	0.32	0.33
20	1	0.29	0.30
21	0.9	0.26	0.28
22	0.8	0.23	0.25
23	0.7	0.20	0.22
24	0.6	0.17	0.19
25	0.55	0.16	0.17

Time [min]	In. Collected	Volume Collected [L]	Average
26	0.45	0.13	0.15
27	0.4	0.12	0.12
28	0.35	0.10	0.11
29	0.32	0.09	0.10
30	0.3	0.09	0.09
Total Volume		13.18	13.13
% Returned	34.94	0.35	0.35
i= (liters/min)	3.771		
equivalent in/hr	6		


Green Roof Hydrograph EVO1 4-28-06
Volume [L]
2.00
1.80
1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
0
5
10
15
20
25
30
35
Time [min]

Date: 1/27/06		Chamber: TO1	Irr. Amount: 37.71 L
Irrigation is to take 10 minutes from start to finish			
Green Roof Hydrograph TO1			
Time [min]	In. Collected	Volume Collected [L]	Average
0	0	0.00	
1	0	0.00	0.00
2	0	0.00	0.00
3	0	0.00	0.00
4	0	0.00	0.00
5	0	0.00	0.00
6	0.05	0.01	0.01
7	0.4	0.12	0.07
8	1.5	0.44	0.28
9	2.6	0.75	0.59
10	3.5	1.02	0.88
11	4.5	1.31	1.16
12	5.1	1.48	1.39
13	5	1.45	1.47
14	4.7	1.36	1.41
15	4.3	1.25	1.31
16	4	1.16	1.20
17	3.7	1.07	1.12
18	3.3	0.96	1.02
19	3.1	0.90	0.93
20	2.8	0.81	0.86
21	2.5	0.73	0.77
22	2.4	0.70	0.71
23	2.2	0.64	0.67
24	1.9	0.55	0.59
25	1.8	0.52	0.54
26	1.6	0.46	0.49

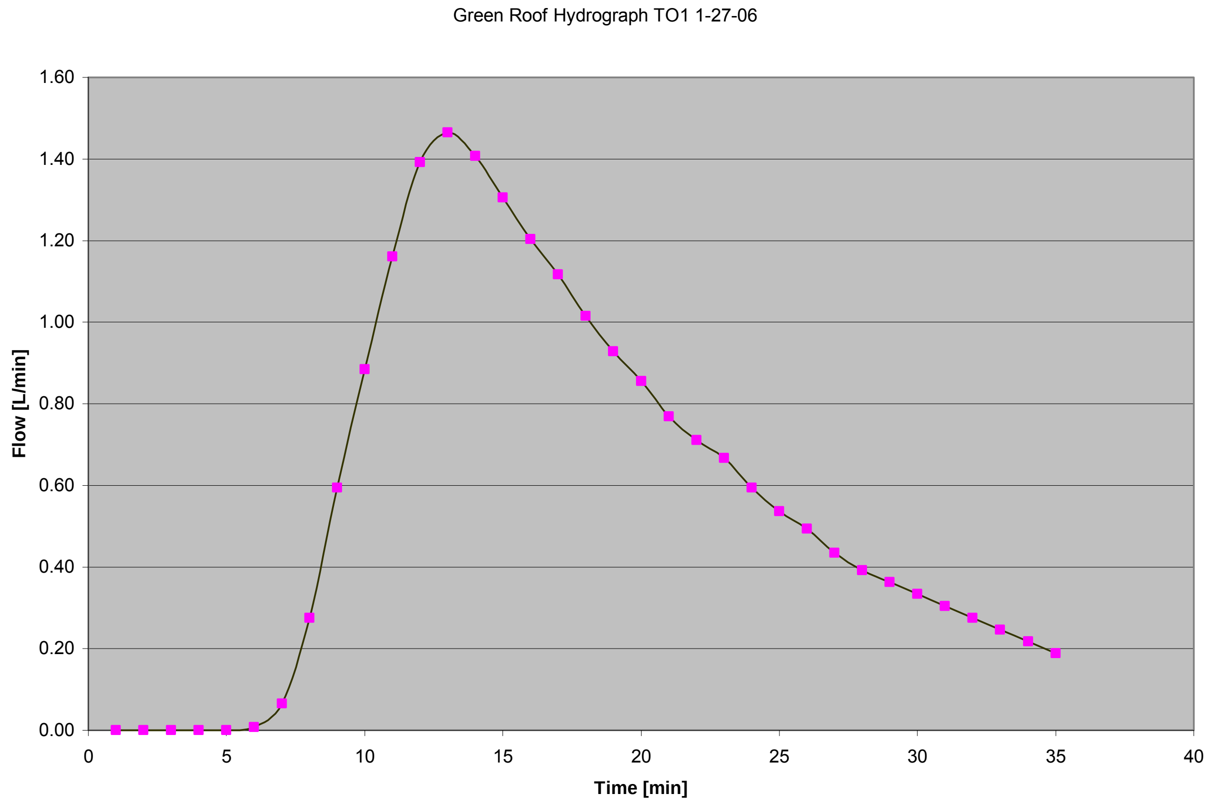
Time [min]	In. Collected	Volume Collected [L]	Average
27	1.4	0.41	0.44
28	1.3	0.38	0.39
29	1.2	0.35	0.36
30	1.1	0.32	0.33
31	1	0.29	0.30
32	0.9	0.26	0.28
33	0.8	0.23	0.25
34	0.7	0.20	0.22
35	0.6	0.17	0.19
Total Volume		20.29	20.21
% Returned	53.81	0.54	0.54
i= (liters/min)	3.771		
equivalent in/hr	6		



Green Roof Hydrograph TO1 12-2-05
Flow [L/min]
1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
0
5
10
15
20
25
30
35
40
Time [min]

Date: 1/27/06		Chamber: TO1	Irr. Amount: 37.71 L
Irrigation is to take 10 minutes from start to finish			
Green Roof Hydrograph TO1			
Time [min]	In. Collected	Volume Collected [L]	Average
0	0	0.00	
1	0	0.00	0.00
2	0	0.00	0.00
3	0	0.00	0.00
4	0	0.00	0.00
5	0	0.00	0.00
6	0.05	0.01	0.01
7	0.4	0.12	0.07
8	1.5	0.44	0.28
9	2.6	0.75	0.59
10	3.5	1.02	0.88
11	4.5	1.31	1.16
12	5.1	1.48	1.39
13	5	1.45	1.47
14	4.7	1.36	1.41
15	4.3	1.25	1.31
16	4	1.16	1.20
17	3.7	1.07	1.12
18	3.3	0.96	1.02
19	3.1	0.90	0.93
20	2.8	0.81	0.86
21	2.5	0.73	0.77
22	2.4	0.70	0.71
23	2.2	0.64	0.67
24	1.9	0.55	0.59
25	1.8	0.52	0.54
26	1.6	0.46	0.49

Time [min]	In. Collected	Volume Collected [L]	Average
27	1.4	0.41	0.44
28	1.3	0.38	0.39
29	1.2	0.35	0.36
30	1.1	0.32	0.33
31	1	0.29	0.30
32	0.9	0.26	0.28
33	0.8	0.23	0.25
34	0.7	0.20	0.22
35	0.6	0.17	0.19
Total Volume		20.29	20.21
% Returned	53.81	0.54	0.54
i= (liters/min)	3.771		
equivalent in/hr	6		

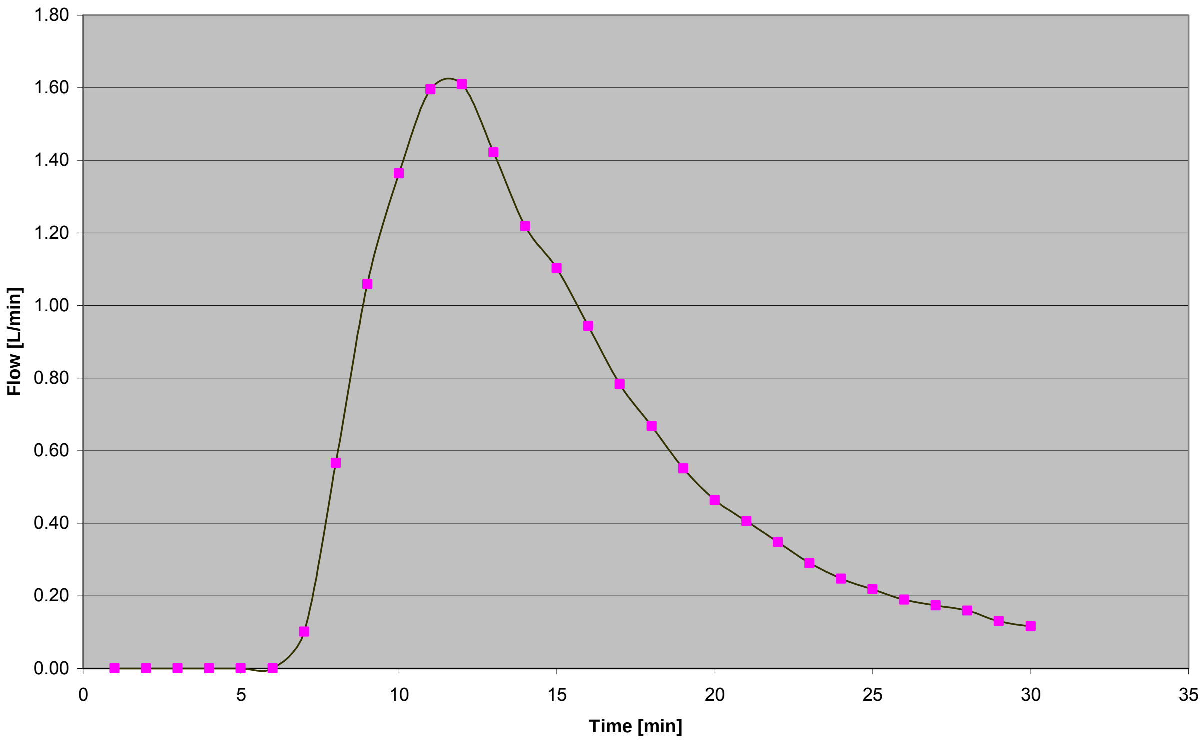


Green Roof Hydrograph TO1 1-27-06
Flow [L/min]
1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
0
5
10
15
20
25
30
35
40
Time [min]

Date: 4/28/06		Chamber: TO1	Irr. Amount: 37.71 L
Irrigation is to take 10 minutes from start to finish			
Green Roof Hydrograph TO1			
Time [min]	In. Collected	Volume Collected [L]	Average
0	0	0.00	
1	0	0.00	0.00
2	0	0.00	0.00
3	0	0.00	0.00
4	0	0.00	0.00
5	0	0.00	0.00
6	0	0.00	0.00
7	0.7	0.20	0.10
8	3.2	0.93	0.57
9	4.1	1.19	1.06
10	5.3	1.54	1.36
11	5.7	1.65	1.60
12	5.4	1.57	1.61
13	4.4	1.28	1.42
14	4	1.16	1.22
15	3.6	1.04	1.10
16	2.9	0.84	0.94
17	2.5	0.73	0.78
18	2.1	0.61	0.67
19	1.7	0.49	0.55
20	1.5	0.44	0.46
21	1.3	0.38	0.41
22	1.1	0.32	0.35
23	0.9	0.26	0.29
24	0.8	0.23	0.25
25	0.7	0.20	0.22
26	0.6	0.17	0.19

Time [min]	In. Collected	Volume Collected [L]	Average
27	0.6	0.17	0.17
28	0.5	0.15	0.16
29	0.4	0.12	0.13
30	0.4	0.12	0.12
Total Volume		15.78	15.72
% Returned	41.85	0.42	0.42
i= (liters/min)	3.771		
equivalent in/hr	6		

Green Roof Hydrograph TO1 4-28-06



Date: 7/18/06		Chamber: TO1	Irr. Amount: 37.71 L
Irrigation is to take 10 minutes from start to finish			
Green Roof Hydrograph TO1			
Time [min]	In. Collected	Volume Collected [L]	Average
0	0	0.00	
1	0	0.00	0.00
2	0	0.00	0.00
3	0.1	0.03	0.01
4	0.5	0.15	0.09
5	1.9	0.55	0.35
6	4.4	1.28	0.91
7	5.7	1.65	1.47
8	6.4	1.86	1.76
9	7.1	2.06	1.96
10	7.4	2.15	2.10
11	7.9	2.29	2.22
12	7.7	2.23	2.26
13	7	2.03	2.13
14	5.4	1.57	1.80
15	5	1.45	1.51
16	4.3	1.25	1.35
17	3.8	1.10	1.17
18	3.2	0.93	1.02
19	2.7	0.78	0.86
20	2.2	0.64	0.71
21	1.9	0.55	0.59
22	1.5	0.44	0.49
23	1.3	0.38	0.41
24	1.1	0.32	0.35
25	1	0.29	0.30
26	0.9	0.26	0.28

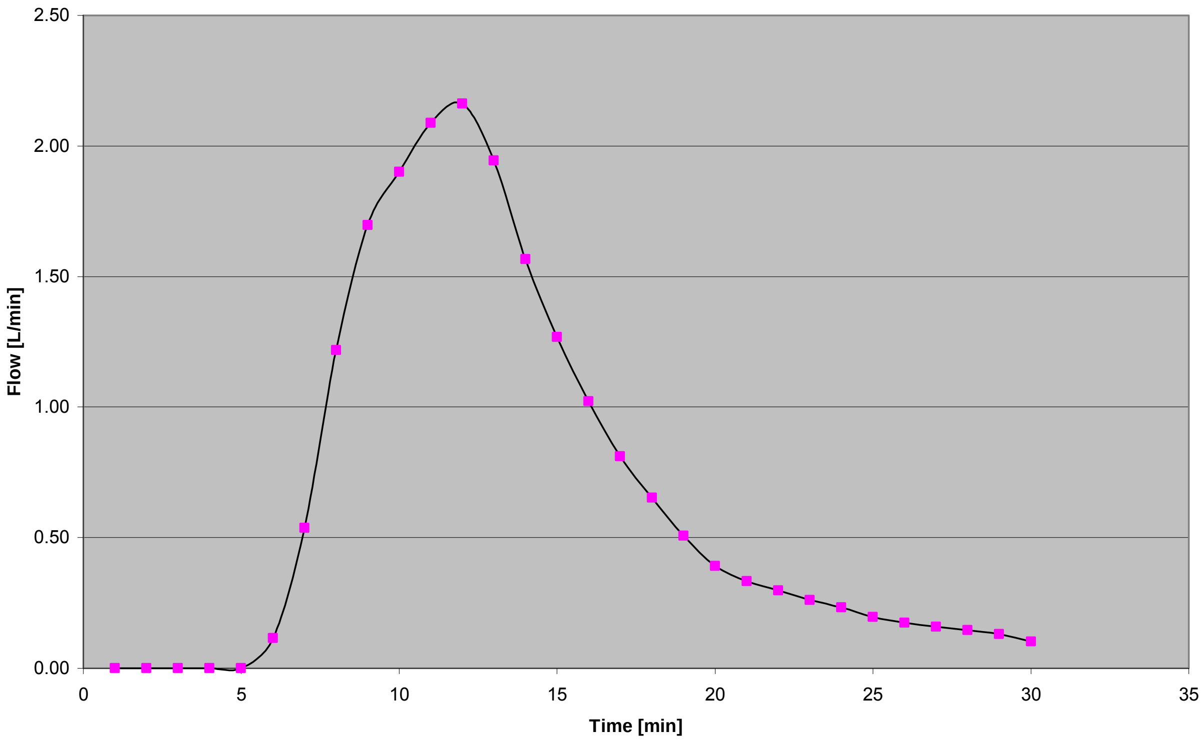
Time [min]	In. Collected	Volume Collected [L]	Average
27	0.8	0.23	0.25
Total Volume		26.46	26.34
% Returned	70.16	0.70	0.70
i= (liters/min)	3.771		
equivalent in/hr	6		


Green Roof Hydrograph TO1 7-18-06
2.50
2.00
1.50
1.00
0.50
0.00
Flow [L/min]
0
5
10
15
20
25
30
Time [min]

Date: 12/2/05		Chamber: TVO1	Irr. Amount: 37.71 L
Irrigation is to take 10 minutes from start to finish			
Green Roof Hydrograph TVO1			
Time [min]	In. Collected	Volume Collected [L]	Average
0	0	0.00	
1	0	0.00	0.00
2	0	0.00	0.00
3	0	0.00	0.00
4	0	0.00	0.00
5	0	0.00	0.00
6	0.8	0.23	0.12
7	2.9	0.84	0.54
8	5.5	1.60	1.22
9	6.2	1.80	1.70
10	6.9	2.00	1.90
11	7.5	2.18	2.09
12	7.4	2.15	2.16
13	6	1.74	1.94
14	4.8	1.39	1.57
15	3.95	1.15	1.27
16	3.1	0.90	1.02
17	2.5	0.73	0.81
18	2	0.58	0.65
19	1.5	0.44	0.51
20	1.2	0.35	0.39
21	1.1	0.32	0.33
22	0.95	0.28	0.30
23	0.85	0.25	0.26
24	0.75	0.22	0.23
25	0.6	0.17	0.20
26	0.6	0.17	0.17

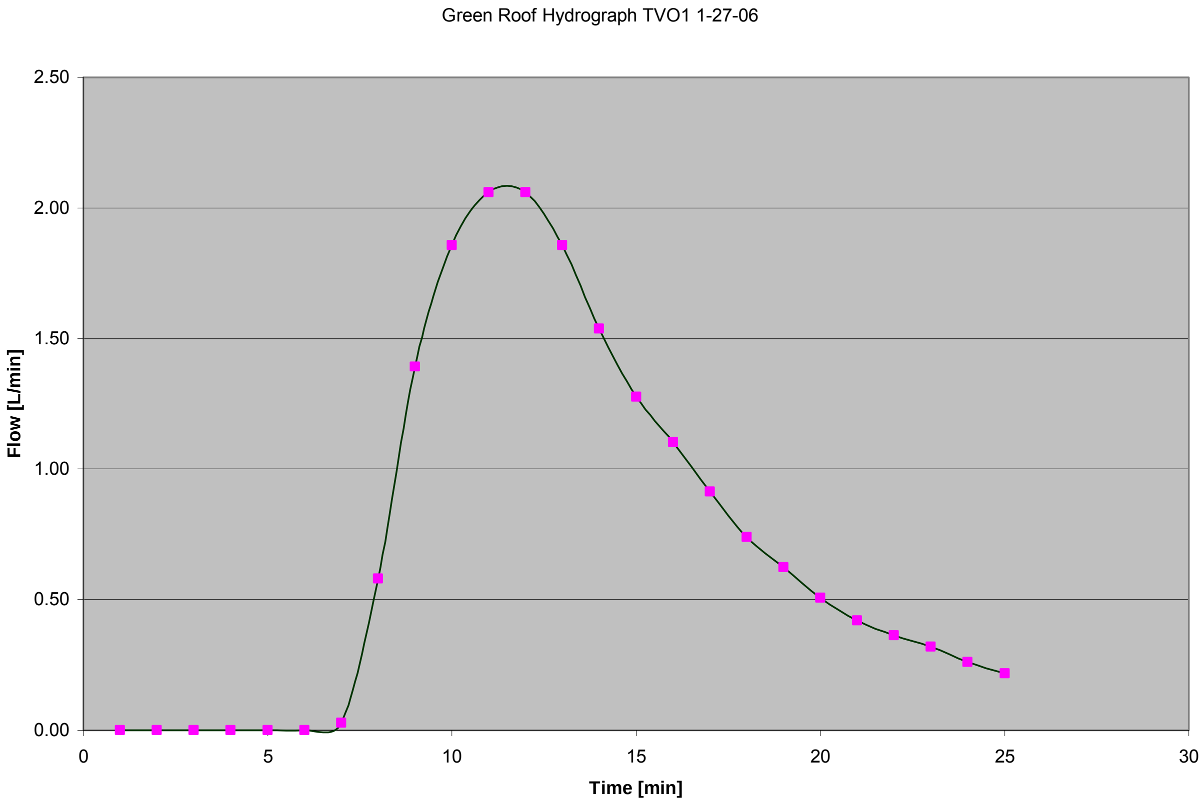
Time [min]	In. Collected	Volume Collected [L]	Average
27	0.5	0.15	0.16
28	0.5	0.15	0.15
29	0.4	0.12	0.13
30	0.3	0.09	0.10
Total Volume		19.96	19.92
% Returned	52.93	0.53	0.53
i= (liters/min)	3.771		
equivalent in/hr	6		

Green Roof Hydrograph TVO1 12-2-06



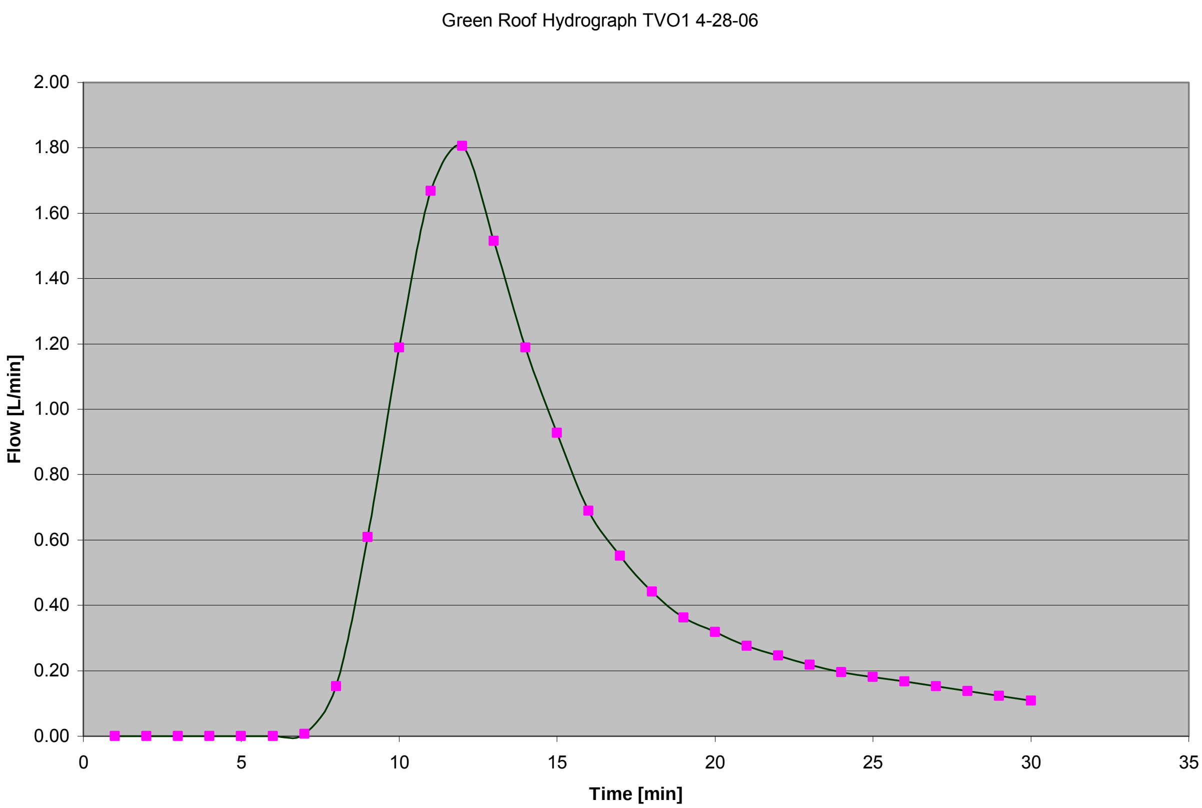
Date: 1/27/06		Chamber: TVO1	Irr. Amount: 37.71 L
Irrigation is to take 10 minutes from start to finish			
Green Roof Hydrograph TVO1			
Time [min]	In. Collected	Volume Collected [L]	Average
0	0	0.00	
1	0	0.00	0.00
2	0	0.00	0.00
3	0	0.00	0.00
4	0	0.00	0.00
5	0	0.00	0.00
6	0	0.00	0.00
7	0.2	0.06	0.03
8	3.8	1.10	0.58
9	5.8	1.68	1.39
10	7	2.03	1.86
11	7.2	2.09	2.06
12	7	2.03	2.06
13	5.8	1.68	1.86
14	4.8	1.39	1.54
15	4	1.16	1.28
16	3.6	1.04	1.10
17	2.7	0.78	0.91
18	2.4	0.70	0.74
19	1.9	0.55	0.62
20	1.6	0.46	0.51
21	1.3	0.38	0.42
22	1.2	0.35	0.36
23	1	0.29	0.32
24	0.8	0.23	0.26
25	0.7	0.20	0.22
Total Volume		18.22	18.12

Time [min]	In. Collected	Volume Collected [L]	Average
% Returned	48.31	0.48	0.48
i= (liters/min)	3.771		
equivalent in/hr	6		


Green Roof Hydrograph TVO1 1-27-06
Flow [L/min]
2.50
2.00
1.50
1.00
0.50
0.00
0
5
10
15
20
25
30
Time [min]

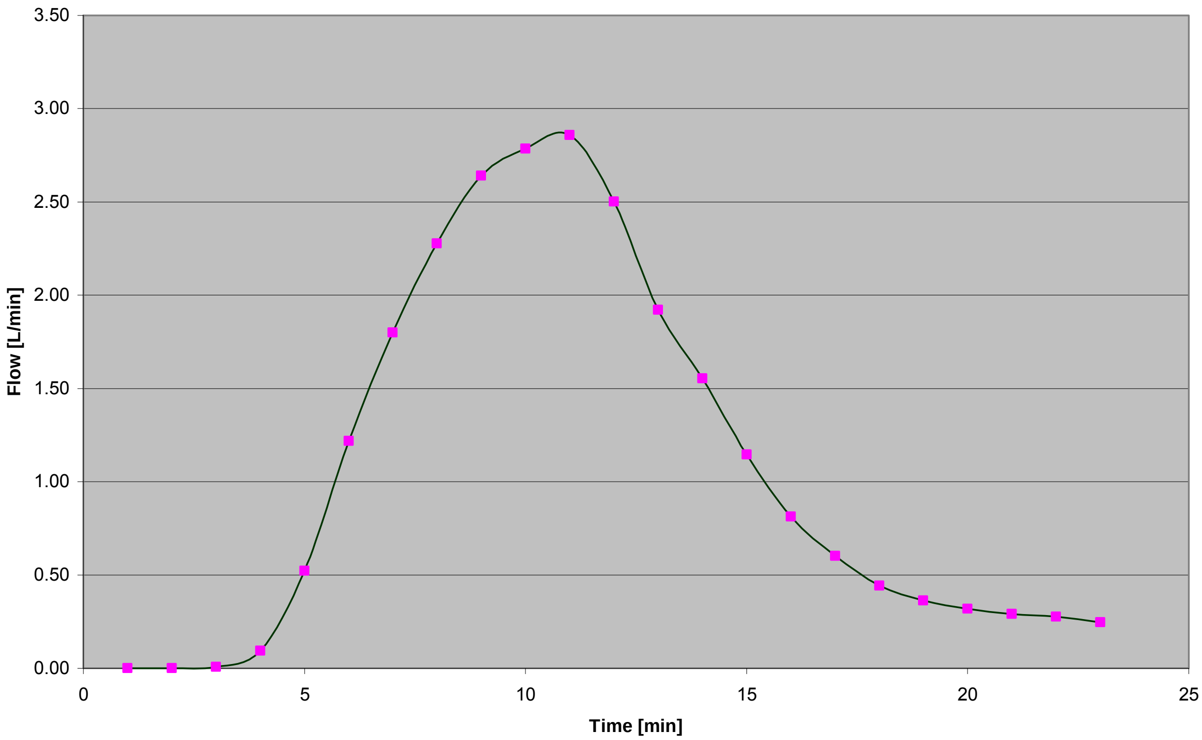
Date: 4/28/06		Chamber: TVO1	Irr. Amount: 37.71 L
Irrigation is to take 10 minutes from start to finish			
Green Roof Hydrograph TVO1			
Time [min]	In. Collected	Volume Collected [L]	Average
0	0	0.00	
1	0	0.00	0.00
2	0	0.00	0.00
3	0	0.00	0.00
4	0	0.00	0.00
5	0	0.00	0.00
6	0	0.00	0.00
7	0.05	0.01	0.01
8	1	0.29	0.15
9	3.2	0.93	0.61
10	5	1.45	1.19
11	6.5	1.89	1.67
12	5.95	1.73	1.81
13	4.5	1.31	1.52
14	3.7	1.07	1.19
15	2.7	0.78	0.93
16	2.05	0.59	0.69
17	1.75	0.51	0.55
18	1.3	0.38	0.44
19	1.2	0.35	0.36
20	1	0.29	0.32
21	0.9	0.26	0.28
22	0.8	0.23	0.25
23	0.7	0.20	0.22
24	0.65	0.19	0.20
25	0.6	0.17	0.18
26	0.55	0.16	0.17

Time [min]	In. Collected	Volume Collected [L]	Average
27	0.5	0.15	0.15
28	0.45	0.13	0.14
29	0.4	0.12	0.12
30	0.35	0.10	0.11
Total Volume		13.29	13.24
% Returned	35.23	0.35	0.35
i= (liters/min)	3.771		
equivalent in/hr	6		


Green Roof Hydrograph TVO1 4-28-06
Flow [L/min]
Time [min]
2.00
1.80
1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
0
5
10
15
20
25
30
35

Date: 7/18/06		Chamber: TVO1	Irr. Amount: 37.71 L
Irrigation is to take 10 minutes from start to finish			
Green Roof Hydrograph TVO1			
Time [min]	In. Collected	Volume Collected [L]	Average
0	0	0.00	
1	0	0.00	0.00
2	0	0.00	0.00
3	0.05	0.01	0.01
4	0.6	0.17	0.09
5	3	0.87	0.52
6	5.4	1.57	1.22
7	7	2.03	1.80
8	8.7	2.52	2.28
9	9.5	2.76	2.64
10	9.7	2.81	2.78
11	10	2.90	2.86
12	7.25	2.10	2.50
13	6	1.74	1.92
14	4.7	1.36	1.55
15	3.2	0.93	1.15
16	2.4	0.70	0.81
17	1.75	0.51	0.60
18	1.3	0.38	0.44
19	1.2	0.35	0.36
20	1	0.29	0.32
21	1	0.29	0.29
22	0.9	0.26	0.28
23	0.8	0.23	0.25
Total Volume		24.79	24.67
% Returned	65.74	0.66	0.65
i= (liters/min)	3.771		
equivalent in/hr	6		

Green Roof Hydrograph TVO1 7-18-06



APPENDIX C: WATER BUDGET HYPOTHESIS TESTING

ET Hypothesis Tests

H_{O1} Media and vegetation are held constant, ET Rates for Over irrigation = ET Rates for Regular irrigation
H_{a1} Media and vegetation are held constant, ET Rates for Over irrigation > ET Rates for Regular irrigation
H_{O2} Media and irrigation rates are held constant, ET Rates for Vegetated boxes = ET Rates for Non Vegetated boxes
H_{a2} Media and irrigation rates are held constant, ET Rates for Vegetated boxes > ET Rates for Non Vegetated boxes
H_{O3} Irrigation rates and vegetation is held constant, ET Rates for Black & Gold = ET Rates for Expanded Clay
H_{a3} Irrigation rates and vegetation is held constant, ET Rates for Black & Gold > ET Rates for Expanded Clay

$\alpha =$ 0.05 $z_\alpha =$ 1.645

Note: R = Reject H_O & A = Accept H_O

	TVO1	TVO2	TVR1	TVR2	TO1	TO2	TR1	TR2	EO1	EO2	ER1	ER2	EVO1	EVO2	EVR1	EVR2
Average	0.15	0.16	0.13	0.14	0.13	0.14	0.11	0.12	0.11	0.11	0.10	0.10	0.13	0.13	0.12	0.12
s	0.086	0.087	0.081	0.081	0.072	0.076	0.058	0.055	0.056	0.056	0.052	0.052	0.062	0.064	0.057	0.057
s^2	0.007	0.008	0.007	0.007	0.005	0.006	0.003	0.003	0.003	0.003	0.003	0.003	0.004	0.004	0.003	0.003
n	103	103	103	103	103	103	102	102	102	102	102	102	79	79	79	79
z_1	1.693	1.577			2.195	2.309			0.537	1.249			1.665	1.376		
H_{O1}	**R**	**A**			**R**	**R**			**A**	**A**			**R**	**A**		
z_2	1.532	2.016	1.757	2.654									3.006	2.036	1.820	1.814
H_{O2}	**A**	**R**	**R**	**R**									**R**	**R**	**R**	**R**
z_3	1.466	2.686	1.179	2.431	2.861	2.773	1.281	1.873								
H_{O3}	**A**	**R**	**A**	**R**	**R**	**R**	**A**	**R**								

Filtrate Factor Hypothesis Tests

H_{O1} When media and vegetation is held constant, The f Factor for Over irrigation = f Factor for Regular irrigation

H_{a1} When media and vegetation is held constant, f Factor for Over irrigation > f Factor for Regular irrigation

H_{O2} When media and irrigation rates are held constant, f Factor for Vegetated boxes = f Factor for Non Vegetated boxes

H_{a2} When media and irrigation rates are held constant, f Factor for Vegetated boxes < f Factor for Non Vegetated boxes

H_{O3} When irrigation rates and vegetation is held constant, f Factor for Black & Gold = f Factor for Expanded Clay

H_{a3} When irrigation rates and vegetation is held constant, f Factor for Black & Gold < f Factor for Expanded Clay

$\alpha =$ 0.05 $z_\alpha =$ 1.645 $-z_\alpha =$ -1.65

Note: R = Reject H_O & A = Accept H_O

	TVO1	TVO2	TVR1	TVR2	TO1	TO2	TR1	TR2	EO1	EO2	ER1	ER2	EVO1	EVO2	EVR1	EVR2
Average	0.59	0.57	0.41	0.35	0.63	0.62	0.45	0.43	0.70	0.68	0.48	0.49	0.61	0.62	0.39	0.39
s	0.159	0.175	0.228	0.240	0.156	0.169	0.231	0.225	0.133	0.129	0.236	0.231	0.148	0.134	0.236	0.237
s^2	0.025	0.031	0.052	0.058	0.024	0.029	0.053	0.051	0.018	0.017	0.056	0.054	0.022	0.018	0.056	0.056
n	104	104	104	104	104	104	103	103	103	103	103	103	78	77	77	78
z_1	6.793	7.330			6.689	6.839			8.105	7.538			7.015	7.353		
H_{O1}	**R**	**R**			**R**	**R**			**R**	**R**			**R**	**R**		
z_2	-1.861	-2.327	-1.320	-2.467									-4.169	-3.131	-2.675	-2.621
H_{O2}	**R**	**R**	**A**	**R**									**R**	**R**	**R**	**R**
z_3	-0.843	-2.273	0.508	-1.098	-3.342	-2.825	-1.078	-1.619								
H_{O3}	**A**	**R**	**A**	**A**	**R**	**R**	**A**	**A**								

APPENDIX D: WATER QUALITY TABLES AND CHARTS

	Parameter									
	OP [mg/L P]			RPD	RPD	TP [mg/L P]			RPD	RPD
Chamber	n	mean	st. dev.	Replicates	Controls	n	mean	st. dev.	Replicates	Controls
TVO1	32	0.279	0.208	1.996	19.231	24	0.534	0.150	7.967	9.027
TVO2	32	0.285	0.232		29.573	25	0.578	0.294		34.434
TVR1	32	0.297	0.135	3.106	25.489	22	0.695	0.292	19.095	35.129
TVR2	32	0.307	0.186		36.814	26	0.574	0.225		33.792
TO1	30	0.366	0.159	10.771	45.638	25	0.652	0.182	1.867	28.783
TO2	30	0.408	0.151		63.471	22	0.640	0.100		44.152
C1	16	0.230	0.141	8.499	-	17	0.488	0.323	17.728	
C2	16	0.211	0.132		-	17	0.408	0.162		
TR1	25	0.335	0.113	3.324	37.264	25	1.740	1.531	36.952	112.437
TR2	30	0.347	0.117		48.544	26	1.197	1.028		98.294
EO1	32	1.498	0.767	15.779	146.753	29	2.163	1.074	11.372	126.414
EO2	32	1.279	0.804		143.289	29	1.930	1.072		130.174
ER1	28	1.060	0.638	29.801	128.662	26	2.088	0.920	12.890	124.270
ER2	28	1.431	1.018		148.537	23	1.835	0.811		127.213
EVO1	31	0.674	0.623	0.382	98.216	22	1.299	1.135	4.704	90.830
EVO2	31	0.676	0.624		104.810	24	1.362	1.310		107.738
EVR1	30	0.978	0.673	26.870	123.841	19	1.792	1.208	38.953	114.439
EVR2	30	0.746	0.570		111.757	23	1.208	0.950		98.955

	Parameter									
	NO_X [mg/L N]			RPD	RPD	NH_3 [mg/L N]			RPD	RPD
Chamber	n	mean	st. dev.	Replicates	Controls	n	mean	st. dev.	Replicates	Controls
TVO1	37	0.114	0.060	4.050	-106.973	35	0.047	0.063	7.425	-79.263
TVO2	37	0.109	0.052		-117.237	35	0.051	0.068		-46.102
TVR1	35	0.119	0.051	3.642	-103.618	37	0.049	0.066	49.251	-76.298
TVR2	36	0.115	0.050		-113.873	36	0.029	0.019		-93.337
TO1	34	0.097	0.035	1.966	-117.712	35	0.029	0.011	0.402	-116.963
TO2	36	0.099	0.038		-123.415	35	0.028	0.015		-96.211
C1	22	0.375	0.241	10.918		20	0.109	0.140	29.268	
C2	22	0.419	0.299			20	0.081	0.067		
TR1	37	0.100	0.039	0.897	-116.022	33	0.031	0.014	5.252	-110.924
TR2	36	0.099	0.034		-123.599	33	0.033	0.033		-84.604
EO1	37	0.136	0.103	8.168	-93.468	36	0.037	0.047	18.167	-99.490
EO2	38	0.126	0.089		-107.718	36	0.030	0.023		-90.779
ER1	33	0.107	0.040	14.923	-111.071	33	0.051	0.078	56.847	-72.840
ER2	35	0.125	0.078		-108.259	33	0.028	0.039		-96.556
EVO1	35	0.112	0.053	17.928	-108.234	33	0.026	0.024	11.280	-122.004
EVO2	35	0.134	0.096		-103.156	33	0.030	0.046		-93.223
EVR1	29	0.111	0.036	6.866	-108.665	30	0.040	0.062	32.745	-93.489
EVR2	28	0.119	0.032		-111.495	30	0.055	0.114		-38.356

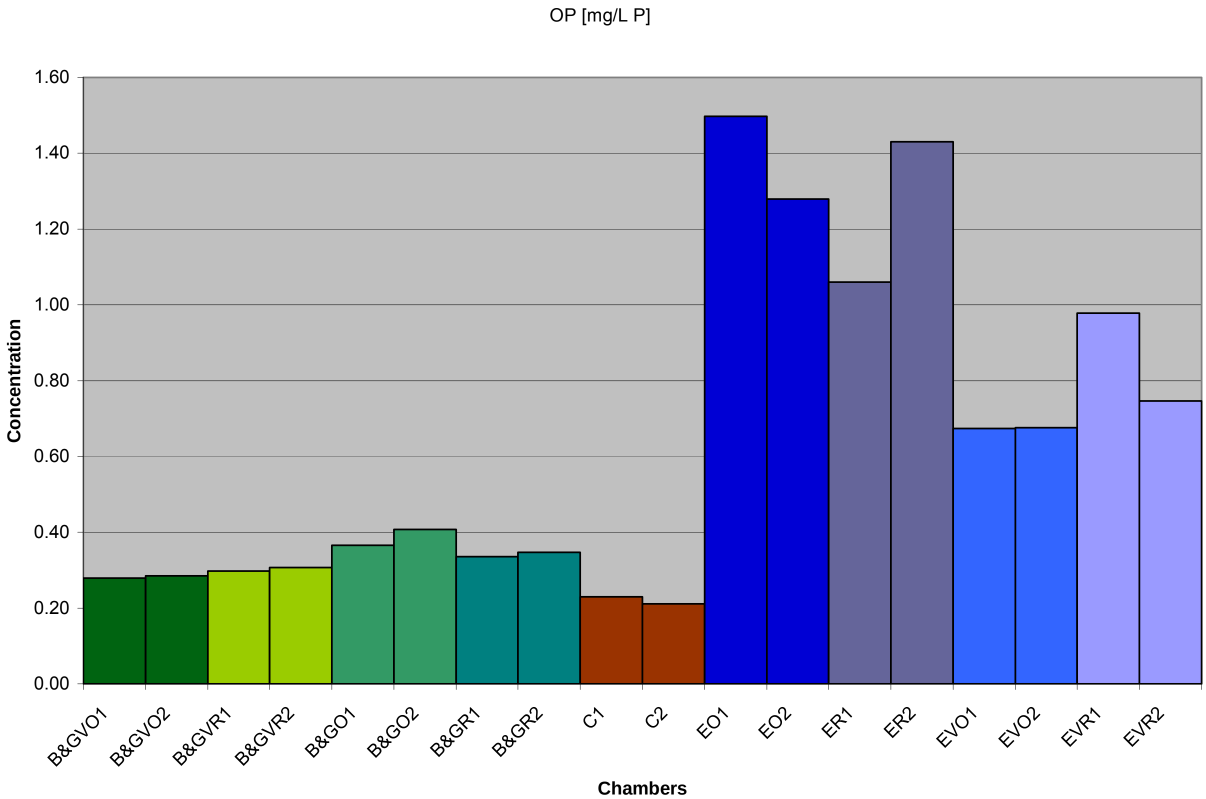
	Parameter										
	TKN [mg/L N]			RPD	RPD	TN [mg/L N]			RPD	RPD
Chamber	n	mean	st. dev.	Replicates	Controls	n	mean	st. dev.	Replicates	Controls
TVO1	5	1.215	0.630	2.230	59.184	6	1.513	0.732	14.815	39.758
TVO2	5	1.188	0.467		45.275	6	1.755	1.166		38.870
TVR1	7	1.202	0.780	13.365	58.175	4	1.649	0.875	5.596	47.967
TVR2	7	1.051	0.788		33.496	4	1.559	0.836		27.384
TO1	8	1.539	1.549	27.851	79.924	5	1.396	0.457	4.332	32.016
TO2	7	1.163	0.520		43.209	6	1.337	0.472		12.180
C1	9	0.660	0.226	12.688		8	1.011	0.082	15.733	
C2	9	0.750	0.499			8	1.184	0.464		
TR1	5	1.886	0.537	7.795	96.290	5	1.978	0.523	7.353	64.724
TR2	5	2.039	0.746		92.477	5	2.129	0.733		57.095
EO1	6	1.570	0.693	32.786	81.577	6	1.687	0.725	30.524	50.095
EO2	7	2.185	1.457		97.834	7	2.294	1.466		63.868
ER1	5	1.992	1.097	25.104	100.412	5	2.128	1.115	23.592	71.164
ER2	3	2.563	1.358		109.488	3	2.697	1.395		77.995
EVO1	8	1.012	0.868	25.150	42.038	8	1.109	0.815	22.828	9.269
EVO2	8	0.786	0.586		4.684	8	0.882	0.534		-29.208
EVR1	5	1.060	1.078	91.354	46.462	5	1.154	1.033	80.219	13.205
EVR2	5	0.395	0.354		-61.923	5	0.493	0.315		-82.340

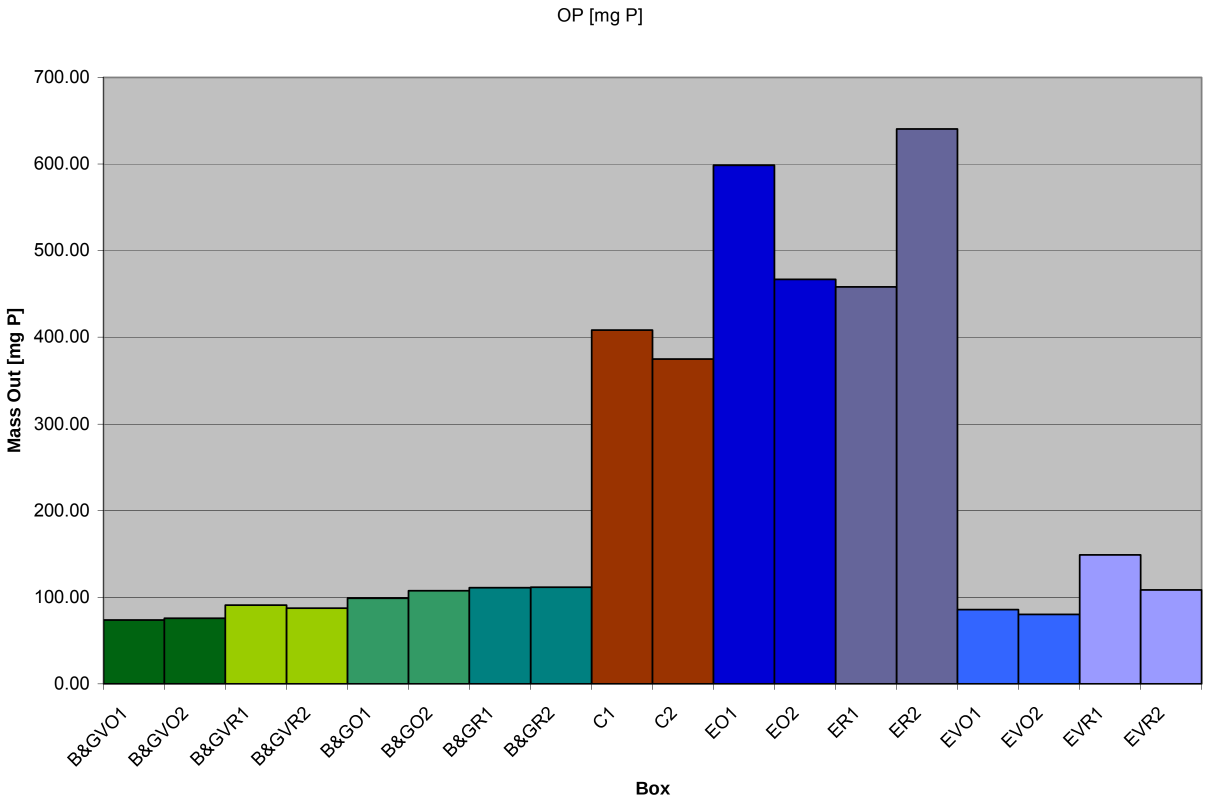
	Parameter									
	Turbidity [NTU]			RPD	RPD	TSS [mg/L]			RPD	RPD
Chamber	n	mean	st. dev.	Replicates	Controls	n	mean	st. dev.	Replicates	Controls
TVO1	34	6.934	3.270	13.234	-16.421	35	26.494	31.396	12.347	12.751
TVO2	35	7.917	3.256		-32.829	35	29.981	34.954		20.333
TVR1	34	12.779	7.231	27.790	43.943	34	32.745	25.339	25.791	33.630
TVR2	34	9.661	6.978		-13.204	34	42.441	62.752		53.802
TO1	32	5.797	2.286	10.385	-34.042	34	31.176	25.145	7.468	28.840
TO2	32	6.432	2.190		-52.637	34	28.932	22.656		16.802
C1	18	8.175	10.203	29.702		23	23.318	32.982	4.728	
C2	18	11.027	16.262			23	24.447	23.501		
TR1	32	6.305	3.912	11.536	-25.824	33	32.222	29.186	30.369	32.064
TR2	32	7.077	10.722		-43.631	32	43.760	42.731		56.630
EO1	34	5.972	5.164	17.950	-31.143	37	25.125	18.526	3.172	7.461
EO2	34	7.150	6.116		-42.659	36	25.935	20.006		5.907
ER1	31	10.005	8.061	32.882	20.127	33	33.040	21.111	20.120	34.500
ER2	31	7.179	4.783		-42.264	31	27.000	22.677		9.924
EVO1	30	2.212	2.733	7.708	-114.817	29	19.414	17.609	2.398	-18.272
EVO2	30	2.389	2.010		-128.762	29	18.954	14.845		-25.313
EVR1	30	3.070	3.145	28.752	-90.805	30	16.999	15.069	13.930	-31.345
EVR2	30	2.298	2.199		-131.015	30	19.545	16.415		-22.289

	Parameter										
	TDS [mg/L]			RPD	RPD	TS [mg/L]			RPD	RPD
Chamber	n	mean	st. dev.	Replicates	Controls	n	mean	st. dev.	Replicates	Controls
TVO1	36	648.556	143.501	3.534	178.543	34	676.714	136.107	2.642	167.257
TVO2	36	671.889	187.071		177.323	34	694.833	175.026		165.682
TVR1	37	760.865	251.352	9.240	181.564	34	783.216	239.075	7.278	171.391
TVR2	36	693.667	259.463		177.995	33	728.212	265.649		167.126
TO1	36	392.667	107.695	2.259	165.757	34	425.764	114.347	2.889	150.353
TO2	35	383.897	109.298		161.930	34	413.638	110.100		145.530
C1	22	36.762	40.072	9.383		22	60.333	66.710	7.764	
C2	22	40.381	52.762			22	65.207	75.322		
TR1	35	353.714	102.474	3.273	162.341	33	388.586	107.625	6.486	146.241
TR2	35	365.486	113.660		160.203	32	414.635	132.656		145.643
EO1	37	183.027	56.548	1.640	133.096	36	206.731	63.414	2.107	109.635
EO2	37	186.054	55.399		128.667	35	211.133	61.596		105.614
ER1	33	186.061	63.845	2.826	134.007	32	218.906	68.250	5.858	113.575
ER2	32	180.875	41.949		126.997	29	206.448	51.505		103.986
EVO1	29	324.276	90.009	12.108	159.271	28	347.012	90.004	11.833	140.755
EVO2	29	366.069	110.602		160.260	28	390.655	110.752		142.784
EVR1	31	375.097	147.400	14.652	164.297	30	400.866	146.356	13.487	147.673
EVR2	30	434.400	184.484		165.979	29	458.839	186.962		150.228

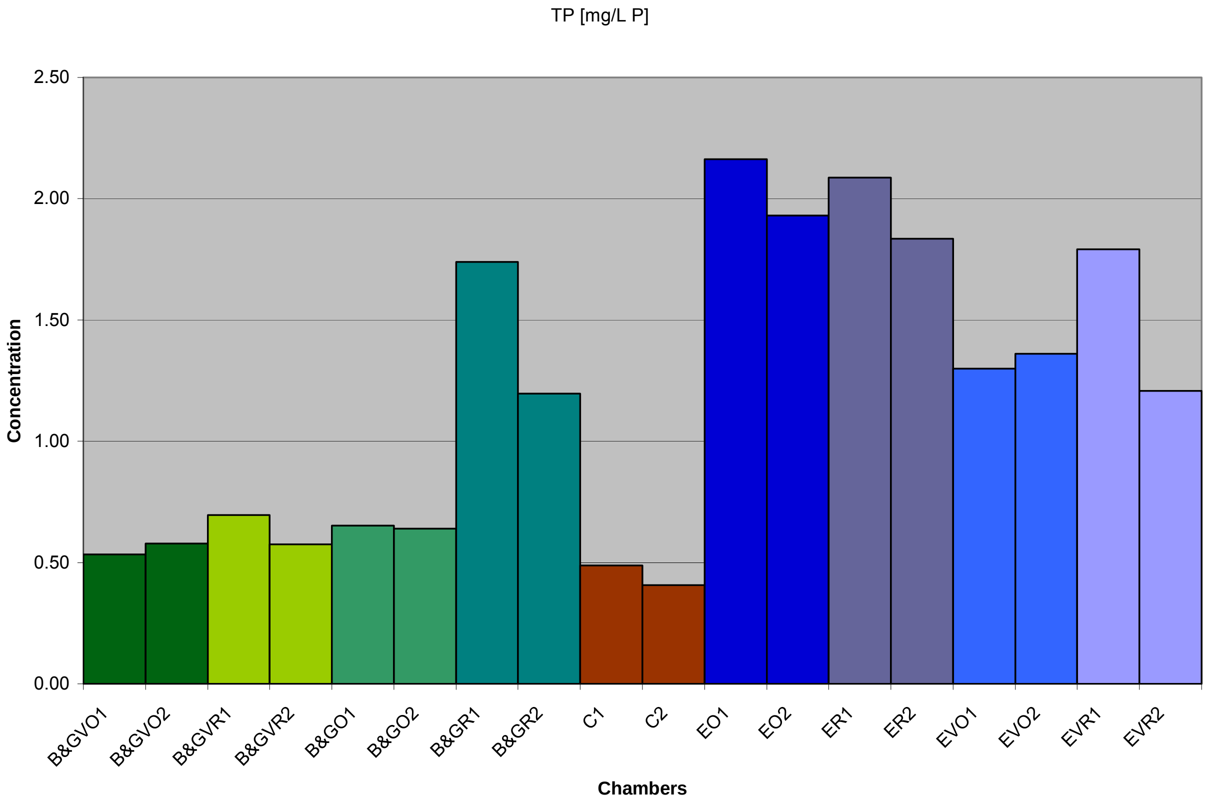
	Parameter										
	Alkalinity [mg/L as $CaCO_3$]			RPD	RPD	pH			RPD	RPD
Chamber	n	mean	st. dev.	Replicates	Controls	n	mean	st. dev.	Replicates	Controls
TVO1	37	119.861	12.140	0.739	179.978	37	8.618	0.394	4.462	35.986
TVO2	37	120.750	11.682		183.165	37	8.242	0.286		34.224
TVR1	37	119.056	19.842	7.008	179.849	37	8.180	0.380	2.743	30.922
TVR2	37	110.994	17.663		181.753	37	8.408	0.448		36.158
TO1	36	84.886	13.826	4.443	172.300	36	9.109	0.580	3.918	41.324
TO2	36	88.743	10.609		177.436	36	8.759	0.555		40.103
C1	20	6.316	5.165	17.391		20	5.989	0.671	2.644	
C2	20	5.305	3.946			20	5.833	0.717		
TR1	35	92.547	10.981	0.854	174.446	35	8.812	0.506	0.526	38.142
TR2	35	93.341	12.709		178.488	35	8.859	0.607		41.188
EO1	38	72.822	24.660	6.207	168.077	38	9.099	0.848	1.075	41.219
EO2	38	77.486	20.743		174.368	38	9.198	0.655		44.767
ER1	34	69.303	21.962	4.697	166.591	34	9.457	0.775	3.927	44.894
ER2	34	72.636	17.108		172.773	34	9.092	0.701		43.674
EVO1	30	82.407	15.053	0.016	171.526	30	8.850	0.636	1.142	38.549
EVO2	30	82.393	16.999		175.802	30	8.951	0.526		42.182
EVR1	30	93.000	19.933	19.038	174.563	30	8.763	0.725	0.330	37.601
EVR2	30	76.833	19.986		174.164	30	8.792	0.656		40.462

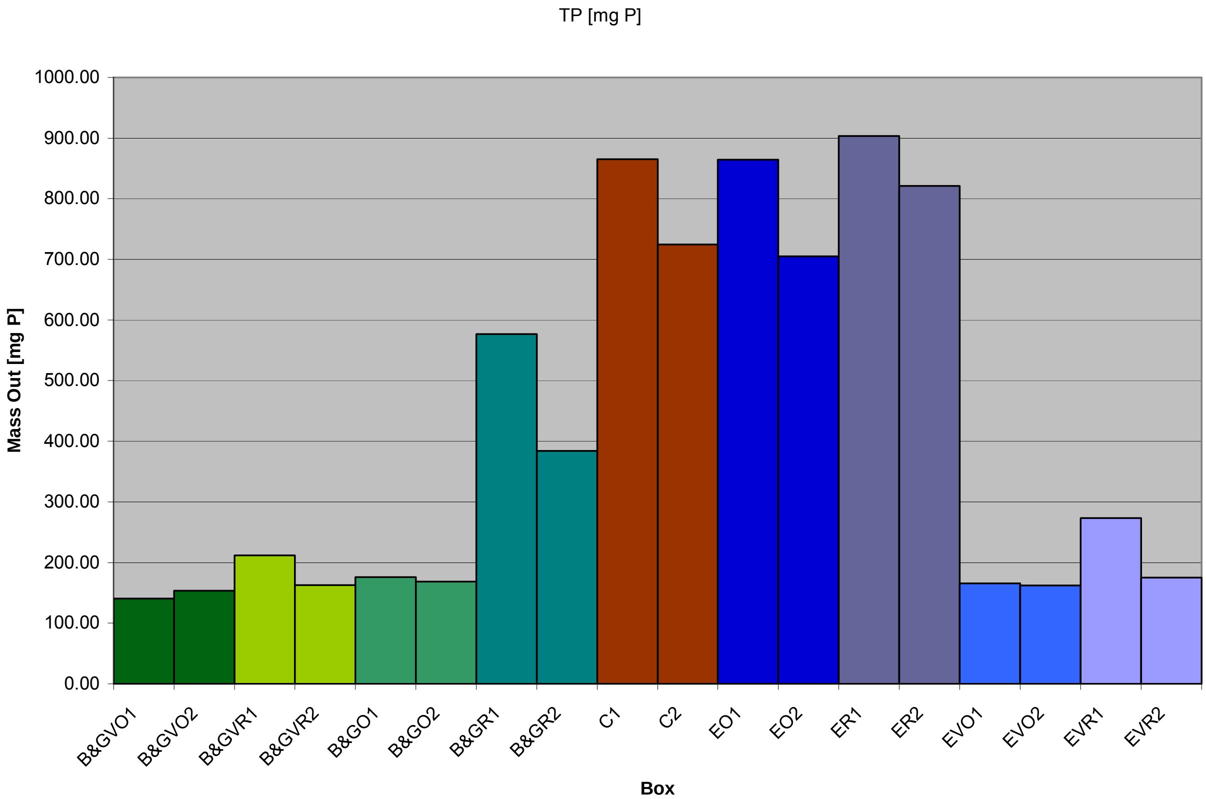
	Parameter				
	Temperature [^oF]			Replicates	Controls
Chamber	n	mean	st. dev.	RPD	RPD
TVO1	13	78.362	9.738	0.482	-4.253
TVO2	13	77.985	9.634		-2.092
TVR1	11	77.582	7.996	1.281	-5.252
TVR2	11	78.582	8.066		-1.329
TO1	13	77.215	8.293	1.434	-5.726
TO2	13	78.331	8.497		-1.649
C1	7	81.767	7.994	2.644	
C2	7	79.633	6.638		
TR1	12	76.858	7.511	0.573	-6.189
TR2	12	77.300	7.294		-2.974
EO1	13	75.508	7.987	1.135	-7.959
EO2	13	76.369	7.344		-4.185
ER1	13	78.354	6.559	0.529	-4.263
ER2	13	78.769	6.329		-1.091
EVO1	9	72.589	8.770	0.737	-11.892
EVO2	9	72.056	8.286		-9.991
EVR1	9	74.556	8.082	0.802	-9.226
EVR2	9	75.156	8.202		-5.786


OP [mg/L P]
1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
Concentration
B&GVO1
B&GVO2
B&GVR1
B&GVR2
B&GO1
B&GO2
B&GR1
B&GR2
C1
C2
EO1
EO2
ER1
ER2
EVO1
EVO2
EVR1
EVR2
Chambers



OP [mg P]
700.00
600.00
500.00
400.00
300.00
200.00
100.00
0.00
Mass Out [mg P]
B&GVO1
B&GVO2
B&GVR1
B&GVR2
B&GO1
B&GO2
B&GR1
B&GR2
C1
C2
EO1
EO2
ER1
ER2
EVO1
EVO2
EVR1
EVR2
Box


TP [mg/L P]
Concentration
2.50
2.00
1.50
1.00
0.50
0.00
B&GVO1
B&GVO2
B&GVR1
B&GVR2
B&GO1
B&GO2
B&GR1
B&GR2
C1
C2
EO1
EO2
ER1
ER2
EVO1
EVO2
EVR1
EVR2
Chambers


TP [mg P]
1000.00
900.00
800.00
700.00
600.00
500.00
400.00
300.00
200.00
100.00
0.00
Mass Out [mg P]
B&GVO1
B&GVO2
B&GVR1
B&GVR2
B&GO1
B&GO2
B&GR1
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C2
EO1
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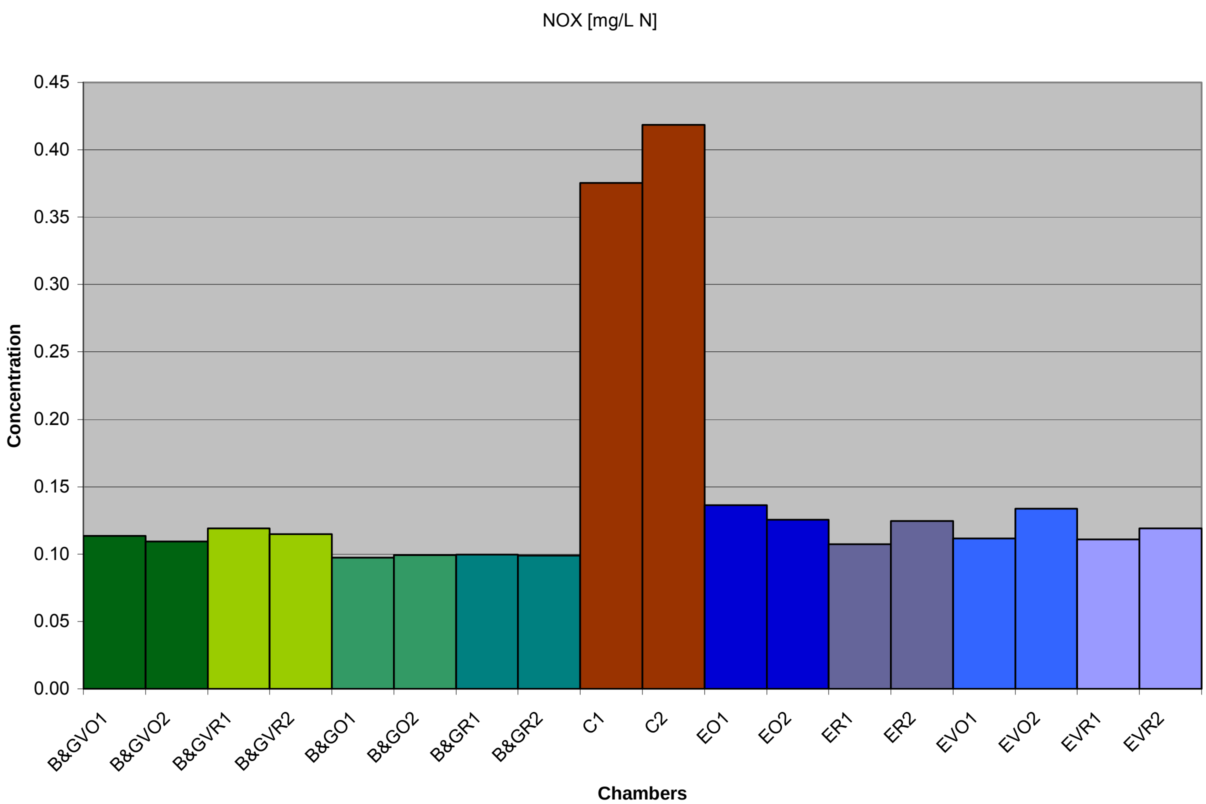
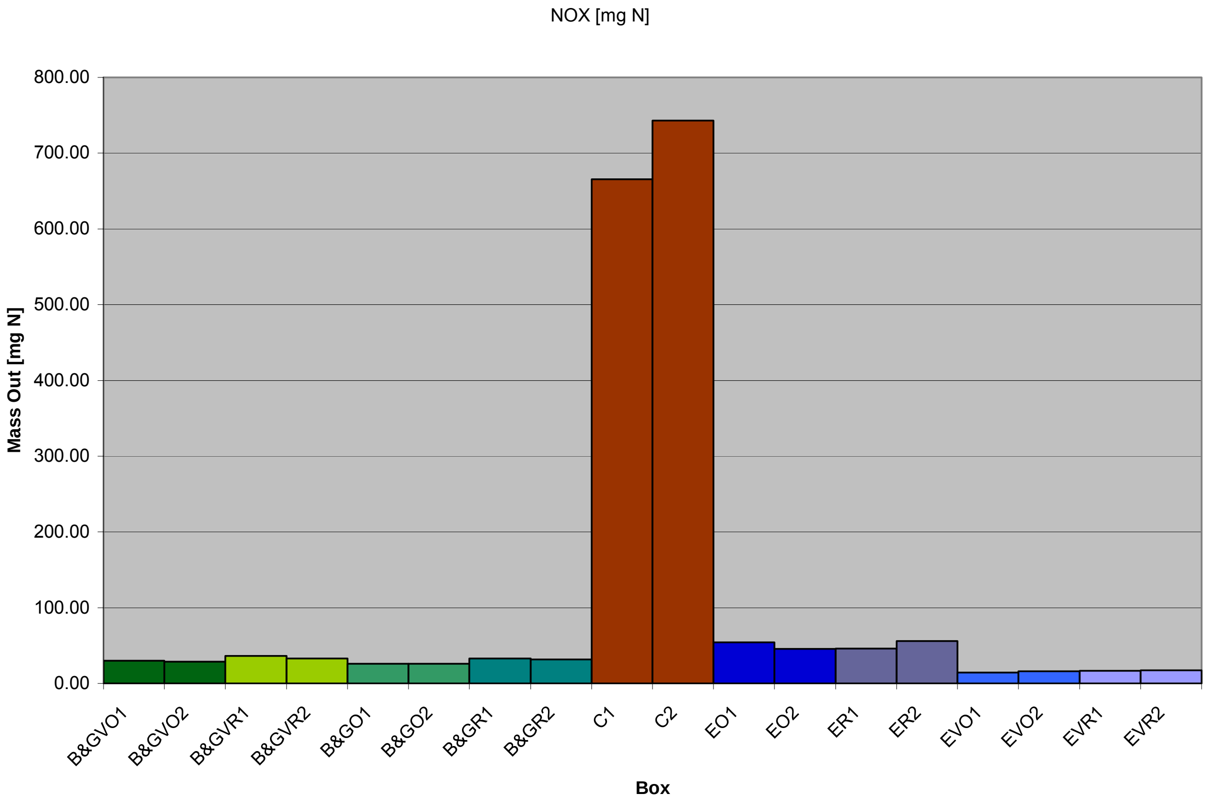
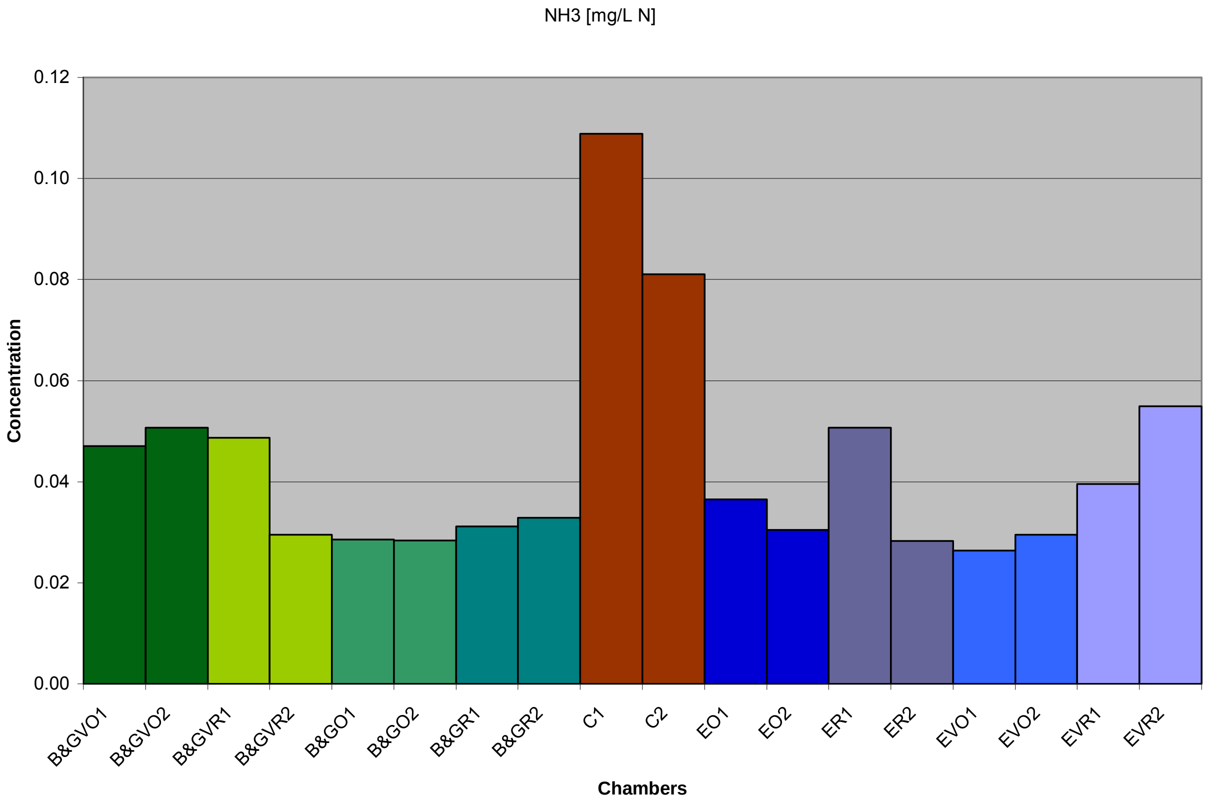
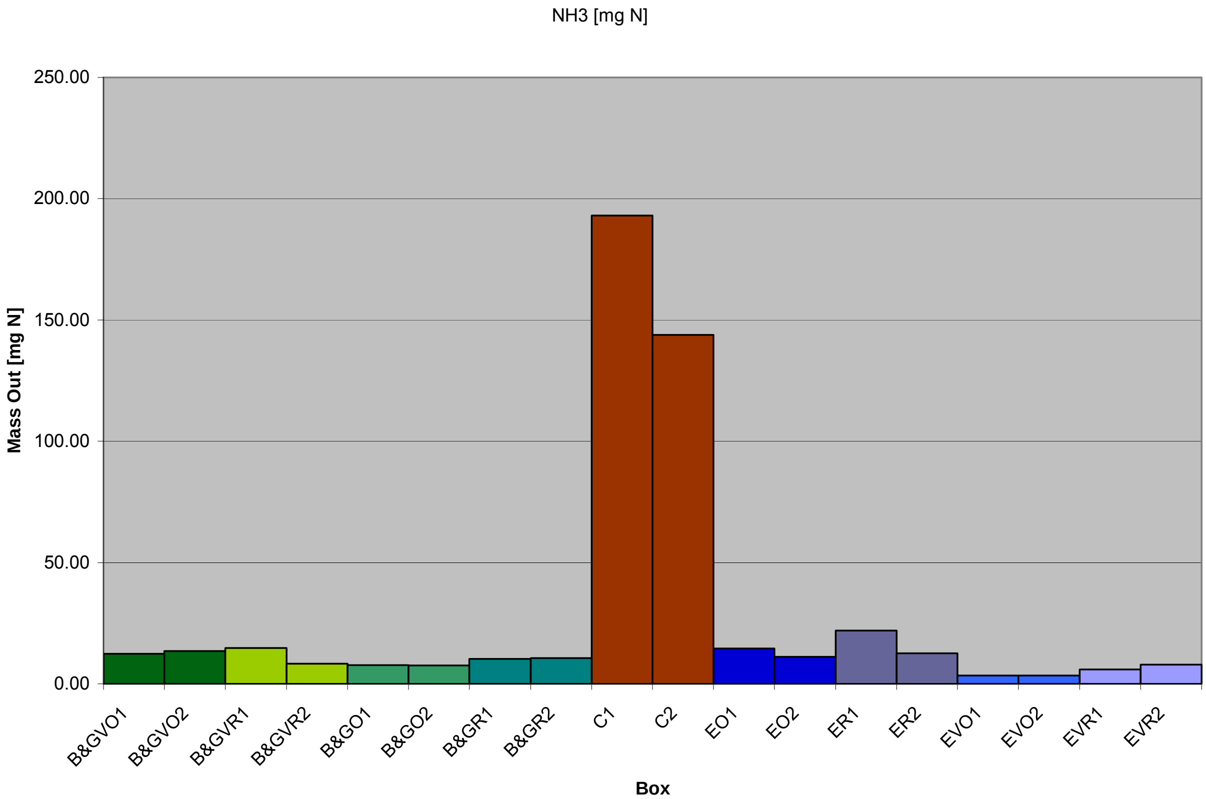
ER1
ER2
EVO1
EVO2
EVR1
EVR2
Box

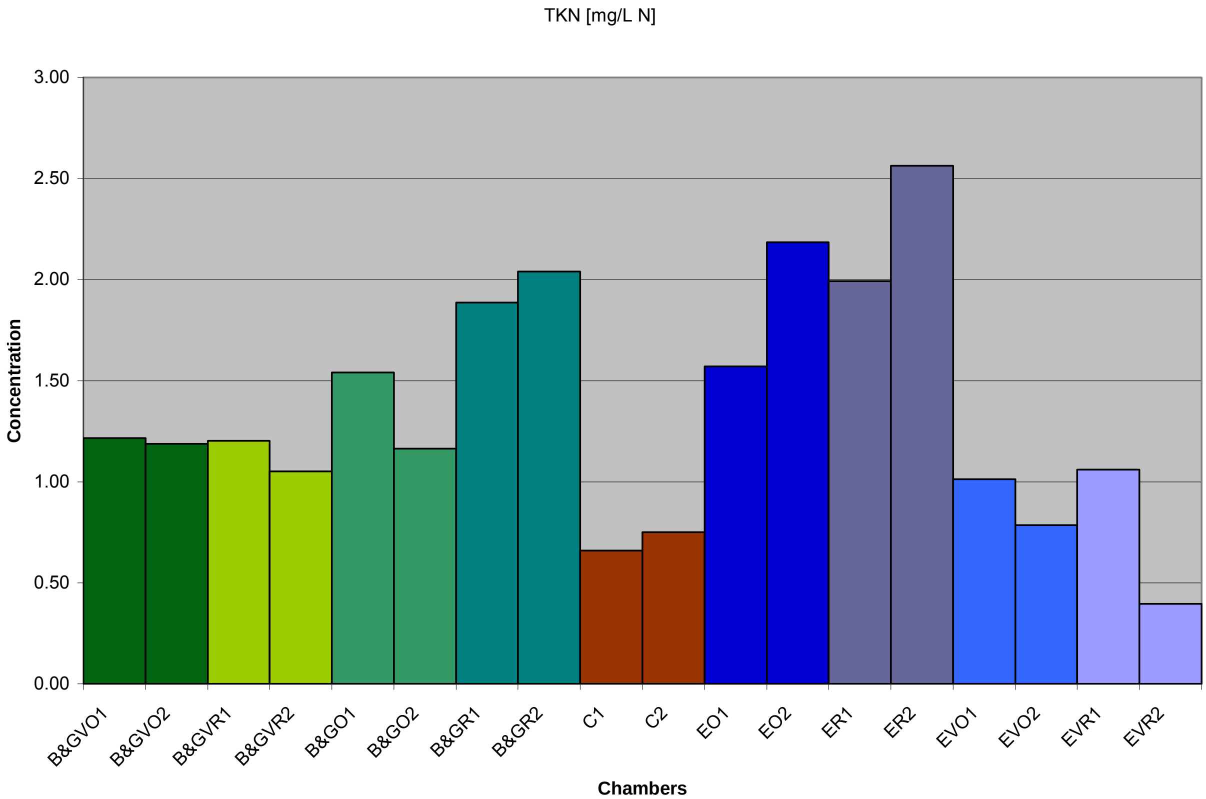

NOX [mg/L N]
Concentration
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
B&GVO1
B&GVO2
B&GVR1
B&GVR2
B&GO1
B&GO2
B&GR1
B&GR2
C1
C2
EO1
EO2
ER1
ER2
EVO1
EVO2
EVR1
EVR2
Chambers

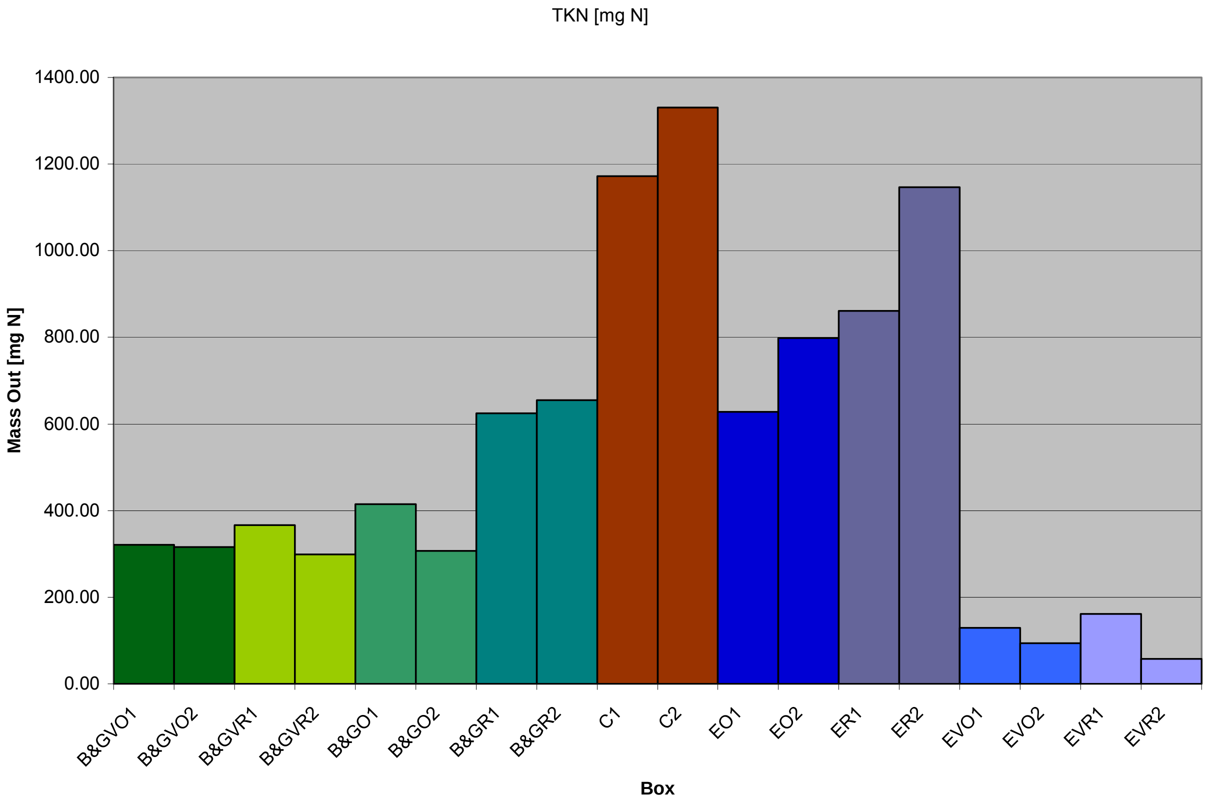

NOX [mg N]
Mass Out [mg N]
800.00
700.00
600.00
500.00
400.00
300.00
200.00
100.00
0.00
B&GVO1
B&GVO2
B&GVR1
B&GVR2
B&GO1
B&GO2
B&GR1
B&GR2
C1
C2
EO1
EO2
ER1
ER2
EVO1
EVO2
EVR1
EVR2
Box


NH3 [mg/L N]
Concentration
0.12
0.10
0.08
0.06
0.04
0.02
0.00
B&GVO1
B&GVO2
B&GVR1
B&GVR2
B&GO1
B&GO2
B&GR1
B&GR2
C1
C2
EO1
EO2
ER1
ER2
EVO1
EVO2
EVR1
EVR2
Chambers

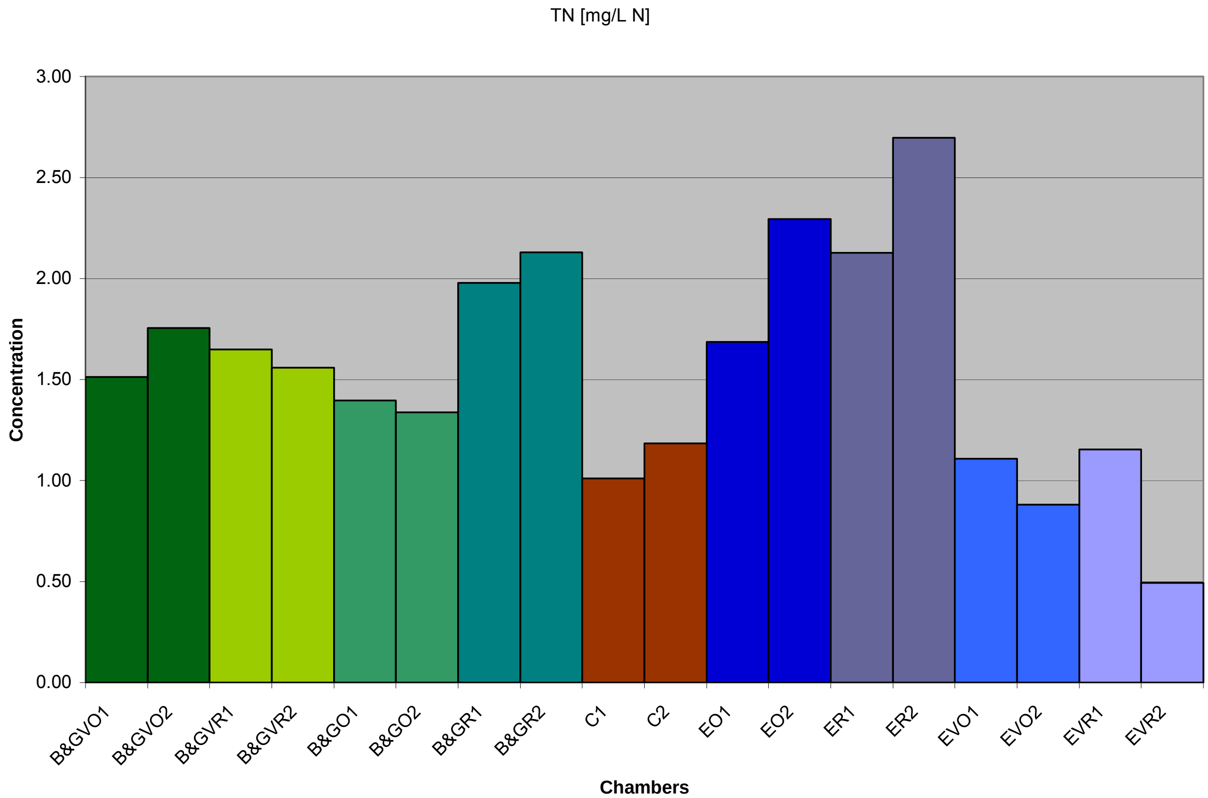


NH3 [mg N]
Mass Out [mg N]
250.00
200.00
150.00
100.00
50.00
0.00
B&GVO1
B&GVO2
B&GVR1
B&GVR2
B&GO1
B&GO2
B&GR1
B&GR2
C1
C2
EO1
EO2
ER1
ER2
EVO1
EVO2
EVR1
EVR2
Box

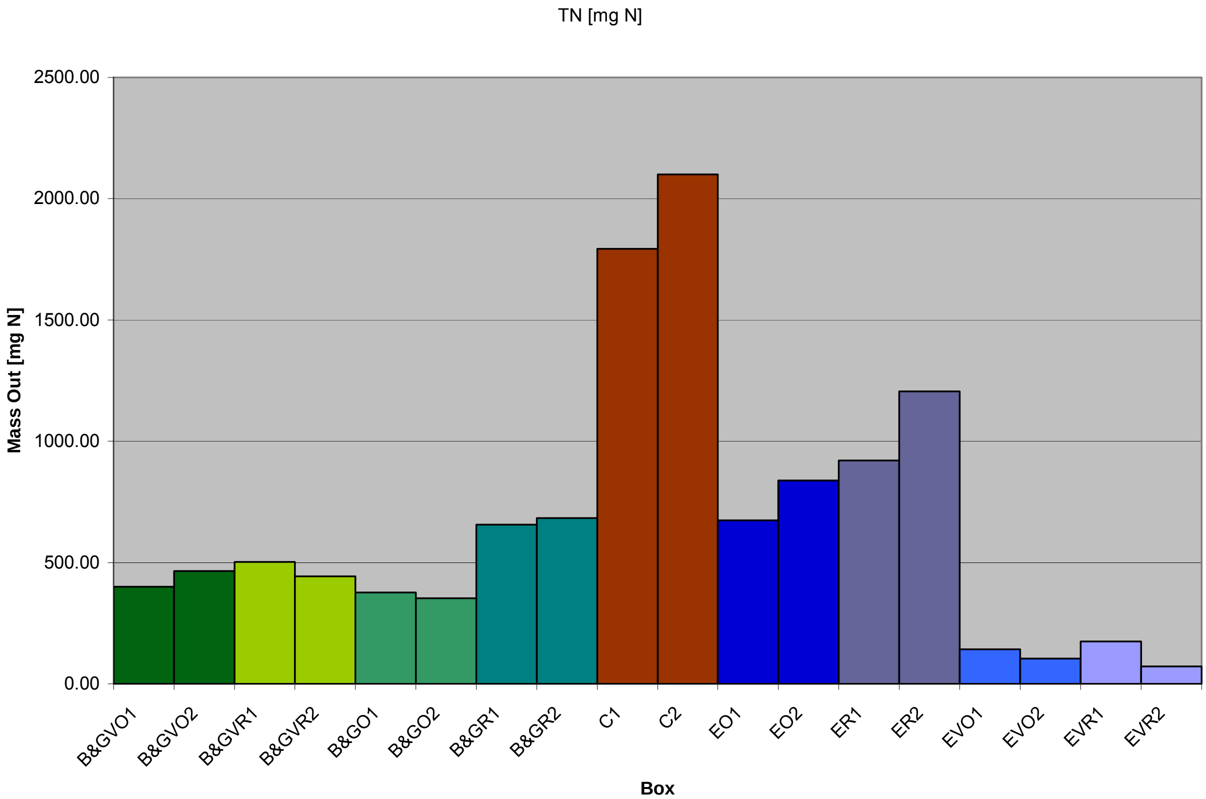

TKN [mg/L N]
3.00
2.50
2.00
1.50
1.00
0.50
0.00
Concentration
B&GVO1
B&GVO2
B&GVR1
B&GVR2
B&GO1
B&GO2
B&GR1
B&GR2
C1
C2
EO1
EO2
ER1
ER2
EVO1
EVO2
EVR1
EVR2
Chambers

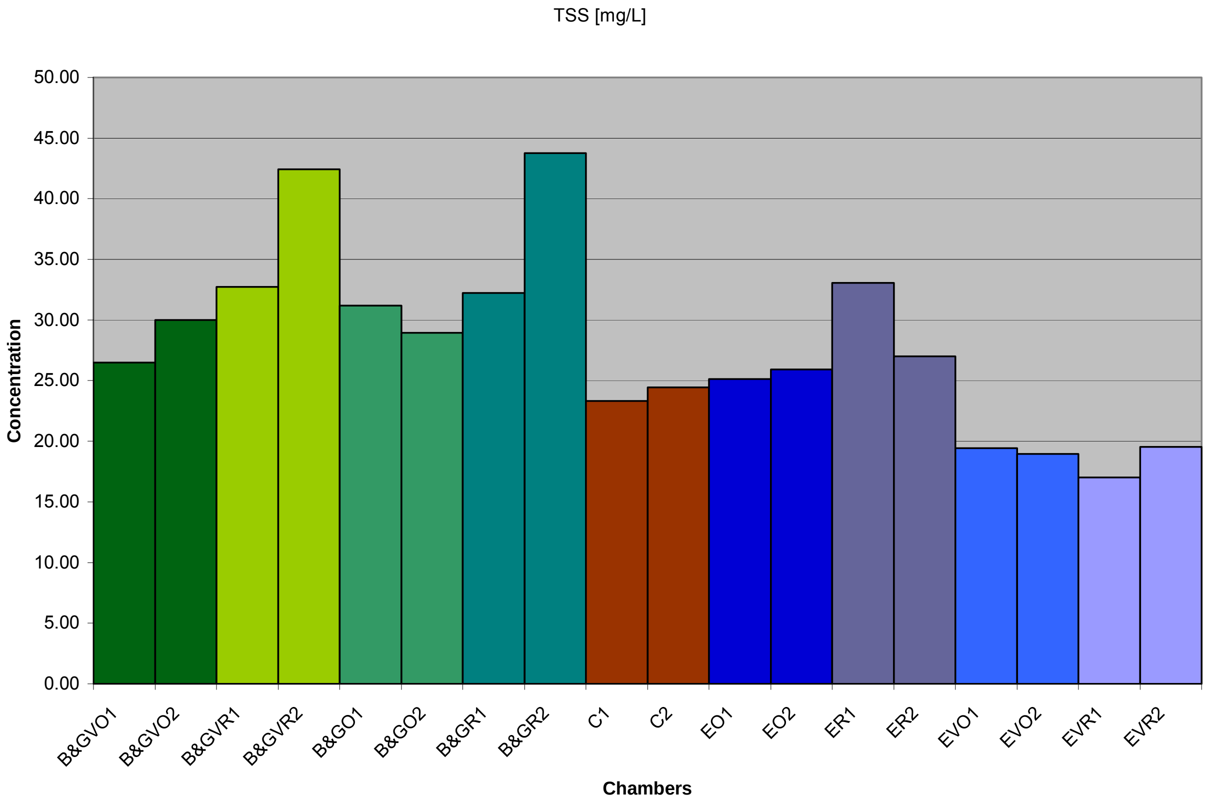


TKN [mg N]
Mass Out [mg N]
1400.00
1200.00
1000.00
800.00
600.00
400.00
200.00
0.00
B&GVO1
B&GVO2
B&GVR1
B&GVR2
B&GO1
B&GO2
B&GR1
B&GR2
C1
C2
EO1
EO2
ER1
ER2
EVO1
EVO2
EVR1
EVR2
Box



TN [mg/L N]
3.00
2.50
2.00
1.50
1.00
0.50
0.00
Concentration
B&GVO1
B&GVO2
B&GVR1
B&GVR2
B&GO1
B&GO2
B&GR1
B&GR2
C1
C2
EO1
EO2
ER1
ER2
EVO1
EVO2
EVR1
EVR2
Chambers


TN [mg N]
Mass Out [mg N]
2500.00
2000.00
1500.00
1000.00
500.00
0.00
B&GVO1
B&GVO2
B&GVR1
B&GVR2
B&GO1
B&GO2
B&GR1
B&GR2
C1
C2
EO1
EO2
ER1
ER2
EVO1
EVO2
EVR1
EVR2
Box



TSS [mg/L]
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45.00
40.00
35.00
30.00
25.00
20.00
15.00
10.00
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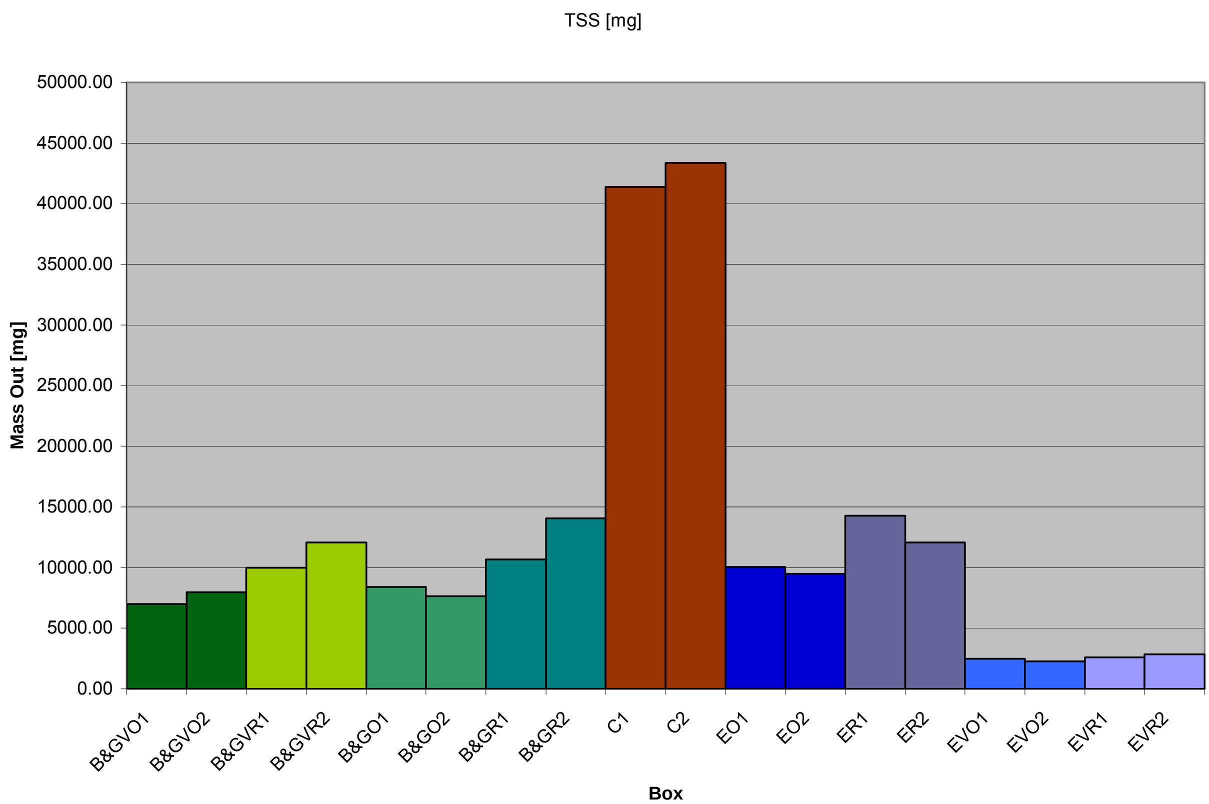
0.00
B&GVO1
B&GVO2
B&GVR1
B&GVR2
B&GO1
B&GO2
B&GR1
B&GR2
C1
C2
EO1
EO2
ER1
ER2
EVO1
EVO2
EVR1
EVR2
Chambers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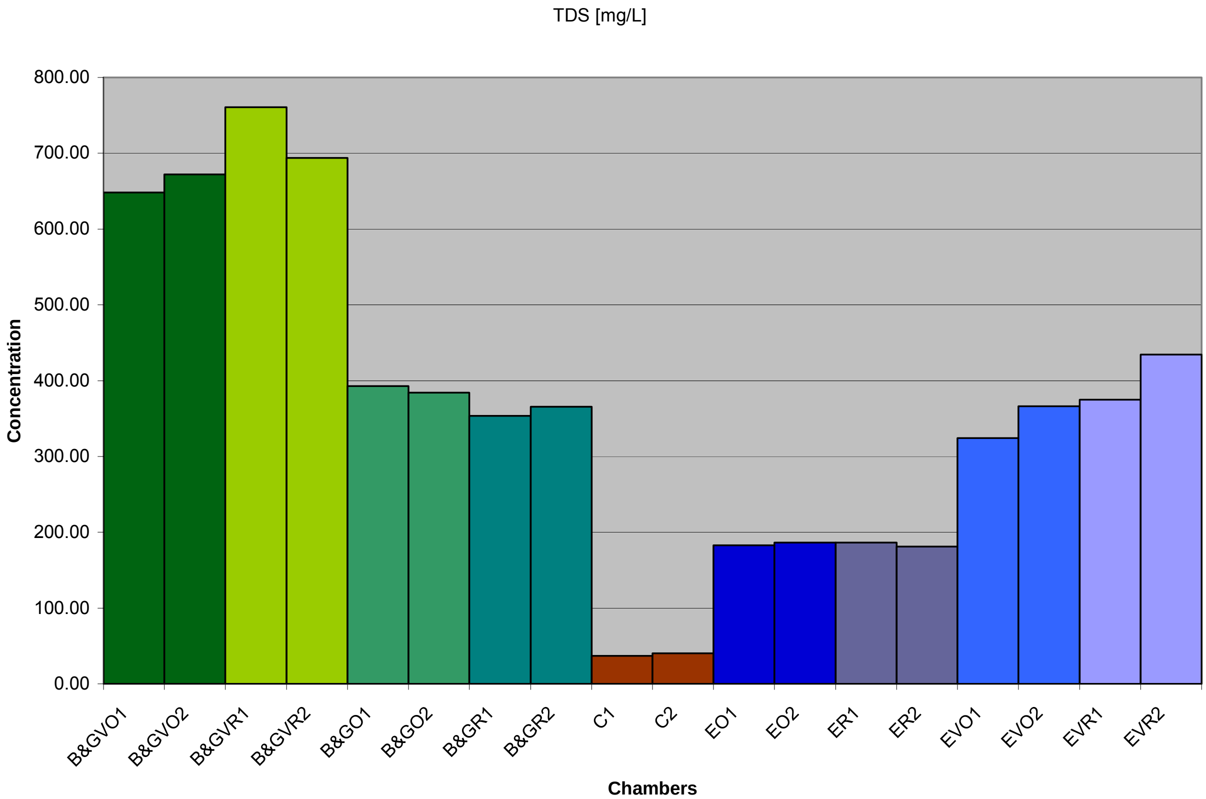
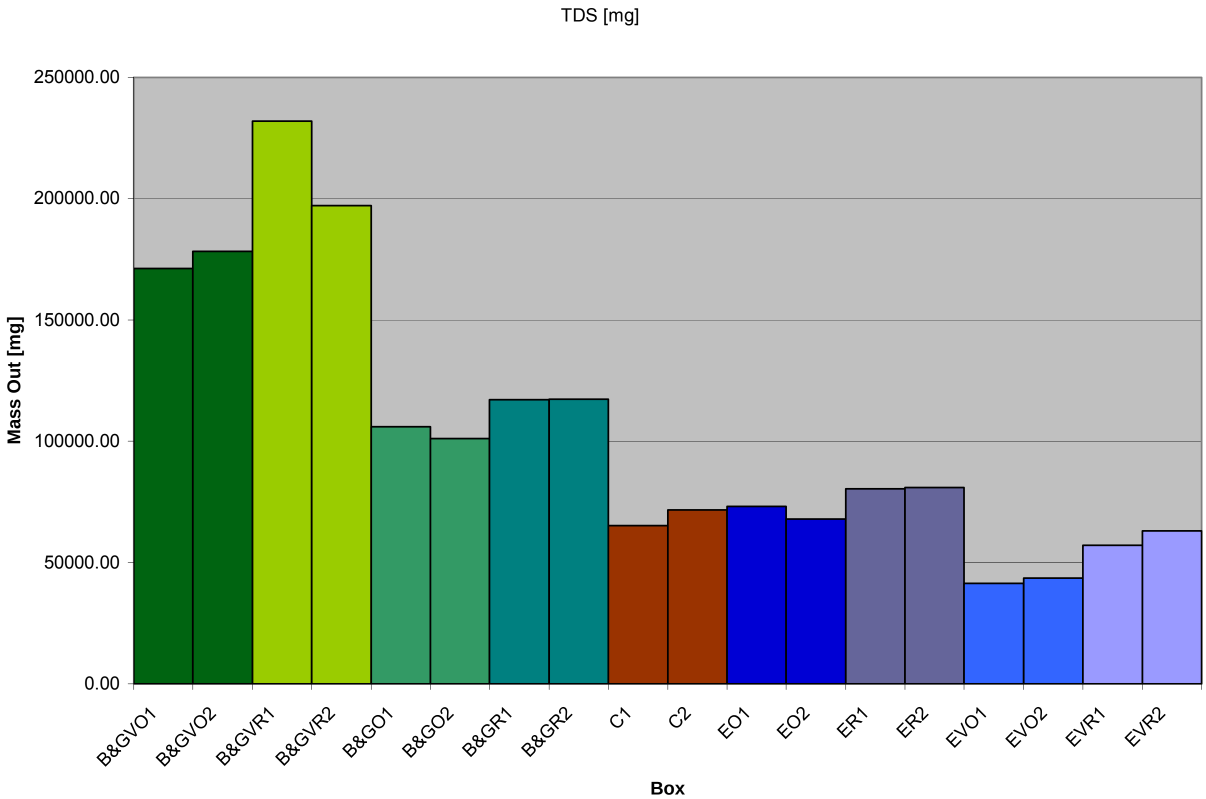
40000.00
35000.00
30000.00
25000.00
20000.00
15000.00
10000.00
5000.00
0.00
Mass Out [mg]
B&GVO1
B&GVO2
B&GVR1
B&GVR2
B&GO1
B&GO2
B&GR1
B&GR2
C1
C2
EO1
EO2
ER1
ER2
EVO1
EVO2
EVR1
EVR2
Box



TDS [mg/L]
800.00
700.00
600.00
500.00
400.00
300.00
200.00
100.00
0.00
Concentration
B&GVO1
B&GVO2
B&GVR1
B&GVR2
B&GO1
B&GO2
B&GR1
B&GR2
C1
C2
EO1
EO2
ER1
ER2
EVO1
EVO2
EVR1
EVR2
Chambers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150000.00
100000.00
50000.00
0.00
Mass Out [mg]
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B&GVO2
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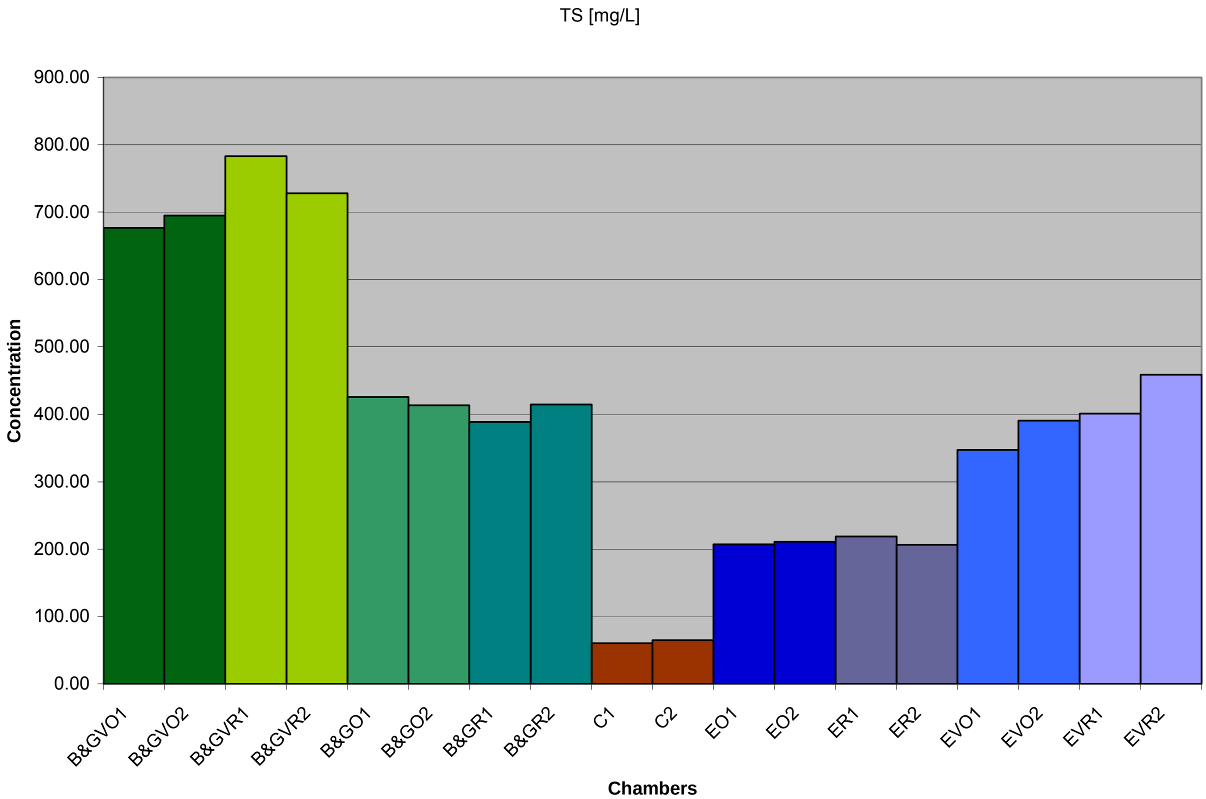
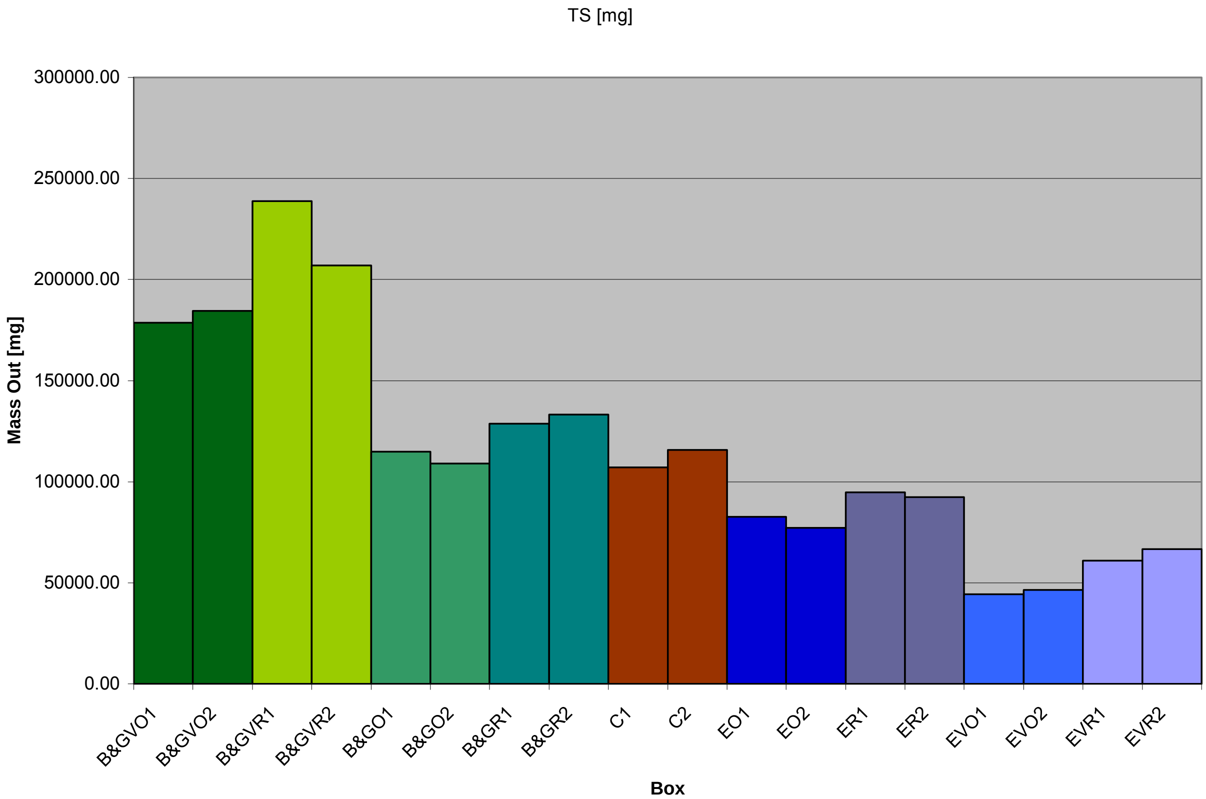
B&GVR2
B&GO1
B&GO2
B&GR1
B&GR2
C1
C2
EO1
EO2
ER1
ER2
EVO1
EVO2
EVR1
EVR2
Box


TS [mg/L]
900.00
800.00
700.00
600.00
500.00
400.00
300.00
200.00
100.00
0.00
Concentration
B&GVO1
B&GVO2
B&GVR1
B&GVR2
B&GO1
B&GO2
B&GR1
B&GR2
C1
C2
EO1
EO2
ER1
ER2
EVO1
EVO2
EVR1
EVR2
Chambers


TS [mg]
Mass Out [mg]
300000.00
250000.00
200000.00
150000.00
100000.00
50000.00
0.00
B&GVO1
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B&GVR1
B&GVR2
B&GO1
B&GO2
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ER1
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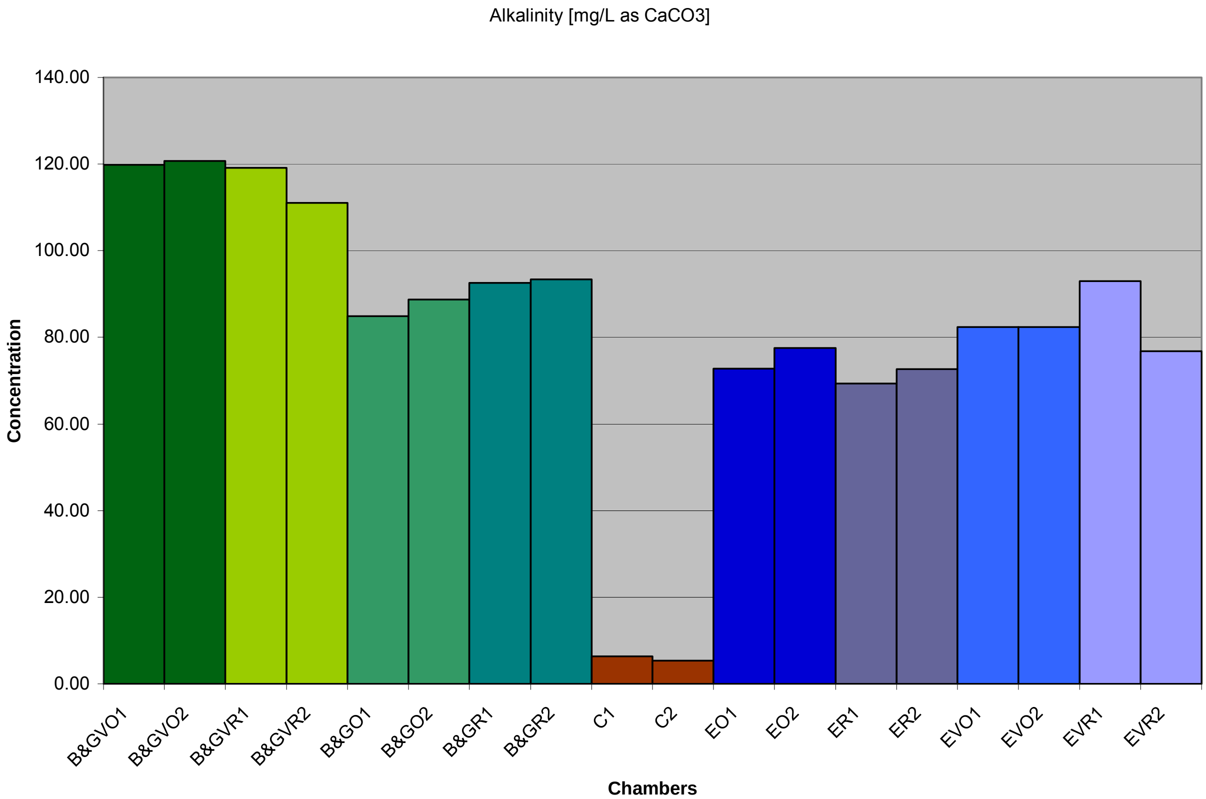
EVO2
EVR1
EVR2
Box



Alkalinity [mg/L as CaCO3]
140.00
120.00
100.00
80.00
60.00
40.00
20.00
0.00
Concentration
B&GVO1
B&GVO2
B&GVR1
B&GVR2
B&GO1
B&GO2
B&GR1
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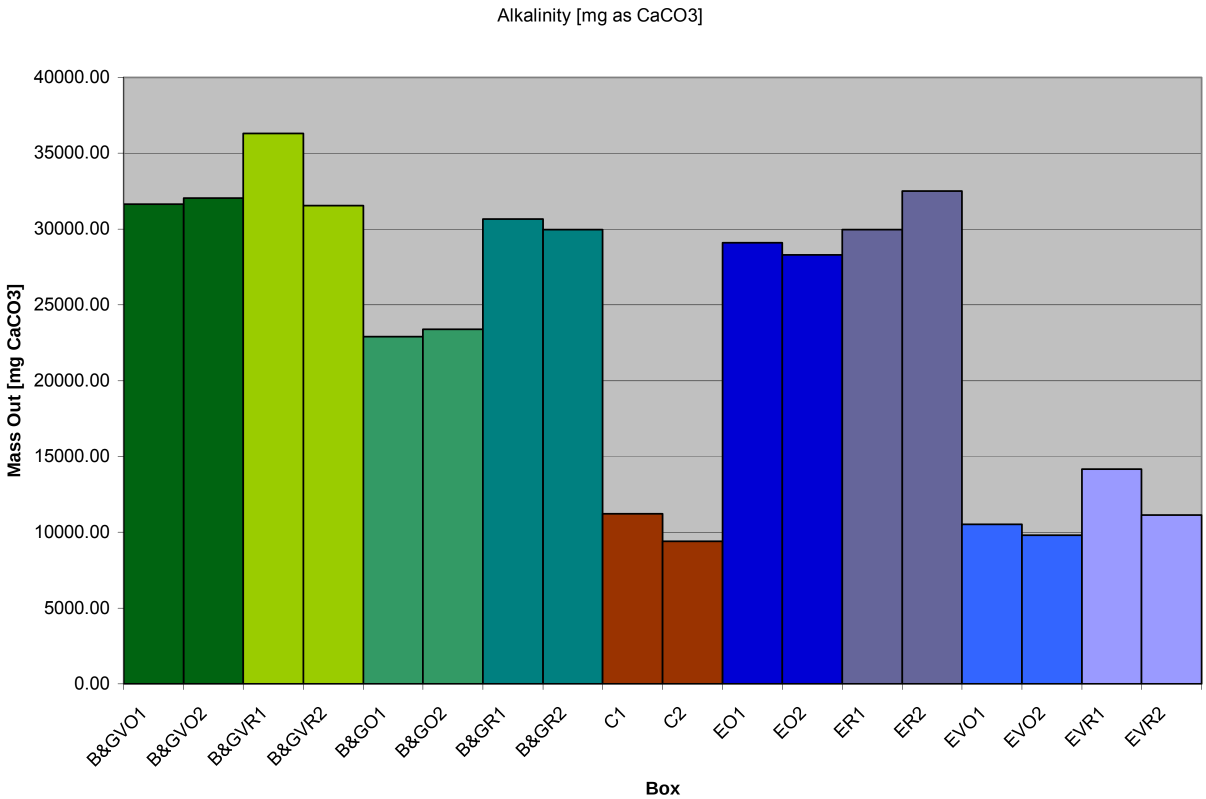
C1
C2
EO1
EO2
ER1
ER2
EVO1
EVO2
EVR1
EVR2
Chambers



Alkalinity [mg as CaCO3]
40000.00
35000.00
30000.00
25000.00
20000.00
15000.00
10000.00
5000.00
0.00
Mass Out [mg CaCO3]
B&GVO1
B&GVO2
B&GVR1
B&GVR2
B&GO1
B&GO2
B&GR1
B&GR2
C1
C2
EO1
EO2
ER1
ER2
EVO1
EVO2
EVR1
EVR2
Box

APPENDIX E: WATER QUALITY HYPOTHSIS TESTS

pH Hypothesis Tests

H_{O1}	When the media and vegetation is held constant, The pH for Over irrigation = pH for Regular irrigation
H_{a1}	When the media and vegetation is held constant, pH for Over irrigation < pH for Regular irrigation
H_{O2}	When the media and irrigation rates are held constant, pH for Vegetated boxes = pH for Non Vegetated boxes
H_{a2}	When the media and irrigation rates are held constant, pH for Vegetated boxes < pH for Non Vegetated boxes
H_{O3}	When the irrigation rates and vegetation is held constant, pH for Black & Gold = pH for Expanded Clay
H_{a3}	When the irrigation rates and vegetation is held constant, pH for Black & Gold < pH for Expanded Clay
H_{O4}	pH for a vegetated box = pH for a control box
H_{a4}	pH for a vegetated box > pH for a control box
H_{O5}	pH for a non-vegetated box = pH for a control box
H_{a5}	pH for a non-vegetated box > pH for a control box

α =	0.05	z_α =	1.645	$-z_\alpha$ =	-1.645

Note: R = Reject H_O & A = Accept H_O

	TVO1	TVO2	TVR1	TVR2	TO1	TO2	C1	C2	TR1	TR2	EO1	EO2	ER1	ER2	EVO1	EVO2	EVR1	EVR2
Average	8.62	8.24	8.18	8.41	9.11	8.76	5.99	5.83	8.81	8.86	9.10	9.20	9.46	9.09	8.85	8.95	8.76	8.79
s	0.39	0.29	0.38	0.45	0.58	0.56	0.67	0.72	0.51	0.61	0.85	0.66	0.77	0.70	0.64	0.53	0.73	0.66
Var	0.16	0.08	0.14	0.20	0.34	0.31	0.45	0.51	0.26	0.37	0.72	0.43	0.60	0.49	0.40	0.28	0.53	0.43
n	37	37	37	37	36	36	20	20	35	35	38	38	34	34	30	30	30	30
z_1	4.859	-1.902			2.298	-0.722					-1.869	0.655			0.492	1.038		
H_{O1}	**R**	**R**			**R**	**A**					**R**	**A**			**A**	**A**		
z_2	-4.220	-4.987	-5.963	-3.571											-1.386	-1.719	-3.698	-1.770
H_{O2}	**R**	**R**	**R**	**R**											**A**	**R**	**R**	**R**
z_3	-1.744	-6.642	-3.980	-2.732	0.059	-3.111			-4.077	-1.478								
H_{O3}	**R**	**R**	**R**	**R**	**A**	**R**			**R**	**A**								
z_4	16.077	14.425	13.474	14.601											15.074	16.697	13.859	14.790
H_{O4}	**R**	**R**	**R**	**R**											**R**	**R**	**R**	**R**
z_5					17.471	15.815			16.337	15.903	15.271	17.497	17.297	16.269				
H_{O5}					**R**	**R**			**R**	**R**	**R**	**R**	**R**	**R**				

Alkalinity Hypothesis Tests

H_{O1}	Media and vegetation is held constant, Alkalinity Concentration for Over irrigation = Alkalinity Concentration for Regular irrigation																	
H_{a1}	Media and vegetation is held constant, Alkalinity Concentration for Over irrigation < Alkalinity Concentration for Regular irrigation																	
H_{O2}	Media and irrigation are held constant, Alkalinity Conc. for Vegetated boxes = Alkalinity Conc. for Non Vegetated boxes																	
H_{a2}	Media and irrigation are held constant, Alkalinity Conc. for Vegetated boxes < Alkalinity Conc. for Non Vegetated boxes																	
H_{O3}	Irrigation rates and vegetation is held constant, Alkalinity Conc. for Black & Gold = Alkalinity Conc. for Expanded Clay																	
H_{a3}	Irrigation rates and vegetation is held constant, Alkalinity Conc. for Black & Gold < Alkalinity Conc. for Expanded Clay																	
H_{O4}	Alkalinity for a vegetated box = Alkalinity for a control box																	
H_{a4}	Alkalinity for a vegetated box > Alkalinity for a control box																	
H_{O5}	Alkalinity for a non-vegetated box = Alkalinity for a control box																	
H_{a5}	Alkalinity for a non-vegetated box > Alkalinity for a control box																	
α =	0.05	z_α =	1.645	$-z_\alpha$ =	-1.645													
	Note: R = Reject H_O & A = Accept H_O																	
	TVO1	TVO2	TVR1	TVR2	TO1	TO2	C1	C2	TR1	TR2	EO1	EO2	ER1	ER2	EVO1	EVO2	EVR1	EVR2
Average	119.86	120.75	119.06	110.99	84.89	88.74	6.32	5.31	92.55	93.34	72.82	77.49	69.30	72.64	82.41	82.39	93.00	76.83
s	12.14	11.68	19.84	17.66	13.83	10.61	5.16	3.95	10.98	12.71	24.66	20.74	21.96	17.11	15.05	17.00	19.93	19.99
Var	147.38	136.48	393.71	311.97	191.16	112.55	26.67	15.57	120.58	161.51	608.13	430.26	482.34	292.68	226.60	288.96	397.31	399.45
n	37.00	37.00	37.00	37.00	36.00	36.00	20.00	20.00	35.00	35.00	38.00	38.00	34.00	34.00	30.00	30.00	30.00	30.00
z_1	0.211	2.802			-2.589	-1.653	0.695				0.640	1.086			-2.323	1.161		
H_{O1}	**A**	**R**			**R**	**R**	**A**				**A**	**A**			**R**	**A**		
z_2	11.473	12.261	7.063	4.887											1.975	1.072	4.525	0.896
H_{O2}	**R**	**R**	**R**	**R**											**R**	**A**	**R**	**A**
z_3	11.027	10.509	5.331	7.325	2.613	2.961			5.536	5.694								
H_{O3}	**R**	**R**	**R**	**R**	**R**	**R**			**R**	**R**								
z_4	49.243	54.621	32.580	34.826											25.524	23.892	22.704	19.053
H_{O4}	**R**	**R**	**R**	**R**											**R**	**R**	**R**	**R**
z_5					30.483	42.224			39.447	37.909	15.972	20.750	15.988	21.977				
H_{O5}					**R**	**R**			**R**	**R**	**R**	**R**	**R**	**R**				

TS Hypothesis Tests

H_{O1}	Media and vegetation is held constant, The TS Concentration for Over irrigation = TS Concentration for Regular irrigation
H_{a1}	Media and vegetation is held constant, TS Concentration for Over irrigation < TS Concentration for Regular irrigation
H_{O2}	Media and irrigation rates are held constant, TS Concentration for Vegetated boxes = TS Concentration for Non Vegetated boxes
H_{a2}	Media and irrigation rates are held constant, TS Concentration for Vegetated boxes < TS Concentration for Non Vegetated boxes
H_{O3}	Irrigation rates and vegetation is held constant, TS Concentration for Black & Gold = TS Concentration for Expanded Clay
H_{a3}	Irrigation rates and vegetation is held constant, TS Concentration for Black & Gold < TS Concentration for Expanded Clay
H_{O4}	TS for a vegetated box = TS for a control box
H_{a4}	TS for a vegetated box > TS for a control box
H_{O5}	TS for a non-vegetated box = TS for a control box
H_{a5}	TS for a non-vegetated box > TS for a control box

α =	0.05	z_α =	1.645	$-z_\alpha$ =	-1.645

Note: R = Reject H_O & A = Accept H_O

	TVO1	TVO2	TVR1	TVR2	TO1	TO2	C1	C2	TR1	TR2	EO1	EO2	ER1	ER2	EVO1	EVO2	EVR1	EVR2
Average	676.71	694.83	783.22	728.21	425.76	413.64	57.64	61.03	388.59	414.64	206.73	211.13	218.91	206.45	331.90	374.15	389.25	436.81
s	136.11	175.03	239.07	265.65	114.35	110.10	62.51	70.34	107.62	132.66	63.41	61.60	68.25	51.50	91.17	113.91	138.30	181.17
Var	18525	30634	57157	70570	13075	12122	3908	4947	11583	17597	4021	3794	4658	2653	8313	12975	19127	32823
n	34.00	34.00	34.00	33.00	34.00	34.00	26.00	26.00	33.00	32.00	36.00	35.00	32.00	29.00	33.00	32.00	35.00	34.00
z_1	-2.257	-0.605			1.371	-0.033					-0.759	0.331			-2.030	-1.692		
H_{O1}	**R**	**A**			**A**	**A**					**A**	**A**			**R**	**R**		
z_2	8.232	7.930	8.754	6.048											6.564	7.191	6.475	7.086
H_{O2}	**R**	**R**	**R**	**R**											**R**	**R**	**R**	**R**
z_3	12.216	8.872	8.347	5.231	9.832	9.392			7.615	8.220								
H_{O3}	**R**	**R**	**R**	**R**	**R**	**R**			**R**	**R**								
z_4	23.480	19.186	16.955	13.826											13.676	12.828	12.563	11.054
H_{O4}	**R**	**R**	**R**	**R**											**R**	**R**	**R**	**R**
z_5					15.918	15.079			14.781	12.997	9.211	8.685	9.376	8.663				
H_{O5}					**R**	**R**			**R**	**R**	**R**	**R**	**R**	**R**				

TDS Hypothesis Tests

H_{O1}	Media and vegetation are held constant, TDS Concentration for Over irrigation = TDS Concentration for Regular irrigation
H_{a1}	Media and vegetation are held constant, TDS Concentration for Over irrigation < TDS Concentration for Regular irrigation
H_{O2}	Media and irrigation rates are held constant, TDS Concentration for Vegetated boxes = TDS Concentration for Non Vegetated boxes
H_{a2}	Media and irrigation rates are held constant, TDS Concentration for Vegetated boxes > TDS Concentration for Non Vegetated boxes
H_{O3}	Irrigation rates and vegetation are held constant, TDS Concentration for Black & Gold = TDS Concentration for Expanded Clay
H_{a3}	Irrigation rates and vegetation are held constant, TDS Concentration for Black & Gold > TDS Concentration for Expanded Clay
H_{O4}	TDS for a vegetated box = TDS for a control box
H_{a4}	TDS for a vegetated box > TDS for a control box
H_{O5}	TDS for a non-vegetated box = TDS for a control box
H_{a5}	TDS for a non-vegetated box > TDS for a control box

α =	0.05	z_α =	1.645	$-z_\alpha$ =	-1.645

Note: R = Reject H_O & A = Accept H_O

	TVO1	TVO2	TVR1	TVR2	TO1	TO2	C1	C2	TR1	TR2	EO1	EO2	ER1	ER2	EVO1	EVO2	EVR1	EVR2
Average	648.56	671.89	760.86	693.67	392.67	383.90	33.92	36.48	353.71	365.49	183.03	186.05	186.06	180.88	311.65	351.64	366.67	415.43
s	143.50	187.07	251.35	259.46	107.69	109.30	37.44	49.12	102.47	113.66	56.55	55.40	63.84	41.95	89.46	111.61	138.23	177.37
Var	20593	34996	63178	67321	11598	11946	1401	2412	10501	12919	3198	3069	4076	1760	8002	12457	19108	31461
n	36.00	36.00	37.00	36.00	36.00	35.00	26.00	26.00	35.00	35.00	37.00	37.00	33.00	32.00	34.00	33.00	36.00	35.00
z_1	-2.352	-0.408			1.562	0.691					-0.209	0.441			-1.988	-1.786		
H_{O1}	**R**	**A**			**A**	**A**					**A**	**A**			**R**	**R**		
z_2	8.557	7.947	9.087	6.935											7.170	7.717	7.061	7.594
H_{O2}	**R**	**R**	**R**	**R**											**R**	**R**	**R**	**R**
z_3	11.857	8.717	8.332	5.288	10.371	9.605			8.146	8.964								
H_{O3}	**R**	**R**	**R**	**R**	**R**	**R**			**R**	**R**								
z_4	24.567	19.472	17.321	14.834											16.329	14.533	13.761	12.034
H_{O4}	**R**	**R**	**R**	**R**											**R**	**R**	**R**	**R**
z_5					18.499	16.675			16.999	15.309	12.587	11.283	11.422	11.878				
H_{O5}					**R**	**R**			**R**	**R**	**R**	**R**	**R**	**R**				

TSS Hypothesis Tests

H_{O1}	Media and vegetation are held constant, TSS Concentration for Over irrigation = TSS Concentration for Regular irrigation
H_{a1}	Media and vegetation are held constant, TSS Concentration for Over irrigation < TSS Concentration for Regular irrigation
H_{O2}	Media and irrigation rates are held constant, TSS Concentration for Vegetated boxes = TSS Concentration for Non Vegetated boxes
H_{a2}	Media and irrigation rates are held constant, TSS Concentration for Vegetated boxes < TSS Concentration for Non Vegetated boxes
H_{O3}	Irrigation rates and vegetation are held constant, TSS Concentration for Black & Gold = TSS Concentration for Expanded Clay
H_{a3}	Irrigation rates and vegetation are held constant, TSS Concentration for Black & Gold < TSS Concentration for Expanded Clay
H_{O4}	TSS for a vegetated box = TSS for a control box
H_{a4}	TSS for a vegetated box > TSS for a control box
H_{O5}	TSS for a non-vegetated box = TSS for a control box
H_{a5}	TSS for a non-vegetated box > TSS for a control box

α =	0.05	z_α =	1.645	$-z_\alpha$ =	-1.645

Note: R = Reject H_O & A = Accept H_O

	TVO1	TVO2	TVR1	TVR2	TO1	TO2	C1	C2	TR1	TR2	EO1	EO2	ER1	ER2	EVO1	EVO2	EVR1	EVR2
Average	26.49	29.98	32.75	42.44	31.18	28.93	23.50	24.24	32.22	43.76	25.13	25.94	33.04	27.00	17.87	18.06	15.31	17.81
s	31.40	34.95	25.34	62.75	25.14	22.66	33.48	23.90	29.19	42.73	18.53	20.01	21.11	22.68	17.06	15.02	14.69	15.88
Var	986	1222	642	3938	632	513	1121	571	852	1826	343	400	446	514	291	226	216	252
n	35	35	34	34	34	34	27	27	33	32	37	36	33	31	34	33	35	35
z_1	-0.911	-1.015			-0.157	-1.746					-1.658	-0.202			0.666	0.067		
H_{O1}	**A**	**A**			**A**	**R**					**R**	**A**			**A**	**A**		
z_2	-0.685	0.148	0.078	-0.100											-1.719	-1.858	-3.998	-1.883
H_{O2}	**A**	**A**	**A**	**A**											**R**	**R**	**R**	**R**
z_3	1.424	1.844	3.484	2.220	1.146	0.585			-0.130	1.953								
H_{O3}	**A**	**R**	**R**	**R**	**A**	**A**			**A**	**R**								
z_4	0.359	0.767	1.190	1.555											-0.796	-1.168	-1.186	-1.207
H_{O4}	**A**	**A**	**A**	**A**											**A**	**A**	**A**	**A**
z_5					0.991	0.779			1.063	2.207	0.229	0.298	1.287	0.449				
H_{O5}					**A**	**A**			**A**	**R**	**A**	**A**	**A**	**A**				

Turbidity Hypothesis Tests

H_{O1}	Media and vegetation are held constant, Turbidity for Over irrigation = Turbidity for Regular irrigation
H_{a1}	Media and vegetation are held constant, Turbidity for Over irrigation < Turbidity for Regular irrigation
H_{O2}	Media and irrigation rates are held constant, Turbidity for Vegetated boxes = Turbidity for Non Vegetated boxes
H_{a2}	Media and irrigation rates are held constant, Turbidity for Vegetated boxes < Turbidity for Non Vegetated boxes
H_{O3}	Irrigation rates and vegetation are held constant, Turbidity for Black & Gold = Turbidity for Expanded Clay
H_{a3}	Irrigation rates and vegetation are held constant, Turbidity for Black & Gold < Turbidity for Expanded Clay
H_{O4}	Turbidity for a vegetated box = Turbidity for a control box
H_{a4}	Turbidity for a vegetated box > Turbidity for a control box
H_{O5}	Turbidity for a non-vegetated box = Turbidity for a control box
H_{a5}	Turbidity for a non-vegetated box > Turbidity for a control box

α =	0.05	z_α =	1.645	$-z_\alpha$ =	-1.645

Note: R = Reject H_O & A = Accept H_O

	TVO1	TVO2	TVR1	TVR2	TO1	TO2	C1	C2	TR1	TR2	EO1	EO2	ER1	ER2	EVO1	EVO2	EVR1	EVR2
Average	6.93	7.92	12.78	9.66	5.80	6.43	6.83	8.94	6.31	7.08	5.97	7.15	10.00	7.18	3.22	3.28	3.16	2.99
s	3.27	3.26	7.23	6.98	2.29	2.19	9.11	14.49	3.91	10.72	5.16	6.12	8.06	4.78	3.74	2.90	2.99	2.59
Var	11	11	52	49	5	5	83	210	15	115	27	37	65	23	14	8	9	7
n	34	35	34	34	32	32	24	24	32	32	34	34	31	31	37	37	37	37
z_1	-4.294	-1.324			-0.635	-0.334					-2.376	-0.022			0.077	0.453		
H_{O1}	**R**	**A**			**A**	**A**					**R**	**A**			**A**	**A**		
z_2	1.646	2.208	4.559	1.153											-2.557	-3.363	-4.480	-4.372
H_{O2}	**R**	**R**	**R**	**A**											**R**	**R**	**R**	**R**
z_3	4.471	6.377	7.215	5.253	-0.180	-0.642			-2.305	-0.049								
H_{O3}	**R**	**R**	**R**	**R**	**A**	**A**			**R**	**A**								
z_4	0.054	-0.342	2.663	0.225											-1.845	-1.892	-1.910	-1.994
H_{O4}	**A**	**A**	**R**	**A**											**R**	**R**	**R**	**R**
z_5					-0.542	-0.842			-0.264	-0.532	-0.416	-0.572	1.348	-0.573				
H_{O5}					**A**	**A**			**A**	**A**	**A**	**A**	**A**	**A**				

TN Hypothesis Tests

H_{O1}	Media and vegetation are held constant, TN Concentration for Over irrigation = TN Concentration for Regular irrigation
H_{a1}	Media and vegetation are held constant, TN Concentration for Over irrigation < TN Concentration for Regular irrigation
H_{O2}	Media and irrigation rates are held constant, TN Concentration for Vegetated boxes = TN Concentration for Non Vegetated boxes
H_{a2}	Media and irrigation rates are held constant, TN Concentration for Vegetated boxes < TN Concentration for Non Vegetated boxes
H_{O3}	Irrigation rates and vegetation are held constant, TN Concentration for Black & Gold = TN Concentration for Expanded Clay
H_{a3}	Irrigation rates and vegetation are held constant, TN Concentration for Black & Gold < TN Concentration for Expanded Clay
H_{O4}	TN for a vegetated box = TN for a control box
H_{a4}	TN for a vegetated box > TN for a control box
H_{O5}	TN for a non-vegetated box = TN for a control box
H_{a5}	TN for a non-vegetated box > TN for a control box

α =	0.05	z_α =	1.645	$-z_\alpha$ =	-1.645

Note: R = Reject H_O & A = Accept H_O

	TVO1	TVO2	TVR1	TVR2	TO1	TO2	C1	C2	TR1	TR2	EO1	EO2	ER1	ER2	EVO1	EVO2	EVR1	EVR2
Average	1.51	1.75	1.65	1.56	1.40	1.34	0.94	1.10	1.98	2.13	1.69	2.29	2.13	2.70	1.09	0.89	1.10	0.70
s	0.73	1.17	0.88	0.84	0.46	0.47	0.21	0.50	0.52	0.73	0.73	1.47	1.11	1.39	0.68	0.46	0.69	0.34
Var	0.54	1.36	0.77	0.70	0.21	0.22	0.05	0.25	0.27	0.54	0.53	2.15	1.24	1.95	0.46	0.22	0.48	0.11
n	6.00	6.00	4.00	4.00	5.00	6.00	9.00	9.00	5.00	5.00	6.00	7.00	5.00	3.00	13.00	13.00	11.00	11.00
z_1	-0.257	0.308			-1.874	-2.082					-0.761	-0.412			-0.044	1.189		
H_{O1}	**A**	**A**			**R**	**R**					**A**	**A**			**A**	**A**		
z_2	0.321	0.813	-0.664	-1.073											-1.698	-2.462	-1.897	-2.462
H_{O2}	**A**	**A**	**A**	**A**											**R**	**R**	**R**	**R**
z_3	1.195	1.745	1.127	2.000	-0.807	-1.632			-0.271	-0.653								
H_{O3}	**A**	**R**	**A**	**R**	**A**	**A**			**A**	**A**								
z_4	1.849	1.296	1.589	1.018											0.724	-0.985	0.720	-2.065
H_{O4}	**R**	**A**	**A**	**A**											**A**	**A**	**A**	**R**
z_5					2.089	0.927			4.227	2.796	2.437	2.063	2.349	1.941				
H_{O5}					**R**	**A**			**R**	**R**	**R**	**R**	**R**	**R**				

TKN Hypothesis Tests																		
H_{O1}	Media and vegetation are held constant, TKN Concentration for Over irrigation = TKN Concentration for Regular irrigation																	
H_{a1}	Media and vegetation are held constant, TKN Concentration for Over irrigation < TKN Concentration for Regular irrigation																	
H_{O2}	Media and irrigation rates are held constant, TKN Concentration for Vegetated boxes = TKN Concentration for Non Vegetated boxes																	
H_{a2}	Media and irrigation rates are held constant, TKN Concentration for Vegetated boxes < TKN Concentration for Non Vegetated boxes																	
H_{O3}	Irrigation rates and vegetation are held constant, TKN Concentration for Black & Gold = TKN Concentration for Expanded Clay																	
H_{a3}	Irrigation rates and vegetation are held constant, TKN Concentration for Black & Gold < TKN Concentration for Expanded Clay																	
H_{O4}	TKN for a vegetated box = TKN for a control box																	
H_{a4}	TKN for a vegetated box > TKN for a control box																	
H_{O5}	TKN for a non-vegetated box = TKN for a control box																	
H_{a5}	TKN for a non-vegetated box > TKN for a control box																	
α =	0.05	z_α =	1.645	$-z_\alpha$ =	-1.645													
	Note: R = Reject H_O & A = Accept H_O																	
	TVO1	TVO2	TVR1	TVR2	TO1	TO2	C1	C2	TR1	TR2	EO1	EO2	ER1	ER2	EVO1	EVO2	EVR1	EVR2
Average	1.22	1.19	1.20	1.05	1.54	1.16	0.62	0.71	1.89	2.04	1.57	2.19	1.99	2.56	0.99	0.79	1.00	0.59
s	0.63	0.47	0.78	0.79	1.55	0.52	0.24	0.49	0.54	0.75	0.69	1.46	1.10	1.36	0.72	0.50	0.72	0.34
Var	0.40	0.22	0.61	0.62	2.40	0.27	0.06	0.24	0.29	0.56	0.48	2.12	1.20	1.84	0.51	0.25	0.52	0.12
n	5	5	7	7	8	7	10	10	5	5	6	7	5	3	13	13	11	11
z_1	0.033	0.377			-0.580	-2.264					-0.745	-0.394			-0.028	1.166		
H_{O1}	**A**	**A**			**A**	**R**					**A**	**A**			**A**	**A**		
z_2	-0.526	0.089	-1.800	-2.210											-1.684	-2.457	-1.855	-2.497
H_{O2}	**A**	**A**	**R**	**R**											**R**	**R**	**R**	**R**
z_3	0.660	1.587	0.562	1.467	-0.050	-1.749			-0.193	-0.615								
H_{O3}	**A**	**A**	**A**	**A**	**A**	**R**			**A**	**A**								
z_4	2.026	1.849	1.896	1.024											1.709	0.399	1.619	-0.640
H_{O4}	**R**	**R**	**R**	**A**											**R**	**A**	**A**	**A**
z_5					1.655	1.821			5.010	3.623	3.228	2.584	2.754	2.322				
H_{O5}					**R**	**R**			**R**	**R**	**R**	**R**	**R**	**R**				

NH4 Hypothesis Tests

H_{O1}	Media and vegetation are held constant, NH4 Concentration for Over irrigation = NH4 Concentration for Regular irrigation
H_{a1}	Media and vegetation are held constant, NH4 Concentration for Over irrigation < NH4 Concentration for Regular irrigation
H_{O2}	Media and irrigation rates are held constant, NH4 Concentration for Vegetated boxes = NH4 Concentration for Non Vegetated boxes
H_{a2}	Media and irrigation rates are held constant, NH4 Concentration for Vegetated boxes < NH4 Concentration for Non Vegetated boxes
H_{O3}	Irrigation rates and vegetation are held constant, NH4 Concentration for Black & Gold = NH4 Concentration for Expanded Clay
H_{a3}	Irrigation rates and vegetation are held constant, NH4 Concentration for Black & Gold < NH4 Concentration for Expanded Clay
H_{O4}	NH4 for a vegetated box = NH4 for a control box
H_{a4}	NH4 for a vegetated box < NH4 for a control box
H_{O5}	NH4 for a non-vegetated box = NH4 for a control box
H_{a5}	NH4 for a non-vegetated box < NH4 for a control box

α =	0.05	z_α =	1.645	$-z_\alpha$ =	-1.645

Note: R = Reject H_O & A = Accept H_O

	TVO1	TVO2	TVR1	TVR2	TO1	TO2	C1	C2	TR1	TR2	EO1	EO2	ER1	ER2	EVO1	EVO2	EVR1	EVR2
Average	0.05	0.05	0.05	0.03	0.03	0.03	0.09	0.07	0.03	0.03	0.04	0.03	0.05	0.03	0.03	0.03	0.04	0.05
s	0.06	0.07	0.07	0.02	0.01	0.02	0.12	0.06	0.01	0.03	0.05	0.02	0.08	0.04	0.02	0.04	0.06	0.10
Var	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.01
n	35.00	35.00	37.00	36.00	35.00	35.00	26.00	26.00	33.00	33.00	36.00	36.00	33.00	33.00	40.00	40.00	37.00	37.00
z_1	-0.110	1.793			-0.845	-0.707					-0.904	0.278			-0.870	-1.106		
H_{O1}	**A**	**R**			**A**	**A**					**A**	**A**			**A**	**A**		
z_2	1.717	1.903	1.568	-0.520											-0.790	0.024	-0.749	1.232
H_{O2}	**R**	**R**	**A**	**A**											**A**	**A**	**A**	**A**
z_3	1.540	1.519	0.725	-1.237	-1.002	-0.441			-1.408	0.515								
H_{O3}	**R**	**A**	**A**	**A**	**A**	**A**			**A**	**A**								
z_4	-1.771	-1.378	-1.701	-3.614											-2.615	-3.166	-2.141	-1.098
H_{O4}	**R**	**A**	**R**	**R**											**R**	**R**	**R**	**A**
z_5					-2.686	-3.738			-2.571	-3.096	-2.253	-3.474	-1.554	-3.319				
H_{O5}					**R**	**R**			**R**	**R**	**R**	**R**	**R**	**R**				

NOx Hypothesis Tests

H_{O1}	Media and vegetation are held constant, NOx Concentration for Over irrigation = NOx Concentration for Regular irrigation
H_{a1}	Media and vegetation are held constant, NOx Concentration for Over irrigation < NOx Concentration for Regular irrigation
H_{O2}	Media and irrigation rates are held constant, NOx Concentration for Vegetated boxes = NOx Concentration for Non Vegetated boxes
H_{a2}	Media and irrigation rates are held constant, NOx Concentration for Vegetated boxes < NOx Concentration for Non Vegetated boxes
H_{O3}	Irrigation rates and vegetation are held constant, NOx Concentration for Black & Gold = NOx Concentration for Expanded Clay
H_{a3}	Irrigation rates and vegetation are held constant, NOx Concentration for Black & Gold < NOx Concentration for Expanded Clay
H_{O4}	NOx for a vegetated box = NOx for a control box
H_{a4}	NOx for a vegetated box < NOx for a control box
H_{O5}	NOx for a non-vegetated box = NOx for a control box
H_{a5}	NOx for a non-vegetated box < NOx for a control box

α =	0.05	z_α =	1.645	$-z_\alpha$ =	-1.645

Note: R = Reject H_O & A = Accept H_O

	TVO1	TVO2	TVR1	TVR2	TO1	TO2	C1	C2	TR1	TR2	EO1	EO2	ER1	ER2	EVO1	EVO2	EVR1	EVR2
Average	0.11	0.11	0.12	0.11	0.10	0.10	0.32	0.35	0.10	0.10	0.14	0.13	0.11	0.12	0.11	0.13	0.11	0.12
s	0.06	0.05	0.05	0.05	0.04	0.04	0.24	0.29	0.04	0.03	0.10	0.09	0.04	0.08	0.05	0.09	0.03	0.03
Var	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.09	0.00	0.00	0.01	0.01	0.00	0.01	0.00	0.01	0.00	0.00
n	37	37	35	36	34	36	28	28	37	36	37	38	33	35	42	42	36	35
z_1	-0.414	-0.473			-0.288	0.035					1.580	0.049			-0.111	0.772		
H_{O1}	**A**	**A**			**A**	**A**					**A**	**A**			**A**	**A**		
z_2	1.437	0.951	1.807	1.586											-1.351	0.239	0.558	-0.386
H_{O2}	**A**	**A**	**R**	**A**											**A**	**A**	**A**	**A**
z_3	0.204	-1.317	0.674	-0.441	-2.172	-1.683			-0.799	-1.796								
H_{O3}	**A**	**A**	**A**	**A**	**R**	**R**			**A**	**R**								
z_4	-4.362	-4.294	-4.266	-4.194											-4.457	-3.852	-4.463	-4.149
H_{O4}	**R**	**R**	**R**	**R**											**R**	**R**	**R**	**R**
z_5					-4.785	-4.497			-4.725	-4.509	-3.715	-3.921	-4.551	-3.957				
H_{O5}					**R**	**R**			**R**	**R**	**R**	**R**	**R**	**R**				

TP Hypothesis Tests

H_{O1}	Media and vegetation are held constant, TP Concentration for Over irrigation = TP Concentration for Regular irrigation
H_{a1}	Media and vegetation are held constant, TP Concentration for Over irrigation < TP Concentration for Regular irrigation
H_{O2}	Media and irrigation rates are held constant, TP Concentration for Vegetated boxes = TP Concentration for Non Vegetated boxes
H_{a2}	Media and irrigation rates are held constant, TP Concentration for Vegetated boxes < TP Concentration for Non Vegetated boxes
H_{O3}	Irrigation rates and vegetation are held constant, TP Concentration for Black & Gold = TP Concentration for Expanded Clay
H_{a3}	Irrigation rates and vegetation are held constant, TP Concentration for Black & Gold < TP Concentration for Expanded Clay
H_{O4}	TP for a vegetated box = TP for a control box
H_{a4}	TP for a vegetated box > TP for a control box
H_{O5}	TP for a non-vegetated box = TP for a control box
H_{a5}	TP for a non-vegetated box > TP for a control box

α =	0.05	z_α =	1.645	$-z_\alpha$ =	-1.645

Note: R = Reject H_O & A = Accept H_O

	TVO1	TVO2	TVR1	TVR2	TO1	TO2	C1	C2	TR1	TR2	EO1	EO2	ER1	ER2	EVO1	EVO2	EVR1	EVR2
Average	0.53	0.58	0.70	0.57	0.65	0.64	0.47	0.39	1.74	1.20	2.16	1.93	2.09	1.84	1.22	1.28	1.63	1.15
s	0.15	0.29	0.29	0.22	0.18	0.10	0.31	0.16	1.53	1.03	1.07	1.07	0.92	0.81	1.08	1.26	1.20	0.93
Var	0.02	0.09	0.09	0.05	0.03	0.01	0.10	0.03	2.34	1.06	1.15	1.15	0.85	0.66	1.18	1.58	1.44	0.87
n	24.00	25.00	22.00	26.00	25.00	22.00	19.00	19.00	25.00	26.00	29.00	29.00	26.00	23.00	25.00	27.00	22.00	25.00
z_1	-2.333	0.052			-3.530	-2.751					0.279	0.364			-1.213	0.409		
H_{O1}	**R**	**A**			**R**	**R**					**A**	**A**			**A**	**A**		
z_2	-2.482	-0.985	-3.343	-3.019											-3.194	-2.084	-1.469	-2.708
H_{O2}	**R**	**A**	**R**	**R**											**R**	**R**	**A**	**R**
z_3	-3.142	-2.816	-3.549	-3.021	-7.458	-6.448			-0.979	-2.424								
H_{O3}	**R**	**R**	**R**	**R**	**R**	**R**			**A**	**R**								
z_4	0.793	2.701	2.364	3.192											3.285	3.632	4.360	4.011
H_{O4}	**A**	**R**	**R**	**R**											**R**	**R**	**R**	**R**
z_5					2.248	5.829			4.033	3.936	7.990	7.605	8.335	8.341				
H_{O5}					**R**	**R**			**R**	**R**	**R**	**R**	**R**	**R**				

OP Hypothesis Tests

H_{O1}	Media and vegetation are held constant, OP Concentration for Over irrigation = OP Concentration for Regular irrigation
H_{a1}	Media and vegetation are held constant, OP Concentration for Over irrigation < OP Concentration for Regular irrigation
H_{O2}	Media and irrigation rates are held constant, OP Concentration for Vegetated boxes = OP Concentration for Non Vegetated boxes
H_{a2}	Media and irrigation rates are held constant, OP Concentration for Vegetated boxes < OP Concentration for Non Vegetated boxes
H_{O3}	Irrigation rates and vegetation are held constant, OP Concentration for Black & Gold = OP Concentration for Expanded Clay
H_{a3}	Irrigation rates and vegetation are held constant, OP Concentration for Black & Gold < OP Concentration for Expanded Clay
H_{O4}	OP for a vegetated box = OP for a control box
H_{a4}	OP for a vegetated box > OP for a control box
H_{O5}	OP for a non-vegetated box = OP for a control box
H_{a5}	OP for a non-vegetated box > OP for a control box

α =	0.05	z_α =	1.645	$-z_\alpha$ =	-1.645

Note: R = Reject H_O & A = Accept H_O

	TVO1	TVO2	TVR1	TVR2	TO1	TO2	C1	C2	TR1	TR2	EO1	EO2	ER1	ER2	EVO1	EVO2	EVR1	EVR2
Average	0.28	0.28	0.30	0.31	0.37	0.41	0.26	0.27	0.34	0.35	1.50	1.28	1.06	1.43	0.63	0.62	0.89	0.68
s	0.21	0.23	0.14	0.19	0.16	0.15	0.18	0.35	0.11	0.12	0.77	0.80	0.64	1.02	0.58	0.58	0.66	0.54
Var	0.04	0.05	0.02	0.03	0.03	0.02	0.03	0.13	0.01	0.01	0.59	0.65	0.41	1.04	0.34	0.33	0.43	0.29
n	32	32	32	32	30	30	21	22	30	30	32	32	28	28	38	38	37	37
z_1	-0.417	-0.419			0.862	1.748					2.415	-0.635			-1.783	-0.460		
H_{O1}	**A**	**A**			**A**	**R**					**R**	**A**			**R**	**A**		
z_2	-1.863	-2.493	-1.207	-1.023											-5.250	-3.870	-1.073	-3.554
H_{O2}	**R**	**R**	**A**	**A**											**R**	**R**	**A**	**R**
z_3	-3.462	-3.277	-5.323	-3.962	-8.162	-6.015			-5.925	-5.601								
H_{O3}	**R**	**R**	**R**	**R**	**R**	**R**			**R**	**R**								
z_4	0.422	0.196	0.888	0.471											3.648	2.922	5.475	3.542
H_{O4}	**A**	**A**	**A**	**A**											**R**	**R**	**R**	**R**
z_5					2.241	1.737			1.774	1.004	8.790	6.278	6.336	5.626				
H_{O5}					**R**	**R**			**R**	**A**	**R**	**R**	**R**	**R**				

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