STORMWATER IRRIGATION OF SAINT AUGUSTINE GRASS: NITROGEN BALANCE AND EVAPOTRANSPIRATION

by

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B.S. University of Central Florida, 2004

A thesis submitted in partial fulfillment of the requirements
for the degree of Master of Science
in the Department of Civil and Environmental Engineering
in the College of Engineering and Computer Science
at the University of Central Florida
Orlando, Florida

Summer Term
2005

ABSTRACT

A change in surface condition of a watershed, which is usually caused by development, can have measured effects on the naturally occurring hydrologic cycle and nitrogen cycle. This could result in environmental problems, such as reduced springflow and eutrophication. In an effort to address these issues, a combination of best management practices (BMPs) can be adhered to. The practice of using excess stormwater as a source for irrigation is proposed as a BMP for the minimization of impacts by development to the hydrologic and nitrogen cycles.

To study the proposed BMP, a field experiment was installed in an outdoor location on the UCF main campus in Orlando, Florida. The experiment consists of three soil chambers, (2x2x4 ft, L:W:H), filled with compacted soil and covered with St. Augustine grass to simulate a suburban lawn. The grass was irrigated up to twice a week with detained stormwater with a nitrate nitrogen concentration of up to 2 mg/L. A mass balance and a total nitrogen balance were performed to determine evapotranspiration (ET) and impacts on groundwater nitrogen content.

It was determined that the groundwater characteristics are largely dependent on the characteristics of the soil. The input nitrogen (precipitation and irrigation) was mostly in the form of nitrate and the output nitrogen (groundwater) was mostly in the form of ammonia. A total nitrogen mass balance indicated the mass output of nitrogen was significantly larger than mass input of nitrogen, which was due to ammonia leaching from the soil. Only small concentrations of nitrate were detected in the groundwater,

resulting in an estimated nitrate removal (conversion to ammonia) of 97 percent at a depth of four feet when the input nitrate concentration was 2 mg/L.

The average ET of the three chambers was compared to the estimated ET from the modified Blaney-Criddle equation on a monthly basis and a yearly basis. The modified Blaney-Criddle equation was proven to be accurate for estimating the actual ET for this application: irrigated St. Augustine grass in the Central Florida climate.

In conclusion, using the available literature and the data collected from the field experiment, it was shown through an example design problem that the proposed BMP of using excess stormwater as a source for irrigation can help achieve a pre- versus post-development volume balance and can help control post-development nitrate emissions.

ACKNOWLEDGEMENTS

I would like to thank my committee member Dr. Chopra and Dr. Nnadi, the staff, and fellow students of the Stormwater Management Academy for their support and allowing for a positive work environment. Specifically, thanks to Dr. Marty Wanielista for his insights, guidance, and for creating this opportunity. Also, thanks to Mike Hardin, whose TKN results really tied this research together.

Personal thanks to my family for their undivided support, without which this work wouldn’t be possible. More thanks to my family for motivating me to pursue my goals. Finally, personal thanks to Dr. Wanielista for his confidence in me and teaching me by example to always have respect for and treat people well.

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CHAPTER 1 – INTRODUCTION

In the subject area of watershed management, a change in surface conditions of the watershed can have measured effects on the volume of water discharged as well as the pollutant loadings in the discharged water. The surface condition of a watershed changes either through natural or anthropogenic alterations. The most common anthropogenic change in surface conditions is development. The alteration due to development of two naturally-occurring cycles, the hydrologic cycle and the nitrogen cycle, are considered in this thesis.

Some of the major impacts to the hydrologic cycle include lowered groundwater levels due to water use for drinking and irrigation purposes, decreased groundwater infiltration due to impervious areas, and increased stormwater runoff due to impervious areas. Explored in this thesis is the practical method of using stormwater for irrigation to alleviate the aforementioned three impacts on the hydrologic cycle. Using excess stormwater runoff as a source for irrigation, can help with reducing the excess runoff volume, promoting groundwater infiltration, and reducing the demand for potable water as an irrigation source.

Development may cause disruptions in the nitrogen cycle. Nitrogen occurs naturally in precipitation, groundwater, surface water bodies, and surface water runoff. Excess stormwater runoff from impervious areas as well as nitrogen added through fertilization can increase the mass emissions of nitrogen from a developed watershed. Nitrogen is an essential element in plant cells and its removal by turfgrass has been documented (Overman et al., 1991), so the use of excess stormwater for irrigation may reduce the nitrogen emission rate to receiving water bodies. In addition, biological activity in the soil may alter the nitrogen content in the groundwater after the irrigation event. Discussed in this thesis are possible alleviations of the impact of development on the nitrogen cycle and the possible impacts on the nitrogen content of groundwater through the use of excess stormwater for irrigation.

Since nitrate (NO_3^-) is the species of nitrogen that is one of the most common groundwater pollutants and is identified as a common limiting nutrient in surface waters (cause for eutrophication), the research is focused on the fate of nitrate in stormwater as the stormwater is used for irrigation. To do this, a field experiment was set up consisting of three chambers filled with compacted soil and covered with St. Augustine grass to simulate a lawn in a developed watershed. A total nitrogen balance (NO_3^-, NO_2^-, NH_3, Org-N) and a water volume balance were performed. From the collected data, conclusions were made about the impacts on the hydrologic cycle and nitrogen cycle if stormwater is used as a source for irrigation.

A feasible and economical solution is suggested for a widespread and commonly unaddressed problem: the control of nitrate emissions from non-point sources. The removal of nitrogen through artificial wetlands, or through stormwater pond modifications is practiced, but the removal of nitrate through irrigation practices has rarely been considered. Many developed sites already have irrigation infrastructure that can be modified for the use of a different water source.

1.1 Objectives

Since the research conclusions were made through a controlled experiment, the research is considered applied and experimental with a direct application to the technical area of Stormwater Management in the field of Environmental Engineering. The objectives are:

1) To investigate the legitimacy of the proposed best management practice (BMP) for minimizing the nitrogen concentration impacts on surface water and groundwater from development through the use of stormwater for irrigation
2) Increase the understanding of nitrogen transport through compacted soil as a result of irrigation with stormwater
3) Explore a relationship between predicted and actual evapotranspiration (ET) data for a post condition Saint Augustine irrigated area.

The objectives will aid in an understanding of a post equal pre volume regulation for volume and mass of nitrate control.

1.2 Limitations

The data collected was limited to the climatic conditions of Central Florida, irrigated Saint Augustine grass, a particular soil type found on the campus of the University of Central Florida, and an irrigation schedule suggested for the Saint John's River Watershed areas.

CHAPTER 2 – BACKGROUND

2.1 Problem Statement

Excess nitrate discharge from either a point source or a non-point source can have detrimental effects on surface water or groundwater, potentially having both health impacts as well as environmental impacts.

2.1.1 Health Impacts

The EPA primary drinking water standard for nitrite is 1 mg/L and for nitrate is 10 mg/L. For infants, intake of water that has a higher concentration than the EPA maximum contaminant level (MCL) of either nitrite or nitrate could cause methemoglobinemia (‘blue-baby syndrome’). For this reason, it is important to control the nitrate levels in groundwater, especially in the vicinity of drinking water wells (EPA 816-F-03-016). Nitrate can have indirect health effects as well. Due to its being an essential food source for algae and in many cases the limiting nutrient for algae, excess nitrate from surface runoff or groundwater seepage into surface waters can cause eutrophication (excessive nutrients), which in turn causes algae blooms, i.e. excessive growth of algae and potentially toxic blue-green algae (a.k.a cyanobacteria). Algae blooms can occur in fresh water as well as salt water and will most likely occur in warmer temperatures. No instances of human poisoning by blue-green algae toxins have been documented in Florida; however, little information is available about blue-green algae toxins (SJRWMD, 2003).

A survey conducted by the Orlando Sentinel and Central Florida News 13 in 2001 ("Toxic Algae Tested in Lakes") tested levels of harmful algae, such as microsystin and cylindrospermopsin in twenty-three lakes in Central Florida. According to the article, twenty thousand cells per millimeter may cause short-term health affects, and 100,000 cells per millimeter may cause long-term health effects. The health risks increase as algae scum accumulates on the lake's surface and increase further if wind causes the scum to accumulate on the side of a lake. The survey results are listed in Table 1.

Table 1 - Toxic Algae Count for 23 Lakes in Central Florida

Lake	**County**	**Count (cells/mm)**
Lake Griffin	Lake	7 million
Lake Harris	Lake	4.9 million
Lake Beresford	Volusia	4.8 million
Lake Harney	Seminole	3.9 million
Lake Tohopekaliga	Osceola	2.2 million
Lake Jesup	Seminole	1.7 million
Lake Howell	Seminole	1.7 million
Lake Apopka	Orange / Lake	1.5 million
Lake Holden	Orange	1.1 million
Lake Triplet	Seminole	1.0 million
Lake Underhill	Orange	903,585
Lake Maitland	Orange	853,615
Clear Lake	Orange	691,380
Lake Fairview	Orange	142,655
Lake Downey	Orange	137,710
Lake Conway	Orange	131,361
E. Lake Tohopekaliga	Osceola	84,948
Lake Eola	Orange	79,040
Lake Butler	Orange	29,355
Crane's Roost	Seminole	21,150
Lake Dorr	Lake	14,110
Like Minneola	Lake	7,010
Lake Ashby	Volusia	2,275

Source: Orlando Sentinel, 2001

Nitrate concentrations should be of concern near drinking water wells as is illustrated in Table 2, which is a summary of groundwater quality data from a study conducted at Heidelberg College in Ohio over several years in eight different states. The most violations of the EPA standard of 10 mg/L occurred in Illinois, which may be explained by the state's agricultural sector.

Table 2 - Summary of Nitrate Groundwater Data by State

State	Counties Tested	Number of Samples	Average Nitrate Concentration (mg/L)	Percent over 10 mg/L
Illinois	8	286	5.76	19.9
Indiana	33	5,685	0.92	3.5
Kentucky	90	4,559	2.50	4.6
Louisiana	23	997	1.19	0.8
New Jersey	5	1,108	2.60	6.8
Ohio	80	18,202	1.32	3.0
Virginia	24	1,054	2.92	7.1
West Virginia	13	1,288	0.83	0.8

Source: Canter, 1997, p.45

2.1.2 Environmental Impacts

Aside from health impacts, excessive nitrate concentrations may cause environmental impacts. According to EPA 841-F-96-004A, forty percent of the surveyed lakes, rivers, and estuaries in the U.S. are "not clean enough to meet basic uses." Blue-green algae are an essential part of the food chain, but in excess they can be damaging to an aquatic ecosystem. The consumption of oxygen through the decay of dead algae lowers the available dissolved oxygen for fish and aquatic plants. Furthermore, algae blooms prevent sunlight from reaching plants at the bottom of lakes (SJRWMD, 2003).

There is a definite need for nitrate control in the environment. For surface waters, nutrient impairment is ranked fourth nationally after sediment, pathogen, and metal impairment in EPA's top 100 impairments as listed in *National Section 303(d) Fact Sheet* (5082 reported impairments, 10.46 % of total). As listed in the *1998 Section 303(d) List Fact Sheet for Florida* by the US EPA, nutrient impairment is the most common surface water body impairment in Florida (539 reported impairments, 27.32 % of total).

An example of the damaging effects of ammonia-rich and nitrate-rich runoff is Lake Apopka near Orlando, Florida. Nutrient rich runoff from agricultural and other sources caused game fish populations to decrease and the Lake's recreational value to be lost. In an effort to reverse the trend, the Saint John's River Water Management District has implemented a reconstruction effort expected to last until 2025 with the intent to "restore Lake Apopka to Class III [fit for recreational] or better water quality." (Gian, 2004) According to Table 1, Lake Apopka had a high algae count of 1.5 million cells per millimeter in 2001.

2.1.3 Economic Impacts

To illustrate the economic impacts, the case of Lake Apopka will be further explored. "Through the 1940s, Lake Apopka was one of Central Florida's main attractions. Anglers traveled from throughout the United States to fish for trophy-sized bass in Lake Apopka, and 21 fish camps lined the lake's western shoreline until the lake began its decline in the late 1940s" (SJRWMD, 2004). Economic impacts were suffered by the businesses related to the Lake's fishing industry and the businesses in the surrounding area. Currently, the Lake Apopka restoration project is costing the Saint John's River Water Management District about 3 to 4 million dollars per year (based on budget for restoration of $4,523,655 and $3,923,023 for fiscal years of 2002-2003 and 2004-2005, respectively).

To relate the economic impacts of excess nutrients discharged into Lake Apopka to other such cases, consider that the economy of a region is dependent on the environment and the input of its natural resources. Therefore, impacts to the local and regional environment have an effect on the economy and it makes economic sense to consider reduction of environmental impacts.

2.2 Nitrogen Cycle

Nitrogen exists in up to seven oxidation states resulting in a number of different nitrogen species. Nitrogen is the fourth most common element in plant and animal cells, after carbon, hydrogen, and oxygen. Along with organic nitrogen, four forms of inorganic nitrogen are commonly found in natural waters: ammonium/ammonia (Equation 1), nitrite (Equation 2), nitrate (Equation 3), and molecular nitrogen (N_2, dissolved gas) (Sawyer et al., 2003, ch.25).

$$NH_3 + H_2O \rightarrow NH_4^+ + OH^- \qquad \text{Equation 1}$$
$$N_2O_3 + H_2O \rightarrow 2H^+ + 2\,NO_2^- \qquad \text{Equation 2}$$
$$N_2O_5 + H_2O \rightarrow 2H^+ + 2\,NO_3^- \qquad \text{Equation 3}$$

Generally, aqueous nitrogen species are divided into Kjeldahl nitrogen (organic + ammonia), dissolved nitrogen (nitrate + nitrite), and total nitrogen (all forms of nitrogen present).

Ammonia is highly soluble in water and acts as a weak base. At a pH of 7.0 or lower ammonium is most prevalent while at a pH of around 9.8 or above ammonia becomes the most prevalent form. Ammonium's tendency to replace other cations in ion exchange processes causes it to be absorbed in the soil which decreases its mobility through the soil.

Nitrite is relatively unstable and is readily oxidized to nitrate by bacteria. Thus, nitrite concentrations in natural surface waters "rarely exceed 1 mg/L" (AWWA, 1970). Nitrate is soluble in water and is relatively stable. The nitrate concentration is controlled in surface waters since it is an essential nutrient for plants and algae, but groundwater can maintain a high concentration of nitrate due to its stability and mobility in groundwater.

Different nitrogen species are transformed through biological or chemical processes. Shown in Figure 1 is the cycle of nitrogen in a stormwater pond, which is used as the source of irrigation water in the BMP proposed in this thesis.

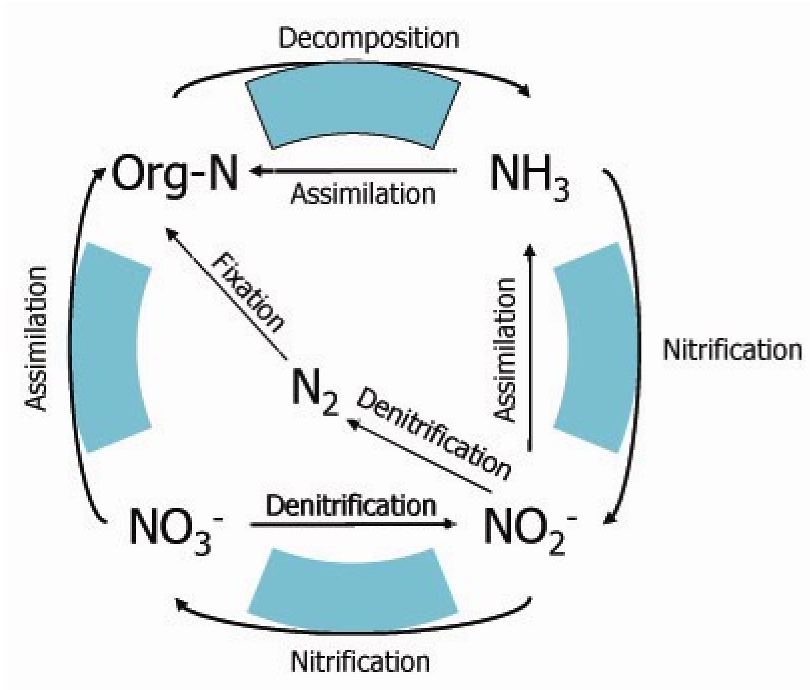


Figure 1- Nitrogen Cycle in Irrigation Source

2.2.1 Nitrification

Nitrification is achieved through biological processes in aerobic conditions. Autotrophic (can use inorganic carbon source), aerobic nitrifying bacteria utilize the chemical energy that is released by converting ammonia to nitrite or converting nitrite to nitrate. Nitrosomonas (Equation 4) and Nitrobacter (Equation 5) are two species of bacteria that utilize ammonia and nitrite, respectively (Sawyer et al.). Nitrification can occur in natural lakes and rivers, depending on the pH, temperature, dissolved oxygen, and the presence of nitrifying bacteria. Either nitrifying bacteria or inorganic oxidizing agents can be a catalyst for nitrification.

$$2NH_3 + 3.5O_2 \rightarrow 2NO_2^- + 3H_2O \qquad \text{Equation 4}$$

$$2NO_2^- + O_2 \rightarrow 2NO_3^- \qquad \text{Equation 5}$$

2.2.2 Denitrification

Denitrification is an anaerobic process in which nitrate is converted to nitrite (Equation 6) or nitrite is converted to nitrogen gas (Equation 7). It is achieved either by inorganic reducing agents or by heterotrophic (dependent on organic sources for food), anaerobic denitrifying bacteria utilizing nitrite or nitrate for protein formation (AWWA, 1970).

$$2NO_3^- \rightarrow 2NO_2^- + O_2 \qquad \text{Equation 6}$$
$$2NO_2^- \rightarrow N_2 + 2O_2 \qquad \text{Equation 7}$$

2.2.3 Assimilation

Assimilation is the conversion of nutrients into living tissues. Through nitrogen assimilation, plants, algae, and bacteria combine either nitrate or ammonia with carbon dioxide and sunlight to form proteins, and cell matter.

$$NH_3 \rightarrow \text{Organic-N} \qquad \text{Equation 8}$$
$$NO_3^- \rightarrow \text{Organic-N} \qquad \text{Equation 9}$$
$$NO_2^- \rightarrow NH_3 \qquad \text{Equation 10}$$

If nitrite is used as a food source, it is first assimilated to ammonia which in turn is assimilated to organic nitrogen. With the exception of ruminants, animals are not capable of utilizing ammonia or nitrate as a food source; instead, they rely on organic nitrogen (plants and other animals) as a source of nitrogen (Sawyer et al., 2003).

2.2.4 *Fixation*

Fixation is achieved through nitrogen-fixing bacteria and certain plants that utilize elemental nitrogen, thus directly converting nitrogen gas into organic nitrogen. At standard temperature and pressure (STP), molecular nitrogen (N_2) is a gas and approximately 15 mg/L will be dissolved in surface waters (AWWA, 1970).

$$N_2 \rightarrow \text{Organic-N} \qquad \text{Equation 11}$$

2.2.5 *Decomposition*

Decomposition is the transformation of organic nitrogen to ammonia through heterotrophic bacteria. Both anaerobic and aerobic conditions are favorable for decomposition. Animal feces and the deceased matter of plants are two common sources of organic nitrogen for decomposition.

$$\text{Organic-N} \rightarrow NH_3 \qquad \text{Equation 12}$$

2.2.6 *Oxidation / Reduction*

Nitric oxide (NO) and nitrogen dioxide (NO_2) are together referred to as NO_x and are formed by lightning or the combustion of N_2 at high temperatures. Nitrogen dioxide in turn can be reduced to nitrite or oxidized to nitrate (Sawyer et al., 2003).

$$2NO_2 + O_2 \rightarrow 2NO_3^- \qquad \text{Equation 13}$$
$$NO_2 + e^- \rightarrow NO_2^- \qquad \text{Equation 14}$$

These sources of nitrite and nitrate might occur in areas of high air pollution. Oxidation and reduction are caused by inorganic oxidizing and reducing agents or by bacteria.

2.3 Sources of Excess Nitrate

Groundwater contamination of nitrate is commonly caused by infiltration into the soil of nitrogen-rich water, such as stormwater, reclaimed water for irrigation, treated sewage, or septic tank effluent. Ammonia dissolves in water but is less mobile in the soil medium when compared to nitrate and nitrite, which also dissolve in water and will not be physically removed through filtration by the soil. However, some soils or clays could allow the removal of nitrate and nitrite through ion exchange. Furthermore, nitrite, nitrate, and ammonia can be converted to other species of nitrogen through biological activity in the soil.

Surface runoff and treated sewage are two common sources of nitrogen in surface waters. Listed in Table 3 through Table 6 are expected nitrogen levels from different sources. Values in Table 3 are specific for Florida and values in Table 4 and Table 5 are national averages. In the case of stormwater non-point pollution, Table 3 and Table 5 provide the most accurate estimates. In Table 3, dissolved nitrogen is assumed to be nitrate.

Table 3 - Sources of Nitrogen from Various Point and Nonpoint Sources in Florida

Source	**Total Nitrogen (mg/L)**	**Estimated Dissolved Nitrogen (mg/L)**
Rainfall	0.66[b]	0.66[c]
Low Density Residential	1.64[a]	0.50[c]
Single Family Stormwater	2.18[a]	0.60[c]
Multi-Family Stormwater	2.42[a]	0.70[c]
High Intensity Commercial Stormwater	2.83[a]	0.80[c]
Highway Runoff	2.23[a]	0.65[c]
Pasture Land Runoff	2.48[a]	0.70[c]
Citrus Land Runoff	2.24[a]	0.65[c]
Row Crops	2.88[a]	0.80[c]
Undeveloped Rangeland/Forrest	1.09[a]	0.45[c]
Wetlands	1.01[a]	0.60[c]
Treated Stormwater	0.72	0.20[c]

[a] Source: Harper, Baker, 2003; [b] Source: Wanielista, Yousef, 1993; [c] From Table 5.15 in Wanielista, Yousef, 1993.

Table 4 - Sources of Nitrogen from Various Point and Nonpoint Sources

Source	**Total Nitrogen (mg/L)**
Urban Runoff	3 - 10
Livestock Operations	6 – 800[a]
Atmosphere (wet deposition)	0.9
Untreated Wastewater	35
Treated Wastewater (Secondary Treatment)	30

Source: EPA 841-B-99-007, [a] as organic nitrogen

Table 5 - Mean Inorganic and Total Nitrogen Concentrations from Stream Sample Data from 904 Nonpoint Source-type Watersheds Distributed throughout the United States

Watershed Type	Inorganic Nitrogen (mg/L)	Total Nitrogen (mg/L)
>90 % Forest	± 0.05	± 0.60
>75 % Forest	± 0.08	± 0.65
>50 % Forest	± 0.25	± 0.90
>75 % Cleared, unproductive	± 0.15	± 1.00
>50 % Cleared, unproductive	± 0.20	± 0.95
Mixed	± 0.60	± 1.20
>50 % Range, remainder predominantly forest	± 0.50	± 1.30
>75 % Range	± 0.50	± 1.30
>50 % Range, remainder predominantly agriculture	± 0.55	± 1.40
>40 % Urban	± 1.00	± 1.90
>50 % Agriculture	± 1.10	± 1.90
>75 % Agriculture	± 1.40	± 2.75
>90 % Agriculture	± 4.20	± 5.30

Source: Follett, 1989, p.44

Table 6 - Summary of Nitrate Loads from Septic Tank Systems

Source	Flow (gal/day)	Units (variable)	Volume (L/day)	NO_3-N (mg/L)	Load (mg/day)
½ Acre Housing	65/person	400 people	98,410	40	3,936,400
High School	20/student	1000 students	75,700	40	3,028,000
1 Acre Housing	65/person	200 people	49,210	40	1,968,400
Condominium	65/person	120 people	29,520	40	1,180,800
Shopping Center	60/employee	50 employees	11,360	40	454,400
Office Building	15/employee	25 employees	1,420	40	56,800
Gas Station	500/island	2 islands	3,785	40	151,400
Church	3/seat	200 seats	2,270	40	90,800
Motel A	75/person	40 people	11,355	35	397,425
Motel B	75/person	160 people	45,420	35	1,589,700
Hospital	200/bed	60 beds	45,420	35	1,589,700

Source: Canter, 1997, p.172

There is variability between the sources of Table 3 through Table 6, but the general trend is that developed watersheds, such as agricultural or urban, are a greater source of nitrate than undeveloped watersheds, such as rangeland or forest.

Following is a ranking of common nitrate sources; a ranking of 1 refers to the largest contributor. Precipitation and Forrest/range runoff are part of the natural nitrogen cycle while urban runoff, agricultural runoff, treated sewage, and septic tanks are not part of the natural nitrogen cycle and are causes of excess nitrate. The ranking was constructed from the data in Table 3 to Table 6.

1. Septic tank effluent
2. Treated Sewage
3. Agricultural runoff
4. Urban Runoff
5. Precipitation
6. Forrest/range runoff

2.4 Total Maximum Daily Load

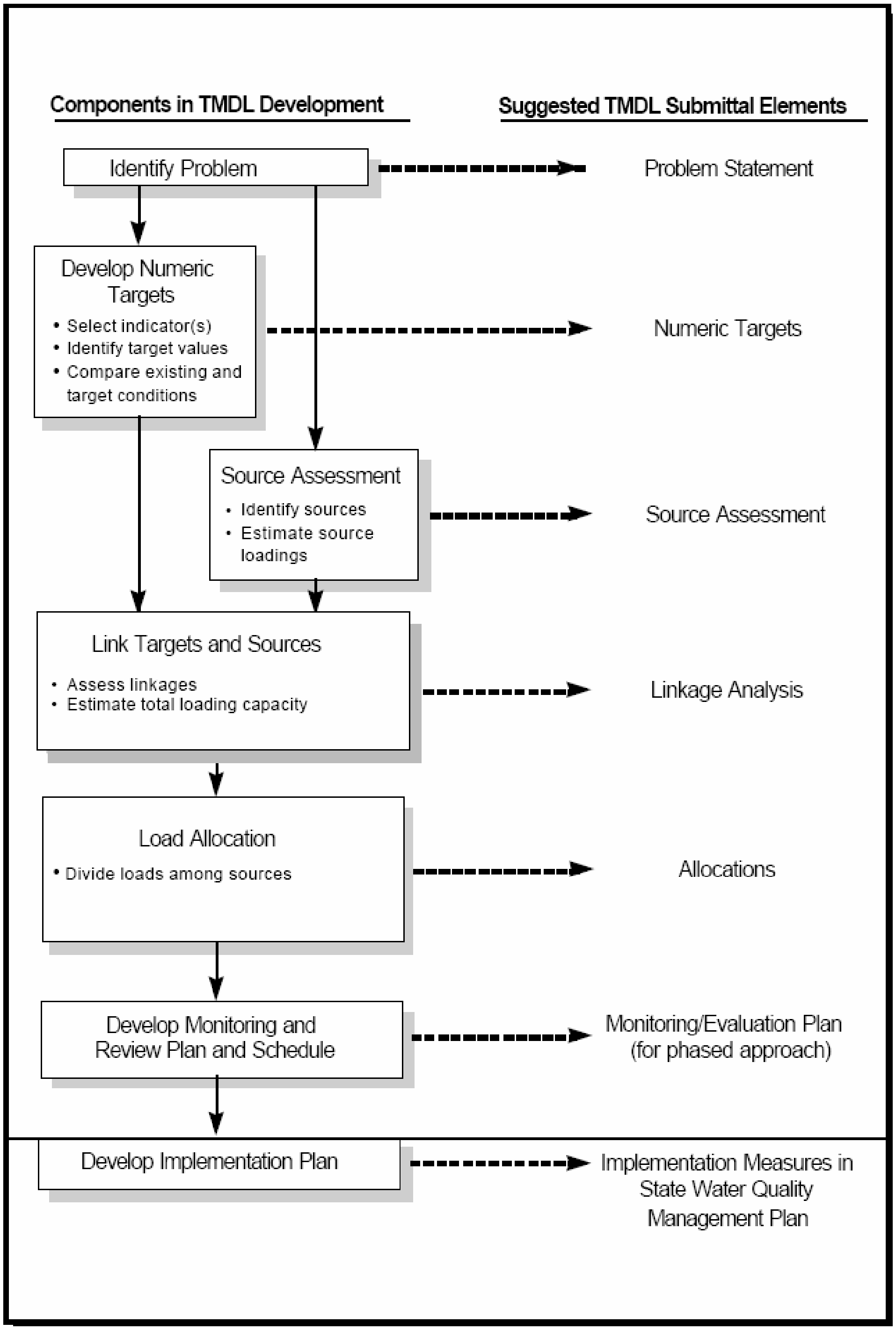
The Total Maximum Daily Load (TMDL) is a parameter that establishes a water quality design goal, a criterion for acceptable loading of pollutants. As is shown by Equation 15, TMDL is determined by the sum of all point source loads, non-point source loads, and an appropriate margin of safety (MOS) (Gao et al., 2003).

$$TMDL = \sum \text{point source} + \sum \text{non - point source} + \text{MOS} \qquad \text{Equation 15}$$

A point source could be the discharge from a wastewater treatment plant, while urban stormwater runoff is an example of a nonpoint source. The margin of safety accounts for the variety of assumptions that are involved in the determination of TMDL and it accounts for any uncertainties of a relationship between nutrient loading and receiving water quality.

TMDLs are established quantitatively such that violations of the TMDL would cause one or more water quality standards to be violated. In the state of Florida 1,973 TMDL impairments were reported by the US Environmental Protection Agency as of the November 24th, 1998 in section 303(d) list of the Clean Water Act. Nutrient impairments were the most common type of impairment at 27.32 percent of the 1,973 impairments.

Historically, nutrient control was implemented only for point sources, but waters continued to be impaired. To address this problem, national water quality guidelines have been established. A list of priority and non-priority pollutants was published (EPA 822-R-02-D47), which are categorized in freshwater, saltwater, and drinking water. The only standard listed for nitrate is 10 mg/L for drinking water. Listed in Appendix C of EPA 822-R-02-D47 is a proposed method for calculating an ammonia TMDL for fresh water bodies; this method depends on the pH and on the types of fish present in the receiving water body. The TMDL varies for individual water bodies, illustrated in Figure 2 is a general method for determining the TMDL for a water body.



Source: EPA 841-B-99-007

Figure 2 - General Components of TMDL Development Plan

The nitrate concentration above which a water body will be impaired is a function of many parameters, including land use, flora and fauna, precipitation, season, water body type, etc. There is no point source or non-point source national standard for a nitrate concentration to determine the concentration of nitrate at which the quality of a natural water body will be impaired.

A general approach can be implemented to control the nutrient levels. Customarily, the ideal nitrate level to be achieved by applying TMDLs is the 'nitrate background level,' which is defined as the concentration of nitrate prior to any alteration.

A pre- versus post-development approach, as is commonplace for volume control in stormwater management, can suffice in preventing receiving water bodies from a nitrate concentration in excess of the background level. For stormwater, in order to maintain the background level for nitrate in surrounding water bodies, the mass of nitrate in the post-development rainfall excess minus the mass of nitrate in the pre-development rainfall excess needs to be removed.

2.5 Current State of the Art

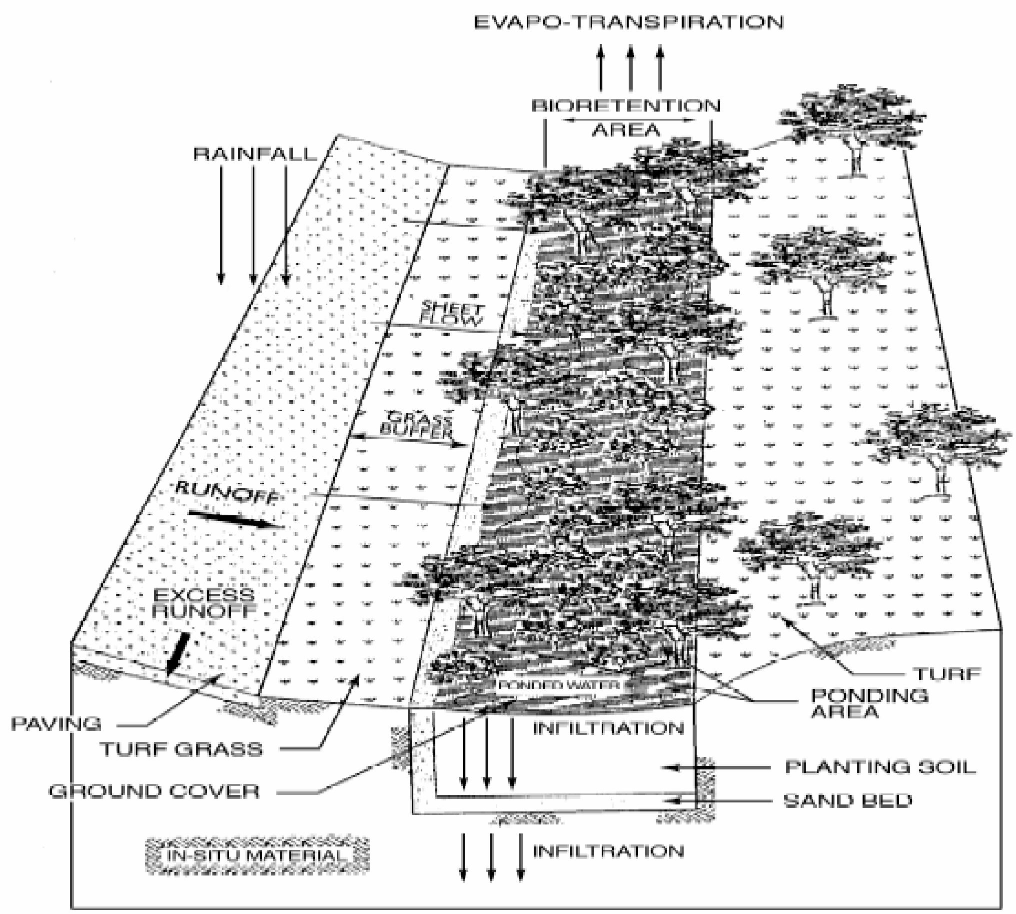
Common stormwater management practices in the United States today are intended to achieve a pre-development peak runoff rate at the post-development surface conditions for a certain 'design storm' of the geographic region (i.e. a 25 year, 24 hour storm event). The excess runoff from the directly connected impervious area is usually directed to detention basins or underground storage basins from which the water is discharged at a rate equal to the pre-development.

The ‘first flush’ of a rainfall event is generally believed to contain the majority of pollutants; any additional rainfall runoff flows over surface area already cleared by the first flush. Determined from probability distributions of rainfall amount per event in Orlando, Baltimore, and Austin, ninety percent of all rainfall events (4 hour inter-event dry period) are one inch or less (Wanielista et al., 1997). Therefore, to address environmental concerns, many municipalities require that one inch of rainfall over the impervious area is retained onsite for water quality control. Retaining the first flush will allow suspended particles to settle, but dissolved particles, such as nitrate, generally remain in solution.

Onsite stormwater management techniques are available for volume control or water quality control, such as hydrodynamic separators, dust control, bioretention, infiltration drainfields, green roofs, infiltration trenches, pervious pavement, sand filters, vegetated swales, baffle boxes, dry/wet detention ponds, and constructed wetlands. Nitrate concentrations are relatively unaffected by many of these techniques. A stormwater pond, which is commonly used for stormwater management, may serve to remove nitrate; this was observed in the results (Chapter 5.1.2) as low concentrations of nitrate were measured. In addition to a stormwater pond, the following methods can be used for the removal of nitrate

2.5.1 Bioretention

Developed in the early 1990's by Prince George's County, Maryland Department of Environmental Resources (PGDER), bioretention incorporates a grass buffer strip, sand bed, and vegetated area to promote evapotranspiration and infiltration of rainfall runoff. Figure 3 is a schematic of a basic design of a bioretention area, which can be modified for specific sites. For instance, an underdrain might be added if the infiltration is low, or anaerobic zones might be created to promote denitrification.



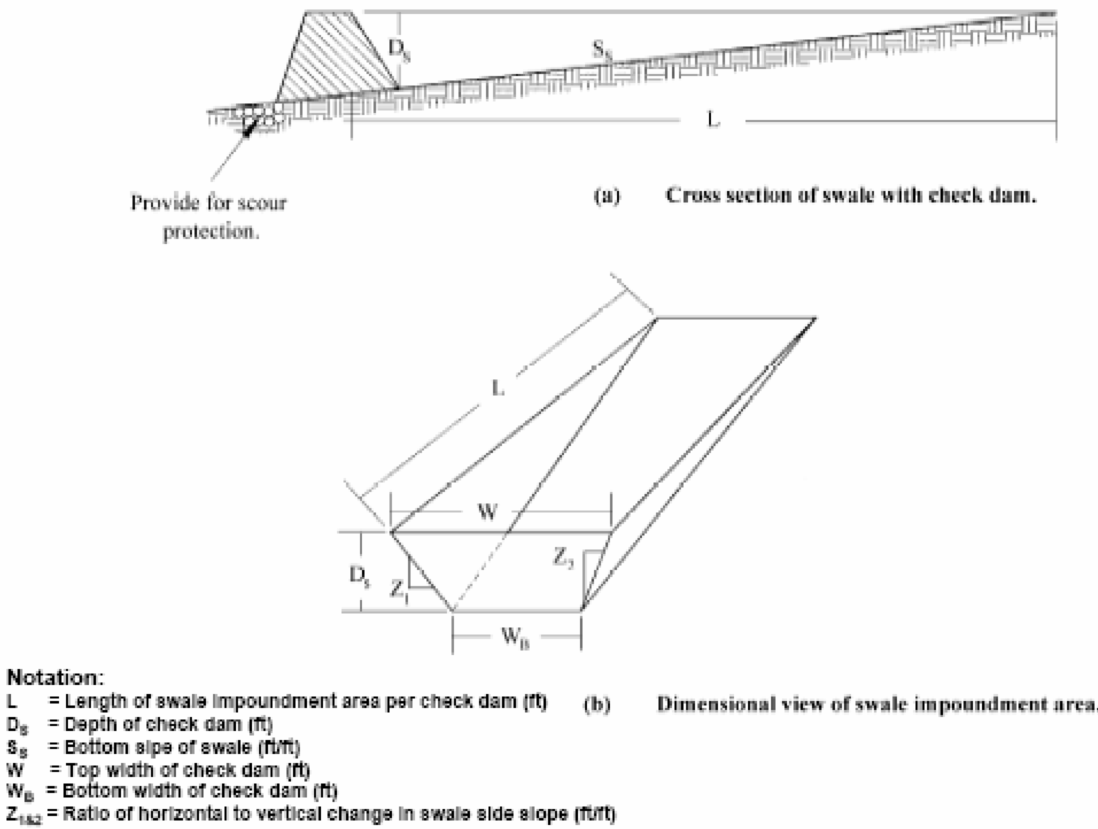
Source: Prince George's County Department of Environmental Resources, 1993

Figure 3 - Bioretention Area

A bioretention area is applicable to many developed sites for it can be fitted in median strips, parking lot islands, or swales. However, infiltration might be prevented by frozen soil or a high water table. It is recommended to design a bioretention area in warmer climates and in locations with a water table at least 6 feet below the surface (EPA 832-F-99-012). The Total Kjeldahl Nitrogen (TKN) removal efficiency of a bioretention area is estimated to be 68 to 80 percent (EPA-832-F-99-012).

2.5.2 Vegetated Swale

A vegetated swale is a broad and shallow channel with the purpose of receiving stormwater to facilitate pollutant removal and flow velocity control. For low flow, it may replace a curb and gutter and storm sewers. Vegetated swales are not applicable for cooler climates where the soil regularly freezes, areas with poorly draining or compacted soils, and areas with flat grades. Vegetated swales are considered standalone stormwater BMPs, but will also work efficiently in combination with other stormwater BMPs. The nitrate removal by vegetated swales is largely dependent on the vegetation type, flow velocity (detention time), and soil porosity, which causes nitrate removal by vegetated swales to vary from site to site. The average nitrate removal efficiency is 38 percent according to EPA 832-F-99-006. A basic vegetated swale design is illustrated in Figure 4.



Source: EPA 832-F-99-006

Figure 4 - Vegetated Swale Design

2.5.3 Constructed Wetland

Artificially constructed wetlands can be a method to control nutrients from either point sources or non-point sources. A wetland is commonly defined as a land area in which the water level is near the surface for a sufficient amount of time per year to maintain a saturated soil. The removal rate is dependent largely on the season, vegetation, and flow velocity (detention time). In certain cases, a first order plug-flow model can be assumed to roughly estimate the nitrate removal in artificially created wetlands (Carleton, 2001). For a plug-flow model, the assumption is made that there is no dispersion as the water moves through the wetland. There are three basic approaches to obtain design criteria for an artificial wetland; no approach is generally agreed to be best. Design criteria can be derived from performance data of operated systems, derived from flow divided by wetland surface area data, or derived from data comparing a wetland to 'attached growth wastewater treatment systems' (Reed et al., 1995).

Constructed wetlands are used throughout the United States. An example of a constructed wetland to control excess nutrients is the Iron Bridge Easterly Wetlands, located in Christmas, Florida. The Iron Bridge Easterly Wetlands receive thirty-five million gallons per day from the Iron Bridge wastewater treatment plant and discharges into the St. John's River. Besides reduction of nutrients, a benefit of the constructed wetland is the Orlando Wetlands Park, which is the portion of the Iron Bridge Easterly Wetlands that is open to the public.

2.6 Past Research

Different interested parties have collected data about the fate of nitrogen in irrigation systems and in soil media. The subject has been covered by a series of articles in the *Journal of Irrigation and Drainage Engineering,* a journal by the ASCE; the relevant articles are summarized below.

Nitrate leaching through the soil was studied by Tamini and Mermound (Irr. and Drain. 51: 77-86, 2002). Nitrate concentrations were measured at different depths up to

50 cm (1.667 ft) under the rootzone of an irrigated and fertilized onion crop in semi-arid climatic conditions in Burkina Faso, which is located in Western Africa and has a warm, tropical climate with dry winters and wet summers. In all cases, the nitrate concentration decreased significantly with depth leading to the conclusion that “irrigation based on maximum evapotranspiration values and fertilization according to INERA [l'institut de l'environnement et de recherches agricoles] advice leads to good yield and relatively little leaching.” The experiment as described in this thesis (Chapter 4) varies in three ways: St. Augustine grass is used for the vegetation, there is no groundwater input (no horizontal flow), and no fertilizer is used (the nitrate input originated from the irrigation water and precipitation).

The effects of the groundwater table and rainfall timing on nitrate transport through soil were considered by Jiang, Wu, Brown, and Workman (Irr. and Drain. 1997). Chambers were prepared with a soil depth of 90 cm (3 ft) to analyze the breakthrough dynamics of nitrate and bromide with varying parameters. It was concluded that the water table has the most significant impact on the nitrate transport when compared to varying soil type and time delay. The difference in dynamics of nitrate and bromide led to the conclusion that a shallow water table and long residence time may contribute to denitrification. The research conclusions of this thesis expand on the contributions of Jiang et. al. by analyzing the nitrate transport in soil chambers that are exposed to the elements (located outdoors), with compacted soil (post development) and grass cover, for a duration of one year instead of event-based.

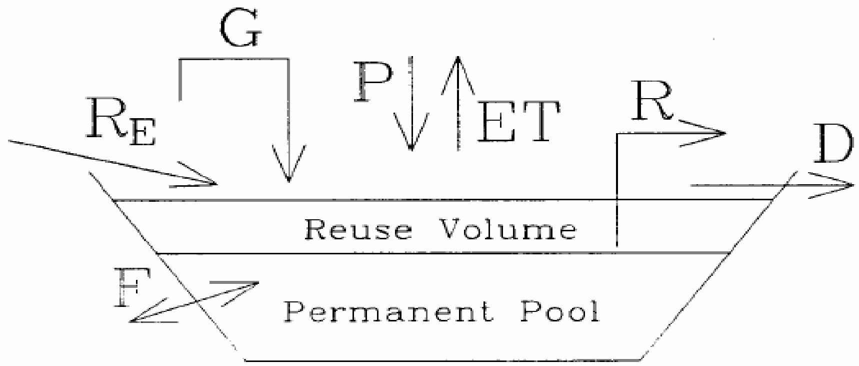
Another study involving soil chambers was conducted by Starrett, Christians, and Austin. Turfgrass-covered chambers 50 cm (1.667 ft) tall were irrigated with distilled water using heavy and light irrigation rates. It was concluded that heavy irrigation rates resulted in increased nitrogen transport; it is suggested this may be due to macro-pores formed in the soil chambers. Some loss of nitrogen occurred, which was contributed to denitrification. The experiment in this thesis expands on the research conducted by Starrett et. al by conducting a similar experiment that is a closer simulation of a natural setting with compacted soil in an outdoor location that is not event-based (resulting in longer detention time in groundwater), and using detained stormwater as the irrigation source.

CHAPTER 3 – APPROACH TO THE PROBLEM: PROPOSED BMP

The approach to the problem of eutrophication caused by excess nitrate emitted from a watershed is to retain all excess runoff onsite and use the retained water as an irrigation source. Considering the past research as discussed in Chapter 2.7 and the documentation of nitrogen removal by turfgrass (Overman et al., 1991), the excess nitrate in the stormwater runoff of a developed watershed can be reduced through irrigation practices.

The total maximum daily load (TMDL) for nitrate in a receiving water body is first determined according to the method provided by the US EPA (Chapter 2.4). Next the pre- and post-development rainfall excess (R_E) is determined, and the nitrate removal efficiency is estimated by a weighted average between nitrate removal in the irrigation system and nitrate removal in the pond. Next, after the vegetation to be irrigated is determined, the crop irrigation demand and the evapotranspiration are determined.

To design a stormwater reuse pond, or a stormwater detention pond which is used as a source of irrigation water, a mass balance is performed around the pond. Figure 5 is an example of a mass balance around a reuse pond; on top of the permanent pool is the reuse volume. The assumption is made that the net infiltration plus the precipitation minus the evaporation is zero, which leaves the following inputs and outputs labeled in Figure 5: Rainfall Excess (R_E), Groundwater Supplement (G), Reuse water (R), and Discharge (D).

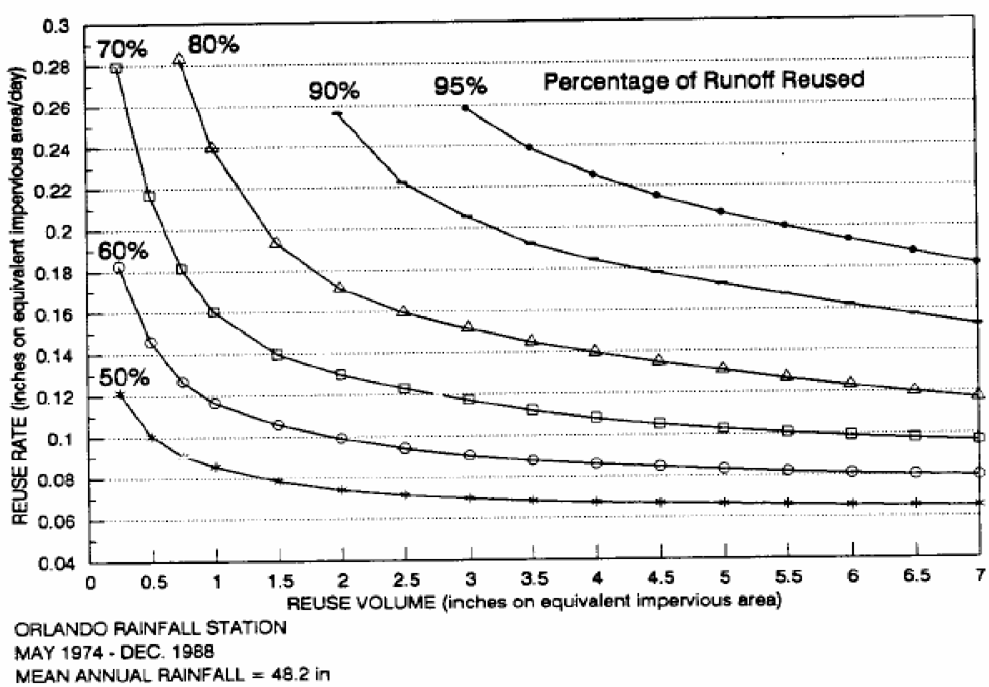


$$R_E + G + \cancel{P} \pm \cancel{F} - R - D - \cancel{ET} = \Delta S$$

$$R_E + G - R - D = \Delta S$$

Source: Wanielista et al., 1991

Figure 5 - Inputs and Outputs for a Stormwater Use Pond



Source: Wanielista et al., 1991

Figure 6 - REV Curve for Orlando, Florida

Figure 6 is a 'Rate-Efficiency-Volume' (REV) chart for Orlando, Florida, which is used to relate the efficiency (percentage of runoff that is reused) to the reuse rate and reuse volume. Figure 6 was constructed using the mass balance shown in Figure 5 and historical rainfall data for the Central Florida region. All values are depth over the equivalent impervious area (EIA), which is equal to the area of a completely impervious watershed which would produce the same runoff volume. For example, if the pond volume is three inches over the EIA and the required efficiency is eighty percent, then the reuse rate is about 0.156 inches per day over the EIA. The required efficiency is the reduction of post-development runoff required to achieve pre-development runoff on an average annual basis.

3.1 Determination of Nitrate Load in Rainfall Excess

The mass of nitrate required to be removed to obtain a nitrate balance is the difference between the pre-development and post-development nitrate loads. Illustrated in Equation 16 is the general nitrate load determination; Equation 17 and Equation 18 are used to estimate nitrate in the pre- and post-development condition, and Equation 19 is used to estimate the mass of nitrate remaining or removed. The nitrate concentration is dependent on the source and can be estimated with the values in Table 3 to Table 6.

$$N = 102.79 * \sum_{i=1}^{n} (A_i)(C_i)(RE_i) + \sum_{i=1}^{k} N_i \qquad \text{Equation 16}$$

102.79 = Unit conversion
N = Nitrate load (kg/yr)

A_i	= Area of nonpoint source i	(acres)
C_i	= Concentration of nitrate in nonpoint source i	(mg/L)
RE_i	= Rainfall Excess from A_i	(in/yr)
N_i	= Nitrate load from point source i	(kg/yr)
n	= Number of nonpoint sources	
k	= Number of point sources	

$$N_{PRE} = (102.79)(R_{E,pre})(C_{PRE})(A) \quad \text{Equation 17}$$

$$N_{POST} = (102.79)(R_{E,post})(C_{POST})(A)(1-\eta_o) \quad \text{Equation 18}$$

$$N_{excess} = N_{POST} - N_{PRE} \quad \text{Equation 19}$$

A	= Total area	(acres)
N_{PRE}	= Pre-development nitrate load	(kg/yr)
N_{POST}	= Post-development nitrate load	(kg/yr)
N_{excess}	= Mass of nitrate to be removed	(kg/yr)
$R_{E,pre}$	= Pre-development Rainfall Excess	(in/yr)
$R_{E,post}$	= Post-development Rainfall Excess	(in/yr)
C_{PRE}	= Pre-development nitrate concentration	(mg/L)
C_{POST}	= Post-Development nitrate concentration	(mg/L)
η_o	= Overall Removal Efficiency	(fraction)

The overall removal efficiency (η_o) is the weighted average of the removal efficiencies for each part of the stormwater management system. Equation 20 is the sum of the rainfall excess fractions, each fraction multiplied by the product of the efficiencies of all preceding stormwater management systems.

$$\eta_o = 1 - \frac{M_{out}}{M_{in}} = 1 - \left\{\sum\left[\prod(1-\eta_i)\right](f_i)\right\} \quad \text{Equation 20}$$

M_{out}	= Mass leaving stormwater management system	(mass)
M_{in}	= Mass entering stormwater management system	(mass)
η_i	= Removal efficiency of stormwater m. device	(fraction)
f	= Fraction of total R_E that passes through i^{th} stormwater management system	(fraction)

Equation 21 (Source: Harper Baker, 2003) is another method of determining the nitrate load, which incorporates the curve number (CN) as presented in Technical Release 55 (TR-55) by the US Department of Agriculture (1986).

$$Load\left(\frac{kg}{yr}\right) = 0.10279 * \sum_{i=1}^{n}\left[(A_i)(P)(CN_i)(C_i)\right] \qquad \text{Equation 21}$$

A_i	= Area of land use for category i	(acres)
n	= Number of different land use categories	
C_i	= Concentration of nitrate in land use category	(mg/L)
P	= Annual Precipitation at site	(in/yr)
CN_i	= Runoff coefficient for land use category i	(no dim.)

3.2 Evapotranspiration

The combination of losses due to evaporation and transpiration (plant water demand) is called evapotranspiration (ET). The amount of evapotranspiration is dependent on climate, season, and the vegetation type. Usually, evapotranspiration is expressed in units of inches per year, which can be converted to a volume by multiplying by the area. Provided in Table 7 are the monthly ET rates for North Florida.

Table 8 is a summary of studies on the daily evapotranspiration rates of different geographic areas in Florida, which were conducted by the University of Florida Cooperative Extension Service Institute of Food and Agricultural Sciences.

Table 7 - North Florida Evaporation Data

Month	Evapotranspiration (in/month)
January	1.20
February	1.92
March	2.70
April	4.05
May	4.80
June	5.10
July	5.10
August	4.49
September	3.60
October	2.60
November	1.79
December	1.18
SUM	38.53

Source: Wanielista et al., 1997.

Table 8 - Daily Evapotranspiration Rates for North, Central, and South Florida

Month	North Florida		Central Florida		South Florida	
	(inches/day)	(gal/Ac/day)	(inches/day)	(gal/Ac/day)	(inches/day)	(gal/Ac/day)
January	0.06	1630	0.09	2440	0.1	2720
February	0.09	2440	0.12	3260	0.13	3530
March	0.12	3260	0.15	4070	0.16	4340
April	0.16	4340	0.19	5160	0.19	5160
May	0.19	5160	0.20	5430	0.19	5160
June	0.19	5160	0.20	5430	0.18	4890
July	0.18	4890	0.19	5160	0.18	4890
August	0.17	4620	0.17	4620	0.17	4620
September	0.15	4070	0.16	4340	0.15	4070
October	0.12	3260	0.14	3800	0.14	3800
November	0.08	2170	0.11	2990	0.12	3260
December	0.06	1630	0.08	2170	0.1	2720

Source: Florida Cooperative Extension Service, Institute of Food and Agricultural Sciences, University of Florida, 1994.

An equation to estimate ET that is used commonly in Florida is the Saint John's River Water Management District's Modified Blaney-Criddle Equation (SJRWMD, 2002):

$$ET = (0.01)(0.0173T - 0.324)kpT$$

Equation 22

Where:

ET	= evapotranspiration	(in/month)
k	= consumptive use coefficient	(dimensionless)
p	= percent daytime hours per year in study month	(%)
T	= average temperature in study month	(°F)

3.3 Irrigation Demand

The theoretical irrigation demand is the difference between evapotranspiration and precipitation. However, if the annual ET is less than the annual P, irrigation may still be performed to ensure good crop growth. Provided in Table 9 are the monthly irrigation demand data for turfgrasses in different regions of Florida; the data are obtained from The University of Florida Cooperative Extension Service Institute of Food and Agricultural Sciences. The irrigation demands take into account the monthly precipitation and average monthly temperature.

Table 9 - Monthly Irrigation Demand for Turfgrasses in Different Florida Regions

Month	Fort Myers	Gainesville	Jacksonville	Miami	Orlando	Pensacola	Tallahassee	Tampa	West Palm Beach	Florida Average
JAN	1.65	0.18	0	2.09	0.85	0	0	0.82	1.49	0.79
FEB	1.38	0	0	1.99	0.55	0	0	0.57	1.34	0.65
MAR	1.86	0.38	0.34	3.12	1.26	0	0	0.99	1.95	1.1
APR	3.57	2.12	1.7	3.24	2.88	0.7	1.09	3.15	3.11	2.4
MAY	4.12	3.7	3.34	3.05	4.73	3.02	3.28	4.9	3.33	3.72
JUN	2.51	3.21	3.22	2.69	3.57	3.74	3.21	3.85	2.68	3.19
JUL	3.26	3.09	3.23	4.32	3.59	3.89	2.59	3.38	4.47	3.54
AUG	4.06	2.85	3.53	4.75	4.68	4.39	3.79	3.67	4.32	4
SEP	2.91	3.51	1.94	2.74	3.41	1.77	2.58	3.96	2.04	2.76
OCT	1.54	2.38	1.59	1.13	3.17	2.13	2.13	3.93	1.3	2.14
NOV	2.96	1.44	1.16	2.85	2.28	0.13	0.35	2.1	2.65	1.77
DEC	2.07	0.58	0	2.61	1.19	0	0	1.07	1.97	1.05
TOTAL	31.89	23.44	20.05	34.58	32.16	19.77	19.02	32.39	30.65	27.11
AVERAGE	2.66	1.95	1.67	2.88	2.68	1.65	1.59	2.7	2.55	2.26

Source: Augustin, 1983

3.4 Nitrate Removal through Irrigation

Removal of nitrate is defined as returning the nitrate to the natural nitrogen cycle. This may be achieved by uptake of the nitrogen by vegetation and/or microorganisms, which are present on the vegetation and in the soil and in a retention pond. “Nitrogen is the nutrient required in the largest amounts by all crops” (EPA 625/K-95-001).

The excess nitrate as calculated in Equation 19 needs to be removed in order to prevent it from entering the groundwater or surface water. The rainfall excess can be stored in a retention pond to be used for irrigation. This method allows for nitrate removal in the pond as well as nitrate removal in the irrigation system. Using the experimental data, an overall nitrate removal efficiency can be calculated, which is shown in the example problem at the end of this thesis.

CHAPTER 4 – FIELD EXPERIMENT

4.1 Experiment Setup

An experiment was installed with the purpose of collecting data relating to the proposed best management practice described in Chapter 3 of this thesis. The experiment consists of three soil chambers; on top of each chamber is Saint Augustine grass. The chambers were installed at an outdoor location at the UCF Stormwater Laboratories on the UCF main campus. Stormwater was collected from a detention pond outside of the student union and was used for irrigation water; the nitrate concentration in the irrigation water was varied to simulate stormwater runoff from different watersheds. The soil moisture was measured and groundwater was collected from each chamber. Meteorological data and samples of precipitation were collected as well.

Data was collected for a one year period (6/4/2004 to 6/3/2005) and used to simulate a mass balance around each soil chamber (Equation 23). Since the parameters in Equation 23 are volume terms, a constant density of water is assumed. Equation 23 is used as a mass balance for nitrogen by multiplying each term by the corresponding nitrogen concentration. The mass balance results are presented in Chapter 5 of this thesis.

$$Storage = Inputs - Outputs$$
$$\Delta S = P + I - ET - F$$

Equation 23

Where:

ΔS = Change in Storage Volume (i.e. soil moisture)
P = Precipitation

I = Irrigation
ET = Evapotranspiration
F = Filtrate (groundwater collected)

Out of four Plexiglas sheets, 4 by 8 ft and ¾ inch thick, three were cut into four 4 by 2 ft pieces to serve as the sides for the chambers; a one inch hole was drilled and threaded ½ inch from the bottom in three of the sides. The fourth piece was cut into three 2’2” by 2’2” to be used for the bottom of each chamber, and three 22” by 22” pieces that were placed in the bottom of the each chamber to minimize standing water. The pieces were glued together with chloroform, which melts the Plexiglas to form one piece. The seems in each chamber were sealed with GE Silicone II caulk to ensure the chambers were watertight. Shown in Figure 7 are the glued chambers brought to the site.

Figure 7 - Plexiglas Chambers at installation site

The chambers were placed along an existing embankment and leveled (Figure 8). Ten foot long, ¾ inch diameter PVC pipes were connected to the bottom hole in each chamber; a 1 inch diameter gate valve was installed at the end of each pipe (Figure 9). PVC cement, Teflon tape, and Silicone caulk were used to prevent leaking.

Figure 8 - Chambers are leveled

Figure 9 – Chambers before backfill

Upon burying the chambers, care was taken to prevent any 'dead spots' created by the bending of the drainage pipes due tot the weight of the soil. Subsequently, each chamber was filled with water and covered for 72 hours. After the 72 hours, no change in water elevation was measured, proving the chambers to be watertight.

The water was then drained out and the 22 by 22 inch Plexiglas pieces were dropped to the bottom of each chamber. A 5 to 6 inch rock layer was then added to each chamber to cover the drainage hole and allow for faster filtrate sample collection. Placed on top of the rock layer was a Mirafi® woven geotextile (donated by R.H. Moore & Associates) to separate the soil from the collected ground water.

Soil was then placed on the geotextile. Water addition and 120 blows using a tamper were performed for every eight inches of soil added in each chamber. This resulted in a circa 94 percent compacted soil, simulating the compaction of a developed site. As the soil was added and compacted in each chamber, six soil moisture sensors (gypsum blocks purchased from Delmhorst Instruments) were added: three located two feet from the top of the chambers and three located six inches from the top of the chambers. According to the instructions provided by Delmhorst Instruments, the gypsum blocks were installed during the compaction process as follows:

1. Soak the blocks for 2 to 3 minutes
2. Dig a hole in the ground with 7/8" soil probe
3. Make a soil and water slurry of creamy consistency and place 1 to 2 teaspoons of slurry in the hole.
4. Push the block to the bottom of the hole, forcing the slurry to envelop the block. The block can be pushed by using a plastic or aluminum tube. Back fill the hole and tamp in small increments.

Finally, the St. Augustine Floratam turfgrass sod was placed on the surface of the compacted soil of each chamber and irrigated every day for one week as recommended by Lucas nursery. Piezometric tubes were installed at the end of the drainage pipes to check the groundwater level inside each chamber. Figure 10 is a picture of the project upon complete installation.

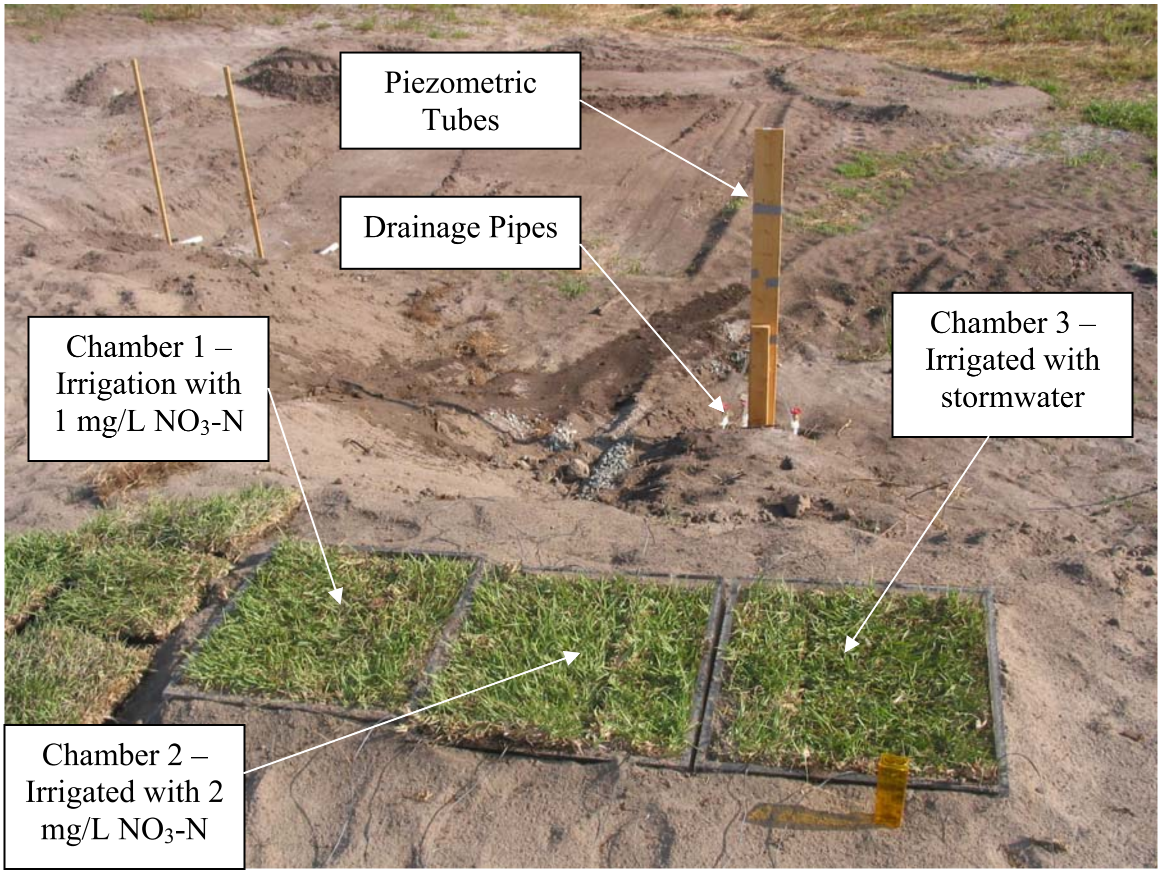


Figure 10 – Chambers after backfill and with grass cover

4.2 Data Collection and Methodology

Three to seven times per week data was collected from the experiment. Lab analyses were performed immediately except for precipitation analyses and total kjeldahl nitrogen tests (TKN), which were performed within 24 hours of the rainfall event or sample collection. Following is an itemization of the data collection.

4.2.1 Precipitation

Precipitation water quality samples were collected in a 12 inch diameter plactic container per event (24 hour inter-event dry period). Precipitation volume was recorded continuously by a weather station (David Instruments – *Vantage Pro*) installed about 100 feet from the chambers. The weather station employs a tipping bucked to measure precipitation at 0.01 inch increments. The precipitation samples were tested for *pH* using a pH probe, *alkalinity* using a 0.02 M sulfuric acid titration to endpoint of pH = 4.5, *ammonia* using an ammonia probe, *nitrate* + *nitrite* using the Hach® spectrophotometer with the Nitraver6 and Nitraver3 packets, *nitrite* using the Hach® spectrophotometer with the Nitraver3 packet, and *TKN* using the method described in Appendix A.

For accuracy, TKN standard solutions were tested alongside the samples in the TKN test, the pH probe was calibrated about every two weeks, the ammonia probe was calibrated before each use, and spikes and duplicates were performed. The quality control data for all experiments are in Appendix D.

4.2.2 Irrigation

Every Thursday and Sunday, stormwater was irrigated to each chamber, distributed equally over the surface. Each chamber received the same amount, which was determined using the values in Table 9. Throughout the experiment, the irrigation water was collected from the stormwater detention pond in front of the Student Union on the UCF main campus, which was chosen because it had been previously studied and its nitrate concentration was low which could be used for control.

One chamber was irrigated with only stormwater, while the other two chambers received stormwater with an added 1 mg/L and 2 mg/L of NO_3-N. Similar to precipitation, the irrigation water was tested for pH, alkalinity, ammonia, nitrite + nitrate, and nitrite.

4.2.3 Soil Moisture

The soil moisture content was measured by six soil moisture sensors: three located in the root zone (six inches from top) and three located in the soil (two feet from top). Model KS-D1 soil moisture tester by Delmhorst Instruments was used to retrieve soil moisture data from the gypsum blocks. The 'CAL CHK' button was used at least once per week make sure the meter was calibrated (values between 79.0 and 81.0 should appear when 'CAL CHK' is pressed). The readings are interpreted as 'available soil moisture'. Guidelines for irrigation were provided with the instrument: to ensure proper moisture for the grass, the meter readings should be above ninety percent.

4.2.4 Groundwater

From the piezometric tubes, the groundwater level inside each chamber was determined. The groundwater level was maintained at three feet from the surface for each soil chamber, but varied from four to one-half feet from the top of the chamber. Depending on the available groundwater, the collection frequency varied from three to seven times per week. The groundwater was tested for pH, alkalinity, nitrate, nitrite, ammonia, and TKN.

4.2.5 Evaporation

The evaporation data is collected from a 'Class A Evapotranspiration Pan' (Model 255-200 from NOVA LYNX Corporation) which was placed near the chambers at the UCF Stormwater Laboratories. The water level inside the pan is to be held constant: water is either added or taken out depending on the rainfall. The evaporation is equal to the volume of precipitation (known from the weather station) plus/minus the volume of water added/subtracted. The diameter of the pan is just under four feet, which yields good accuracy (the larger the diameter the greater the accuracy).

CHAPTER 5 – RESULTS AND DISCUSSION

5.1 Mass Balance Parameters

5.1.1 Input: Precipitation

During the data collection phase of the experiment (6/4/2004 to 6/3/2005), hurricanes Charley, Frances, and Jeanne passed through Central Florida, leaving 2.76, 6.29, and 4.72 inches of rainfall, respectively. This caused the experiment to be performed during a 'wet year' with a total precipitation of 67.22 inches. The average yearly is about 50 inches for the region (Wanielista et al., 2005).

Table 10 is a summary of the water quality results for precipitation. As can be seen from the standard deviations, there was variation in the results. Variation could be due to inter-event dry period, meteorological conditions (wind direction, temperature), and volume of rainfall.

Most of the nitrate + nitrite nitrogen was in the form of nitrate, the average nitrite concentration was 0.05 mg/L. In the process of denitrification (Chapter 2.2.2), there are two consecutive biological reactions. The kinetics of the reactions is such that nitrite is more quickly denitrified than nitrate (AWWA, 1970). Therefore, nitrite is found in much lower concentrations than nitrate in nature, which is illustrated in the precipitation results and the test results of detained stormwater (see Table 11).

Table 10 - Water Quality Summary for Precipitation

	n	Mean	St. Dev.
pH	60	6.22	1.44
Alkalinity (mg/L as $CaCO_3$)	28	7.79	10.16
NO_3-N (mg/L)	63	0.41	0.28
NO_2-N (mg/L)	19	0.05	0.050
NH_3-N (mg/L)	16	0.16	0.23
Org-N (mg/L)	1	0	-

5.1.2 Input: Irrigation

Irrigation water was collected from the stormwater pond and analyzed after collection; the results are listed in Table 11. The concentration of the nitrogen species varied some, while the pH and alkalinity values were fairly consistent. The majority of the nitrogen in the stormwater detention pond is in the form of organic nitrogen, which varied between 0 and 0.8 mg/L.

Table 11 - Summary of Water Quality Data for Irrigation Source

	n	Mean	St. Dev.
pH	43	7.20	0.37
Alkalinity (mg/L as $CaCO_3$)	15	43.47	10.51
NO_3-N (mg/L)	42	0.02	0.01
NO_2-N (mg/L)	12	0.00	0.00
NH_3-N (mg/L)	14	0.143	0.183
Org-N (mg/L)	5	0.386	0.375

The volume irrigated depended on the suggested irrigation values from Table 9 and on the precipitation amount prior to the irrigation. According to the 2002 Florida Statutes Chapter 373.62, Water Conservation, Automatic Sprinkler Systems, “Any person who purchases and installs an automatic sprinkler system….shall install…a rain sensor device…that will override the irrigation cycle of the sprinkler system when adequate rainfall has occurred." Since the experiment was intended to simulate a suburban lawn which is oftentimes equipped with an automatic sprinkler system, no irrigation was performed if the rainfall in the 24 hours prior exceeded the irrigation requirement; the difference was irrigated if the rainfall volume in the 24 hours prior was less than the irrigation requirement. The irrigation per month along with the recommended irrigation and monthly precipitation is shown in Table 12.

Table 12 - Monthly Irrigation Amount

Month	Irrigation Volume (in)	Recommended (in)	Precipitation (in)
Jun-04	3.31	3.57	10.10
Jul-04	2.18	3.59	5.35
Aug-04	2.00	4.68	15.90
Sep-04	0.68	3.41	15.30
Oct-04	1.64	3.17	2.40
Nov-04	1.76	2.28	1.65
Dec-04	1.81	1.19	1.72
Jan-05	1.81	0.85	2.53
Feb-05	1.13	0.55	2.79
Mar-05	1.42	1.26	5.30
Apr-05	2.55	2.88	1.61
May-05	2.95	4.73	2.57
SUM:	23.24	32.16	67.22

Due to the high precipitation values, the total volume irrigated was less than recommended. The irrigation in the summer months was less than recommended and the irrigation in the winter months was more than recommended. Although the grass cover rarely appeared dry, the occurrence of precipitation oftentimes eliminated the need for irrigation and thus the grass evapotranspiration likely never reached the potential evapotranspiration.

5.1.3 Soil Analysis

The soil can be described as brown fine sand and was obtained from a construction site on the UCF main campus. The soil in each chambers 1, 2, and 3 was compacted to 94.5, 99.8, and 93.5 percent of the maximum dry density, respectively. The maximum dry density of the soil is 104 lb/ft^3 and was determined by a Modified Proctor (FM 1-T180). The porosity of the compacted soil is 43 % and the soil has a dry unit weight of 96.3 lb/ft^3.

The results of the soil moisture measurements are illustrated in Figure 11 to Figure 13. The soil moisture content follows a similar trend for all three chambers, which is because of the identical inputs (rainfall and irrigation schedule) and because the groundwater level was kept as consistent as possible between the three chambers. Overall, the soil moisture at the beginning and end of measurements was considered equal and the storage term, ΔS, term in Equation 23 can be assumed to be zero.

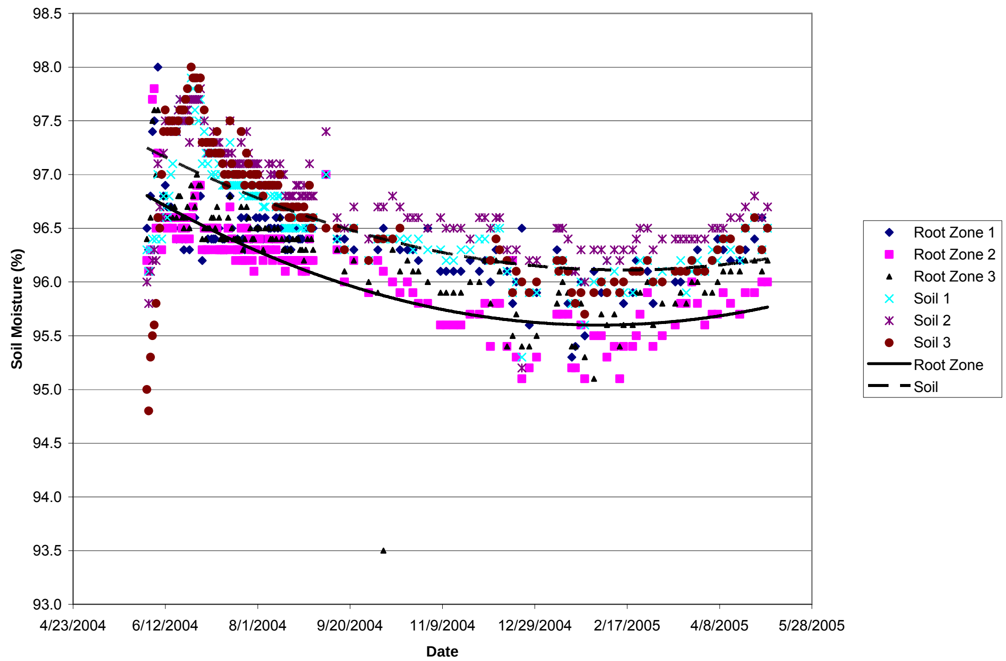


Figure 11 - Soil Moisture Chamber 1

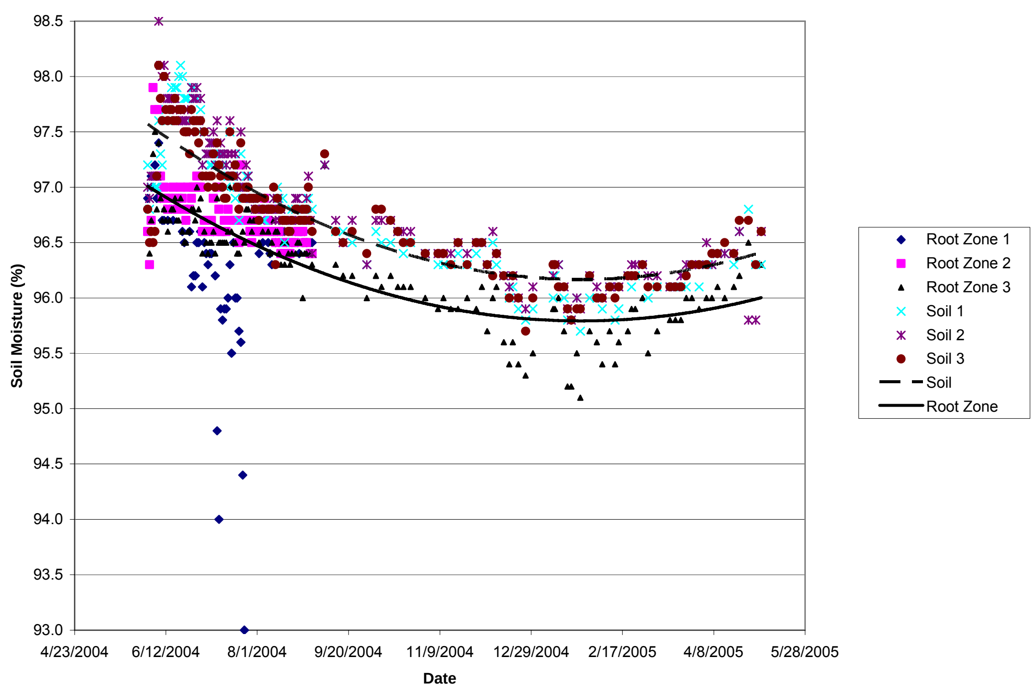


Figure 12 - Soil Moisture Chamber 2

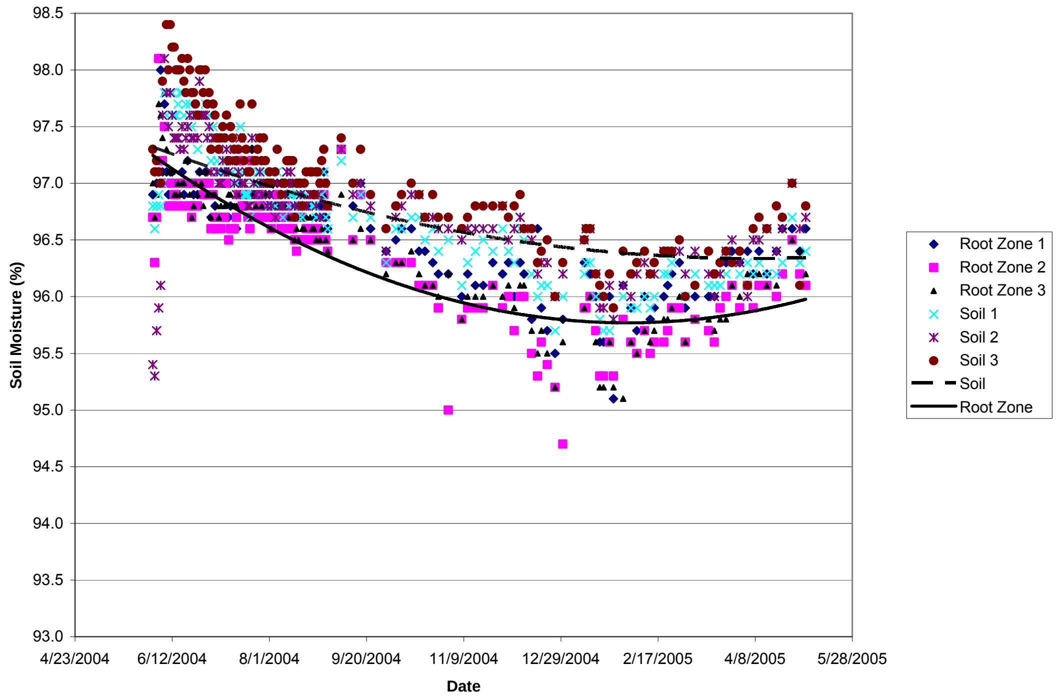


Figure 13 - Soil Moisture Chamber 3

In the first week after installation of the sensors, the readings varied considerably before they converged. After convergence, the readings for the sensors in the soil were consistently higher than the readings for the sensors in the root zone, which is due to evapotranspiration of the soil water in the root zone. The soil moisture decreases after the summer months, but converges around 96.5 percent, which indicates the irrigation amount is sufficient.

The soil chemistry was analyzed by Flowers Laboratories in Altamonte Springs, FL and by University of Florida IFAS, both reports are included in Appendix B. Both labs were sent two samples and the results are listed below.

Table 13 - Soil Test Results

	Flowers Lab 1	**Flowers Lab 2**	**UF/IFAS 1**	**UF/IFAS 2**
pH	6.55	7.10	6.50	6.30
Total Nitrogen (as N)	778 (mg/kg)	822 (mg/kg)	-	-
Nitrite (as N)	0.42 (mg/kg)	0.156 (mg/kg)	-	-
Nitrate (as N)	57.7 (mg/kg)	56.6 (mg/kg)	-	-
TKN (as N)	720 (mg/kg)	765 (mg/kg)	-	-
Phosphorous (ppm P)	-	-	77	72
Potassium (ppm K)	-	-	33	30
Magnesium (ppm Mg)	-	-	69	63
Calcium (ppm Ca)	-	-	>1966	>1500

According to the soil nutrient criteria of UF/IFAS, the soil is high in all tested nutrients except for potassium. The pH is around 6.5 and the majority of the nitrogen is in the ammonia form (organic nitrogen and ammonia nitrogen have the same oxidation state).

The initial mass of nitrate in each chamber is approximately:

$$\left(96.3\frac{lb}{ft^3}\right)\left(\frac{kg}{2.205\,lb}\right)\left(\frac{57.15\,mg-Nitrogen}{kg}\right)\left(16\,ft^3\right)\cong 39{,}935 \text{ mg as Nitrogen}$$

The initial mass of total Kjeldahl Nitrogen is:

$$\left(96.3\frac{lb}{ft^3}\right)\left(\frac{kg}{2.205\,lb}\right)\left(742.5\frac{mg-Nitrogen}{kg}\right)\left(16\,ft^3\right)\cong 518{,}841 \text{ mg as Nitrogen}$$

The total nitrogen variation in the soil sample is approximately:

$$\left(96.3\frac{lb}{ft^3}\right)\left(\frac{kg}{2.205\,lb}\right)\left(822-778\frac{mg-Nitrogen}{kg}\right)\left(16\,ft^3\right)\cong 30{,}746 \text{ mg as Nitrogen}$$

5.1.4 Output: Groundwater

The groundwater was collected at the bottom of each chamber from the drainage pipes such that the water level inside the chambers was consistently between 3 and 3.5 feet below the grass surface. There was, however, fluctuation in the groundwater table since after a large rainfall event, a few days were sometimes needed to bring the water table back down. The water quality results were influenced by the soil and were similar for all three chambers, as is summarized in Table 14, Table 15, and Table 16.

Table 14 - Chamber 1 Groundwater Quality

	n	**Mean**	**St. Dev.**
pH	166	6.69	0.13
Alkalinity (mg/L as $CaCO_3$)	34	447.44	101.68
NO_3-N (mg/L)	118	0.03	0.01
NO_2-N (mg/L)	12	0.00	-
NH_3-N (mg/L)	56	7.04	2.93
Org-N (mg/L)	5	0.00	-

Table 15 - Chamber 2 Groundwater Quality

	n	**Mean**	**St. Dev.**
pH	162	6.66	0.17
Alkalinity (mg/L as $CaCO_3$)	33	390.00	72.41
NO_3-N (mg/L)	108	0.03	0.02
NO_2-N (mg/L)	12	0.00	-
NH_3-N (mg/L)	55	7.67	2.92
Org-N (mg/L)	5	0	-

Table 16 - Chamber 3 Groundwater Quality

	n	Mean	St. Dev.
pH	143	6.77	0.19
Alkalinity (mg/L as $CaCO_3$)	32	356.09	36.93
NO_3-N (mg/L)	92	0.03	0.02
NO_2-N (mg/L)	10	0.00	-
NH_3-N (mg/L)	50	5.87	1.90
Org-N (mg/L)	5	0	-

For each chamber, the pH values were consistent with the pH of the soil (Table 13). The alkalinity is higher than the alkalinity of the precipitation and irrigation water.

Small amounts of nitrate were detected and no nitrite was detected. The input of up to 2 mg/L NO_3-N, therefore, has negligible impact on the groundwater nitrate concentration. No org-N was detected from five total Kjeldahl nitrogen analyses. Since there is a small amount of nitrate in the soil and the nitrate concentration in the groundwater is consistent for all three columns, much of the nitrate in the groundwater may be from soil leaching. For simplicity, it can be assumed that all of the nitrogen present in the groundwater is in the form of ammonia.

The hydraulic detention time, or the average length of time the water stays inside the chamber, can be estimated by dividing the volume of water inside the chambers by the average flow of groundwater leaving the chambers. The average daily groundwater flow was estimated by taking the total volume of filtrate collected during the experiment duration (one year) and dividing by 365 days, or Q = Volume / time = V / 365 days. The volume of groundwater collected for each collection day is included in Appendix C. With a porosity (volume of voids over total volume) of 0.42 and assuming thirty-five percent of this space is saturated with water, the volume of water inside each chamber is approximately (0.42)(0.35)(16) = 2.35 ft^3. The estimated average hydraulic detention time for chamber 1 is thus:

$$t_d = \frac{V}{Q} = \frac{(2.35\ ft^3)}{0.042\ cfd} \cong 56\ days$$ [Average Q of experiment duration]

$$t_d = \frac{V}{Q} = \frac{(2.35\ ft^3)}{0.333\ cfd} \cong 7.1\ days$$ [Constant infiltration of 1 inch per day and $\Delta S = 0$]

Similarly, the estimated hydraulic detention time for chamber 2 is about 48.54 days and for chamber 3 is about 52.64 days. For the period of measurement, the average hydraulic detention time about 52 days.

In 52 days, the groundwater is allowed to move towards chemical equilibrium with the soil. This is shown in Table 13 to Table 16 as the groundwater displays characteristics similar to the soil in terms of nitrogen content, pH, and alkalinity. Moreover, one to two months is a sufficient period of time for any biological activity to occur concerning nitrogen because a typical specific growth rate for nitrification (μ_n) is 0.75 gVSS/gVSS-day and the corresponding residence time (1/ μ_n) is 1.33 days (Tchobanoglous et al., 2003). Biological activity refers to nitrogen uptake by the grass cover and by microorganisms inside the chambers.

5.2 Evapotranspiration

For the grass cover on each chamber, the evapotranspiration was calculated using the mass balance in Equation 23. The ET measured from the field experiment was then compared to the estimated ET from Equation 22, the modified Blaney-Criddle Equation, which is an equation to estimate actual ET from monthly temperature, a crop consumptive used coefficient, and percent daytime hours per year in study month. Also compared to the measured ET data were the Priestly-Taylor and the Penman-Monteith Equations, which require many additional parameters for which assumptions were made since the data was not measured. For both the Priestly-Taylor and the Penman-Monteith, the calculated ET was significantly different from the measured ET. The Priestly-Taylor and Penman-Monteith results are not included because it is not known whether or not the inaccuracy is due to the assumptions. The results were also compared to a Class A evapotranspiration pan, which is a direct method of measuring evaporation (E), which may be related to ET by a 'pan coefficient'.

The potential evapotranspiration is "evapotranspiration that would occur were there an adequate soil-moisture supply at all times" (Chow, 1964). Throughout the experiment, there were dry periods between the irrigation events and irrigation events were omitted if the rainfall volume in the 24 hours prior exceeded the irrigation volume (according to the 2002 Florida Statutes, Title XXVIII, Chapter 373.62), thus the measured ET is the actual ET not the potential ET. It should be noted that many equations serve to estimate potential ET, but the Modified Blaney-Criddle Equation (Equation 22) is an estimate of actual ET. The actual and predicted cumulative ET for chambers 1 to 3 is presented in Figure 14 to Figure 16. It can be seen that the predicted and measured are similar, thus indicating the Modified Blaney-Criddle Equation is accurate for predicting actual evapotranspiration for the conditions of this experiment.

The measured yearly ET (average of three chambers) was 41.3 as determined from the mass balance and the Modified Blaney Criddle yearly predicted ET was 41.0 inches.

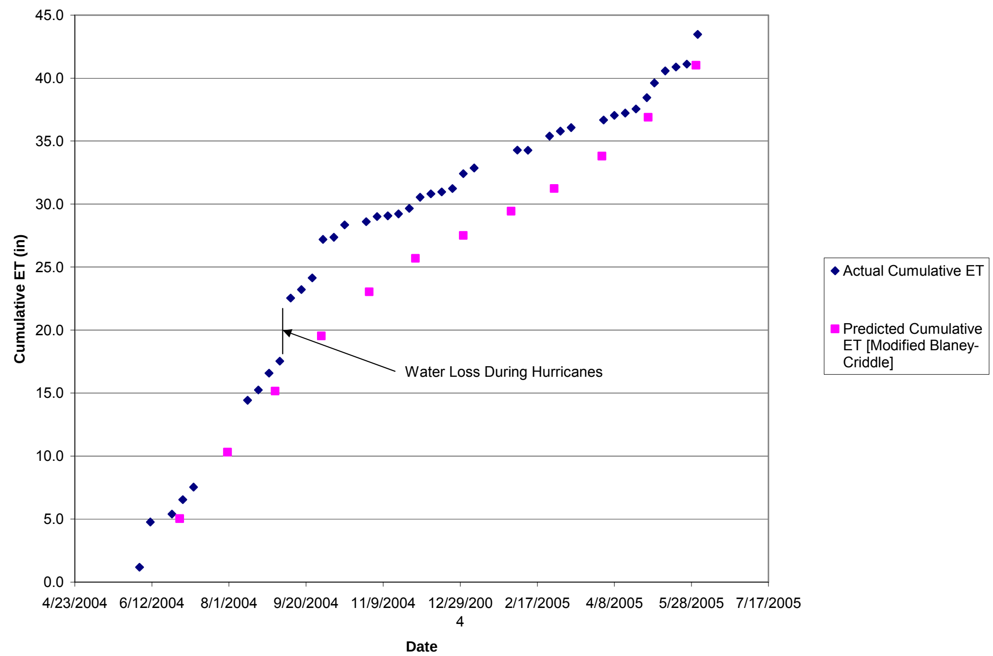


Figure 14 - Chamber 1 Cumulative Evapotranspiration

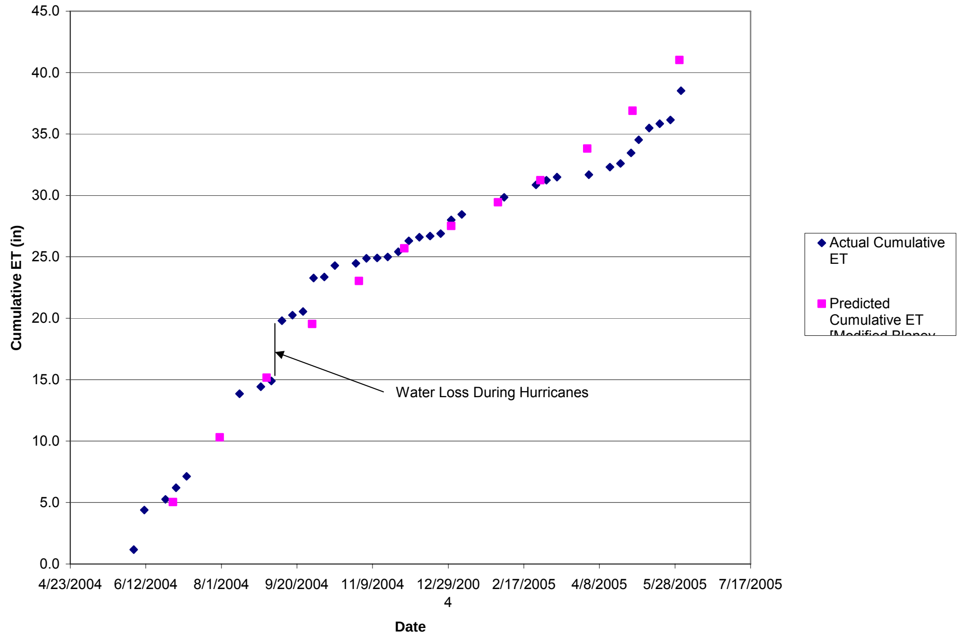


Figure 15 - Chamber 2 Cumulative Evapotranspiration

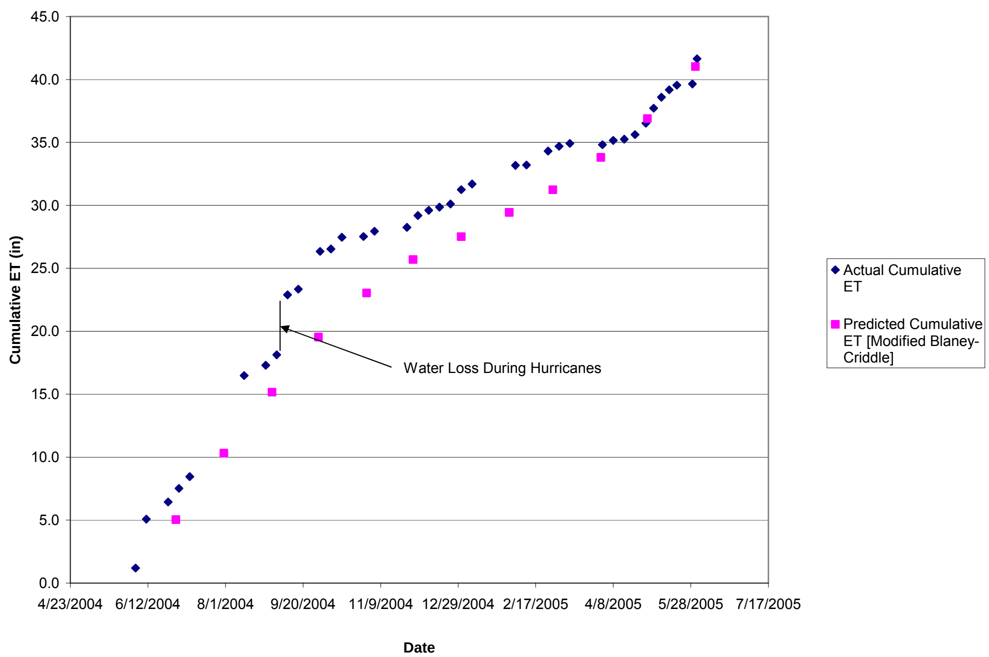


Figure 16 - Chamber 3 Cumulative Evapotranspiration

The piezometric tubes were blown over after hurricane Francis on September 7th, which caused each chamber to lose an unknown quantity of water. The loss of water resulted in an over-estimate of evapotranspiration using the mass balance in Equation 23. Since throughout the experiment the water level in each chamber was assumed constant as the soil moisture remained relatively constant and the change in storage (ΔS) was assumed to be zero. In Equation 23 ($ET = P + I - F - \Delta S$), the filtrate (F) term is reduced because the water lost due to hurricane damage left the chambers as filtrate water but was not measured. The precipitation (P) and Irrigation (I) are known, so for ΔS to remain zero, ET has to increase for a decreased F, thus resulting in an over estimated value for ET.

The hurricane damage is a source of error for each chamber. The volume of water lost is unknown and varies for each chamber since the rate of groundwater flow from the each chamber may vary.

The comparison between the predicted ET (Modified Blaney-Criddle) and measured ET is illustrated in Figure 14 to Figure 16 and shown in Table 17. For accuracy, the average of the three chamber data was compared per season (i.e. summer months: June, July, August, fall months: September, October, November, etc.).

Table 17 - Comparison of Estimated and Measured ET (average of three chambers)

	Average Temperature (°F) [a]	p [Table 4.6, Latitude 28.5°] [b]	Calculated ET (k = 0.65)	Mass Balance ET	Difference (in)
June	78.705	9.412			
July	79.526	9.604	15.17	14.98	0.19
August	78.214	9.181			
September	78.023	8.320			
October	72.047	8.020	10.53	11.70	1.17
November	66.920	7.253			
December	57.144	7.231			
January	58.220	7.369	5.54	5.61	0.07
February	57.578	7.063			
March	62.170	8.395			
April	65.875	8.687	9.80	7.45	2.34
May	72.100	9.470			
TOTAL			41.04	39.74	

[a] Measured continuously on-site; [b] Interpolated from Table 4.6 in Wanielista et al., 1997

There is some difference between the measured and estimated ET; however, from visual observation of Figure 14 to Figure 16 can be concluded that the modified Blaney-Criddle can be used to estimate ET for theses precipitation, soils, grass cover, and irrigation conditions.

Figure 17 is a graph to illustrate the comparison between the evaporation pan and the measured ET. The evapotranspiration pan data are in Appendix C. Equation 24 is used to relate evapotranspiration to pan evaporation (E_p) through a pan coefficient (k_p). The continuous calculation and the average value of the pan evaporation coefficient are shown in Figure 17.

$$ET = k_p(E_p) \quad \text{Equation 24}$$

ET	= Evapotranspiration	(inch)
k_p	= Pan Coefficient for Conversion to ET	(dimensionless)
E_p	= Pan Evaporation	(inch)

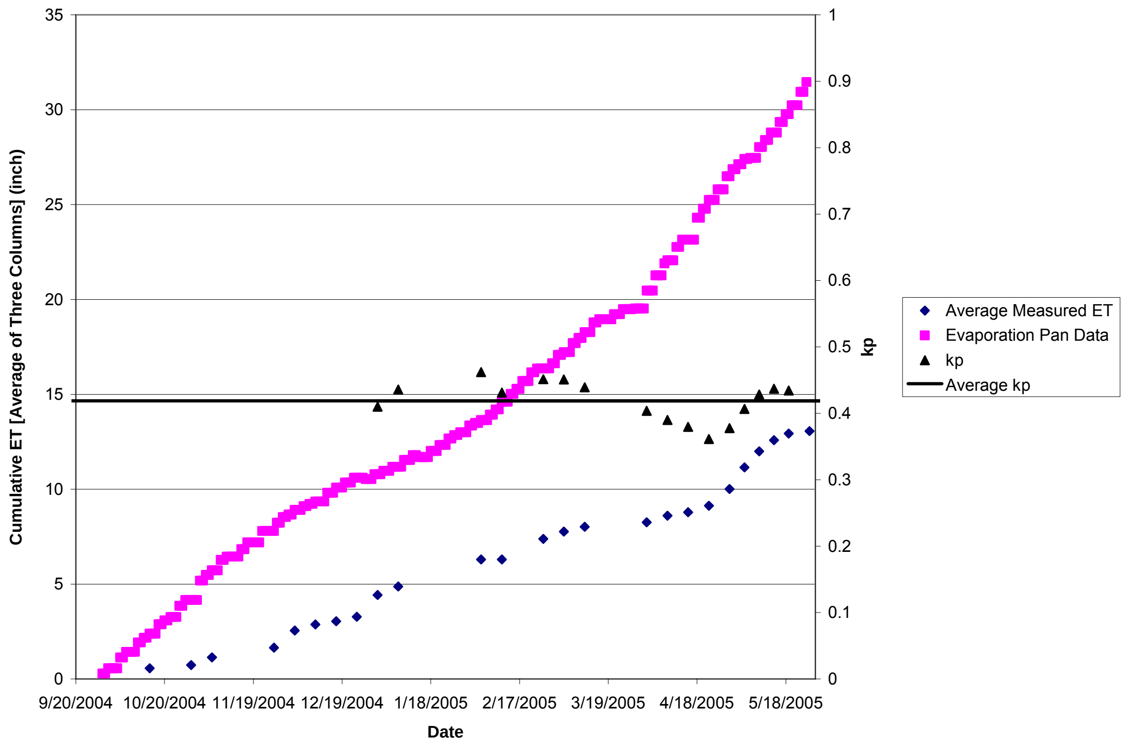


Figure 17 - Comparison between Measured ET and Pan Evaporation

In an effort to estimate evapotranspiration for a specific situation, the pan evaporation rates may be used to measure evaporation directly and then to indirectly predict evapotranspiration through a pan coefficient (k_p). Since evaporation is higher than evapotranspiration, k_p ranges from zero to one. For this particular situation (St. Augustine grass, irrigation schedule listed in Table 12, Central Florida climate, and the experiment soils), the pan coefficient was estimated to be 0.42 (average value as illustrated in **Figure 17 - Comparison between Measured ET and Pan Evaporation**Figure 17).

5.3 Nitrogen Balance

The total nitrogen concentration for each of the terms in the mass balance of Equation 23 was measured. By multiplying each concentration by the corresponding volume, the mass of nitrogen entering and leaving the chambers is calculated.

The only procedural difference between the three chambers is the input of 1 mg/L NO_3-N irrigation water to chamber 1, 2 mg/L NO_3-N irrigation water to chamber 2, and stormwater without added nitrate to chamber 3. The majority of the nitrogen input was in the form of nitrate and the majority of the nitrogen output was in the form of ammonia. Figure 18 illustrates a total nitrogen balance around each chamber and Figure 19 is a nitrate + nitrite balance around each chamber.

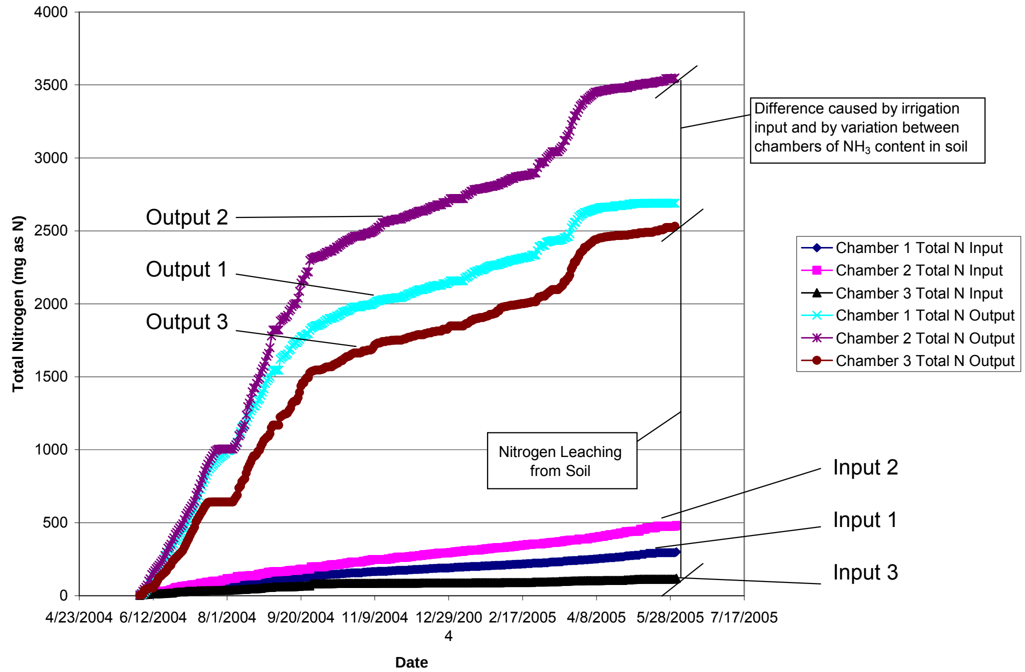


Figure 18 - Total Nitrogen Balance

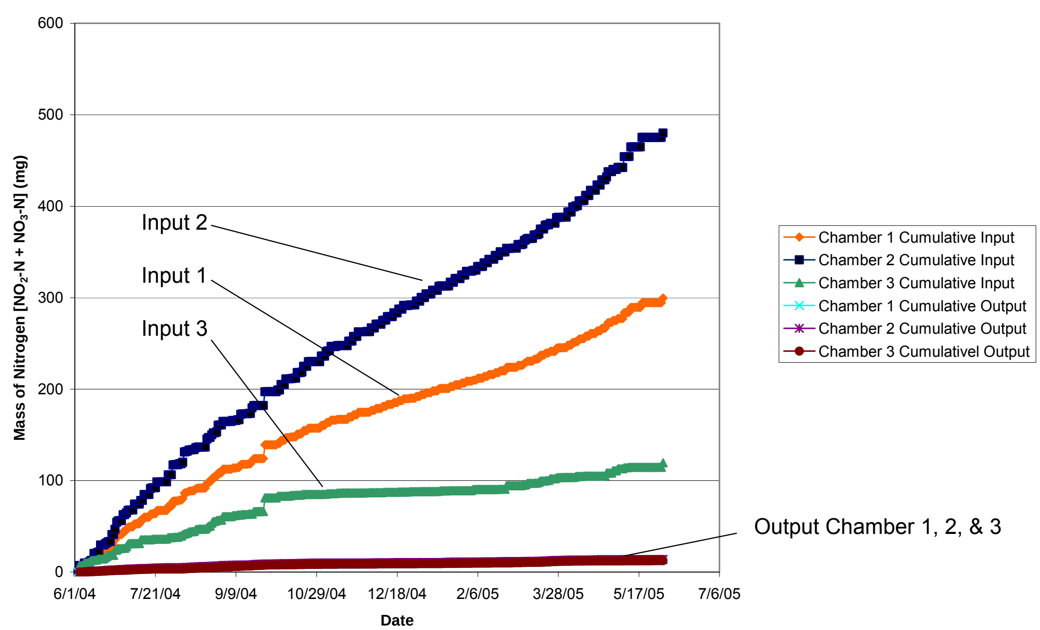


Figure 19 – Nitrate + Nitrite Balance around each Chamber

Nitrate was the nitrogen species that was added to the stormwater and was the predominant nitrogen species found in precipitation. The predominant species of nitrogen in the groundwater was ammonia. Focusing on nitrate, which is one of the most common groundwater contaminants in the United States, shown in Figure 19 are the chamber irrigation input and groundwater output for nitrate for each soil chamber. The nitrate leaching from all three chambers was essentially equal, which may indicate the nitrate concentration in the groundwater was affected by the soil nitrate content. The nitrate removal efficiency from the irrigated stormwater with NO_3-N concentration raised to 2.0 mg/L by the turfgrass-covered soil chambers is 97 percent: $\frac{(480-13)}{480} = 97\,\%$.

'Nitrate removal' is defined as the conversion of excess nitrate to nitrogen found in the natural nitrogen cycle or its conversion to other species of nitrogen.

It is clear from Figure 18 that there was significantly more total nitrogen output than input, thus the majority of the nitrogen in the groundwater originated from the soil. From Figure 19, it can be seen that the input nitrate is removed, or is either adsorbed to the soil or converted to other species of nitrogen.

Because the nitrogen variation within the soil varies by about 30,700 mg (Chapter 5.1.3) and the nitrogen output variation between the columns is about 1,900 mg, the variation of nitrogen output between the chambers can be explained by variations in the soil nitrogen content between the chambers. However, since the groundwater ammonia concentration in chambers 1 and 2 was higher than chamber 3, and chambers 1 and 2 had higher nitrate input, some of the variation in nitrogen output could be explained by the different nitrate input from the irrigation water. This may occur through assimilation of the nitrate into organic nitrogen (grass cover or microorganisms in soil) and the subsequent decomposition of organic nitrogen to ammonia.

To further understand the fate of nitrogen as it passes through the soil chamber, the following explanation is proposed. Figure 20 is an illustration of the different zones believed to be inside the soil chambers. Also included in Figure 20 is the nitrogen cycle to show the paths between nitrate and ammonia.

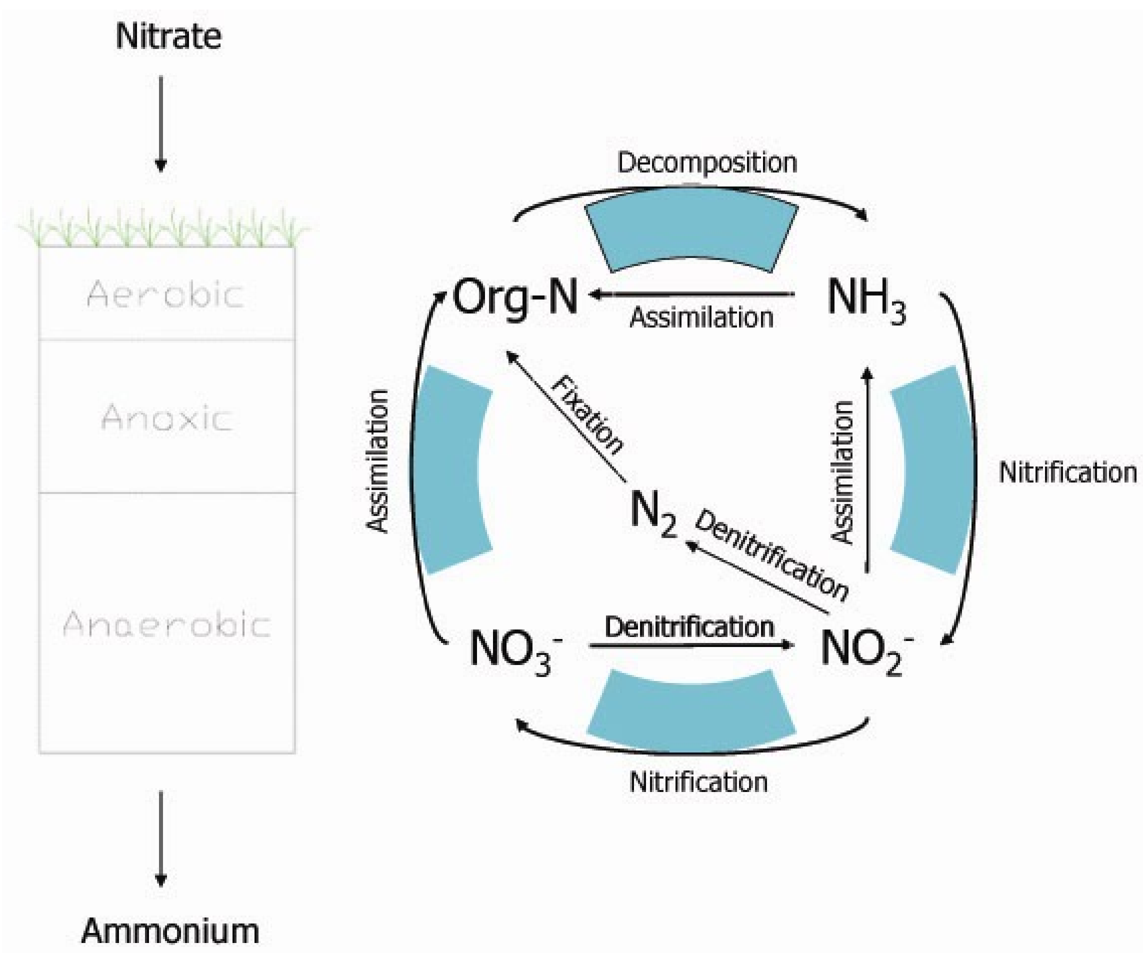


Figure 20 - Different Zones believed to be inside the Chambers

Aerobic Zone

In the aerobic zone, various forms of nitrogen are added from precipitation and irrigation, the majority of which was measured to be nitrate. Some of the nitrate is used as a nutrient by the grass, thus assimilated to organic nitrogen and subsequently decomposed to ammonia. Ammonia is nitrified to nitrite and then to nitrate by nitrosomonas and nitrobacter, respectively, until the oxygen is depleted. (Tchobanoglous et al., 2003).

$$NH_4^+ + 2O_2 \rightarrow 2NO_3^- + 2H^+ + H_2O \qquad \text{Equation 25}$$

$$NO_3^- \rightarrow \text{Org-N} \rightarrow NH_3 \qquad \text{Equation 26}$$

Anoxic Zone

The anoxic zone is defined as a zone without oxygen but with nitrate present. Ammonia can be used as a nitrogen source for cell synthesis. Nitrate can be used as a nitrogen source for cell synthesis and/or as an electron acceptor (Sawyer et al., 2003). The following stoichiometric equation is an example of cell synthesis with NH_4^+ as the nitrogen source, NO_3^- as the electron acceptor, and carbohydrates as the electron donor. $C_5H_7O_2N$ is the stoichiometric ratio for a bacterial cell and represents organic nitrogen. Sixty percent of the electron donor is used for cell synthesis and forty percent of the electron donor is used for energy (Table 6.5, Sawyer et al., 2003).

$$3HCO_3^- + 3NH_4^+ + 8H^+ + 8NO_3^- + 25CH_2O \rightarrow 13CO_2 + 26H_2O + 4N_{2(g)} + 3C_5H_7O_2N \qquad \text{Equation 27}$$

Equation 28 is an example of cell synthesis using nitrate as both the nitrogen source and as the electron acceptor. Carbohydrate is the electron donor in this example, but any number of compounds can serve as the electron donor.

$$101.4NO_3^- + 101.4H^+ + 250CH_2O \rightarrow 143CO_2 + 225.8H_2O + 40N_{2(g)} + 21.4C_5H_7O_2N \quad \text{Equation 28}$$

Equation 27 and Equation 28 are examples to illustrate quantitatively the mechanism of nitrate conversion to organic nitrogen. There are variations of the Equations above that occur in the chambers as there can be different electron acceptors, electron donors, and sources for cell synthesis and cell energy.

Organic nitrogen decomposes into ammonia. Since no organic nitrogen was detected in the groundwater collected from the bottom of each chamber, it is hypothesized that the organic nitrogen is in particulate form and may be filtered out by the soil and by the geotextile at the bottom of each chamber; subsequently the organic nitrogen is decomposed and leaves the chambers in the form of ammonia.

Anaerobic Zone

After all the oxygen and nitrate has been utilized, the conditions are anaerobic. Organic nitrogen decomposes to ammonia, which is not oxidized to nitrite or nitrate.

CHAPTER 6 – EXAMPLE PROBLEM

6.1 Problem Statement

This example problem illustrates the use of ET estimates for irrigated Saint Augustine grass in the climatic conditions of Central Florida. A twenty acre watershed has an equivalent impervious area (EIA) of 8 acres. The volume of irrigation required by the vegetation in the irrigation area is 0.75 inches per week. A diagram of the mass balance around the pre-developed watershed is provided below, which are typical annual values for sandy soils in Central Florida. A stormwater pond is to be designed as a source for irrigation.

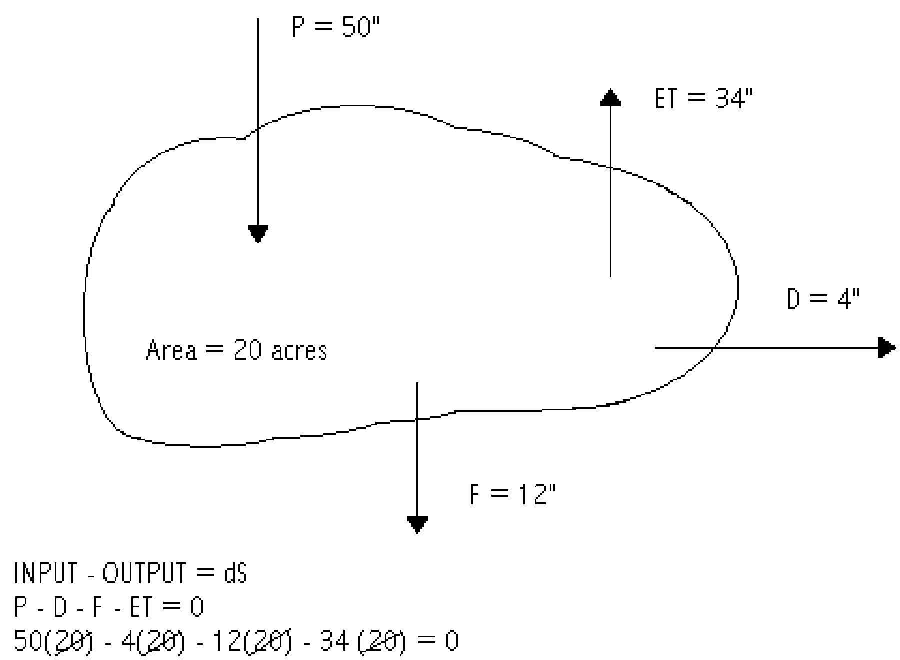


Figure 21 - Pre-Developed Woodland Pasture Watershed in Central Florida

a) What percentage of the rainfall excess has to be retained on-site to match the pre-development surface discharge of 4 inches per year?

b) Using a stormwater pond for irrigation what is the required irrigation area to retain post equal to pre development rainfall excess if the pond volume is 3 in. over the EIA? How much water (Ac-in) is irrigated per year?

c) Is supplemental water required to maintain the permanent pool while meeting irrigation demand? If so, what is the volume per year in (Ac-ft/yr)? Is the new annual discharge greater than 4 inches?

d) What is the required irrigation area to achieve volume control for drip irrigation and spray irrigation?

e) What is the post-development infiltration?

f) What is the average annual nitrate removal efficiency over the watershed if the reuse pond achieves 70 percent removal?

6.2 Solution

a) Percent Rainfall Excess Retained:

The following diagram represents the post-development condition. The evapotranspiration increases as vegetation receives a steady supply of water and is calculated using the modified Blaney-Criddle Equation for the conditions of Central Florida. For the calculations in this example problem, the ET of the irrigated vegetation was rounded to 40 inches per year.

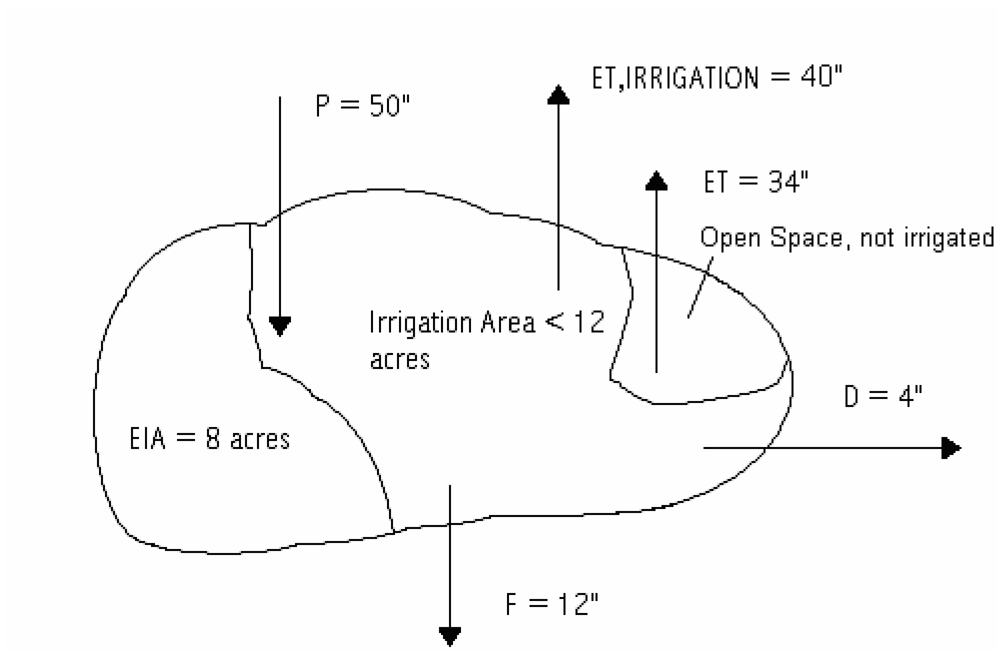


Figure 22 - Post-Development Watershed

The EIA is equal to the total area times the average runoff coefficient, or equal to the area of an equivalent 100% impervious watershed which produces the same runoff volume. To maintain 4 in. over the 20 acres, the 8 acre EIA will contribute 8 * 50 = 400 Ac-in, or 400 / 20 = 20 inches over the whole watershed. To maintain a pre-development discharge of 4 inches, 16 inches over the watershed area needs to be retained. This means eighty percent of the yearly rainfall excess needs to be retained:

[(16)(20) / (8)(50)] * 100 = 80 %

b) Post = Pre Design:

For operation and design of the stormwater irrigation pond, the REV curve in Figure 6 applies to Central Florida and can be used. Assuming a 3 inch reuse volume, to achieve 80 percent efficiency (80 percent of rainfall excess is irrigated) the corresponding reuse rate is 0.15 inches per day over the EIA. Keep in mind that to fit a certain land use, the reuse (irrigation) rate can be varied by changing the pond volume.

Irrigation Rate from pond	= 0.15 inches per day per equivalent impervious area
Irrigation Volume from pond	= 0.15 * 8 = 1.2 Ac-in/day or 436.8 Ac-in/year
Irrigation required by plants	= 0.75 inches per week = 0.107 inches per day

R = Volume Irrigated

$0.15 * 8 = 0.107 * A_{IRR}$ $\quad$ $A_{IRR} = 11.2$ acres

NOTE:
- * Is 11.2 acres available? Yes, 12 acres are available.
- * Check to establish balance.
- * Re-do if pond area not available.
- * Volume irrigated is equal to volume delivered to irrigation area (100 percent efficiency)

c) Supplemental Water:

Using the Equation from Figure 21 and assuming $\Delta S = 0$:

$D = (0.2)R_E$

$G = R + D - R_E = R + 0.2 * R_E - R_E$

$G = (0.75 \text{ in/wk})(52 \text{ wk/yr})(11.2 \text{ Ac}) - 0.8(50 \text{ in/yr})(8 \text{ Ac})$

$G = 436.8 - 320 = 116.8$ Ac-in/year

Check discharge:

$R_E + G - R - D = 0$

$D = (50)(8) + (116.8) - (0.75)(52)(11.2)$

$D = 400 + 116.8 - 436.8 = 80$ Ac-in

D = 80 / 20 = 4 inches per year

d) Irrigation Area:

Assume drip irrigation is 100 percent efficient and spray irrigation is 60 percent efficient (Hammond, 2005). Volume to reach vegetation:

Spray irrigation → V = (0.6)(436.8) = 262.08 Ac-in/yr

Drip irrigation → V = 436.8 Ac-in/yr

Required Irrigation Area:

Spray irrigation → 262.08 = (0.75)(52)A → A = 6.72 acres

Drip irrigation → 436.8 = (0.75)(52)A → A = 11.2 acres

e) Post Development Infiltration:

To calculate the infiltration the mass balance depicted in the following diagram is used. The input is precipitation and the outputs are infiltration, discharge, ET from irrigated areas, ET from non-irrigated areas, and losses from spray irrigation.

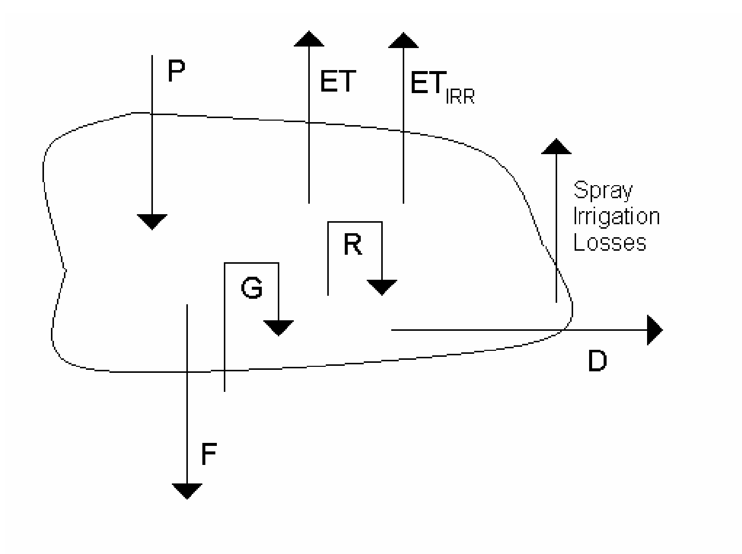


Figure 23 - Inputs and Outputs of Watershed with Stormwater as a Source for Irrigation

Post-development infiltration:

INPUT – OUTPUT = dS = 0

Drip irrigation:

$P - ET - ET_{IRR} - D - F = 0$

$F = (50)(20) - (12 - 11.2)(34) - (11.2)(40) - (20)(4)$

F = 451.6 Ac-in/year = 22.58 in/yr over the 20 acre watershed

Spray irrigation:

$P - ET - ET_{IRR} - D - F - (\text{Spray Irr. Losses}) = 0$

$F = (50)(20) - (12 - 6.72)(34) - (6.72)(40) - (20)(4) - (0.4)(436.8)$

F = 296.96 Ac-in/year = 14.85 in/yr over the 20 acre watershed

The post-development F is higher than the pre-development F of 12 in/yr because the rainfall over the added impervious area resulted in runoff which was used for irrigation and thus infiltrated, while the same area (impervious area) required water for ET in the pre-developed watershed.

f) Overall nitrate removal efficiency:

Using the 97 percent removal of nitrate from the irrigated stormwater and assuming a pond nitrate removal efficiency of 70 percent, the overall efficiency is calculated. So if 80 percent is used for irrigation and 20 percent is discharged from the pond, the overall nitrate removal efficiency from the rainfall excess (infiltration plus discharge) using Equation 20 is:

$$\eta_o = 1 - [(1 - 0.7)(1 - 0.97)(0.8) + (1 - 0.7)(0.2)] = 0.9328 = 93.28\ \%$$

From Table 5, assuming 'mixed' land cover and all the inorganic nitrogen is in the form of nitrate. The pre-development nitrate concentration in the runoff is assumed at 0.6 mg/L. Assuming >40 percent urban for the post-developed condition and all the inorganic nitrogen is in the nitrate form, the post-development nitrate concentration in the rainfall excess is 1.0 mg/L.

Using Equation 17, Equation 18, and Equation 19 and with NO_3-N = 1.0 mg/L:

$(N_{PRE})_{infiltration}$ = (102.79)(12 in/yr)(0.6 mg/L)(20 Ac) = 14,802 kg/yr

$(N_{PRE})_{runoff}$ = (102.79)(4 in/yr)(0.6 mg/L)(20 Ac) = 4,934 kg/yr

$(N_{PRE})_{total}$ = 14,802 + 4,934 = 19,736 kg/yr

Irrigation:

$(N_{POST})_{infiltration}$ = (102.79)(22.58 in/yr)(1.0 mg/L)(20 Ac)(1 – 0.7)

= 13,926 kg/yr

$(N_{POST})_{discharge}$ = (102.79)(4 in/yr)(1.0 mg/L)(20 Ac)(0.3)

= 2,467 kg/yr

$(N_{POST})_{total}$ = 13,926 + 2,467 = 16,393 kg/yr

CHAPTER 7 – CONCLUSIONS AND RECOMMENDATIONS

7.1 Overview

The best management practice of using excess stormwater as a source for irrigation was examined. Through a literature search and data collected from a field experiment, the impacts of the BMP on the hydrologic cycle and the nitrogen cycle were studied. Both cycles are naturally occurring and are impacted by development. The goal is to develop a watershed without impacting these cycles, which implies the post-development condition of the aforementioned cycles are identical to the pre-development condition.

The research presented in this thesis is intended to contribute to that goal. Many parameters and BMPs are considered for low-impact development; using excess stormwater for irrigation can be a part of this system. The results were presented to allow the reader to reach conclusions and expand on this research in addition to using the conclusions.

7.2 Conclusions

From the data that were collected for the duration of one year from a field experiment it was concluded that detained stormwater can be used as an irrigation source and a hydrologic balance and nitrogen balance between post- and pre-development can be achieved. Also, the characteristics of the groundwater beneath a typical suburban lawn depend largely on the soil type and characteristics. By performing a total nitrogen balance, it was discovered that more mass of nitrogen was leaving in the groundwater than was entering as precipitation or irrigation, which indicates leaching of nitrogen from the soil. After analyzing different species of nitrogen it was determined that the input nitrogen was mostly in the form of nitrate and the output nitrogen was mostly in the form of ammonia. The conclusion was made that irrigating with stormwater with a nitrate nitrogen concentration of up to 2 mg/L had little effect on the groundwater nitrate content at a depth of four feet; the maximum nitrate conversion efficiency was determined to be about 97 percent. Furthermore, it was assumed that the nitrate was converted first to organic nitrogen and then the ammonia through biological processes on the grass surface and in the soil. These processes are thought to consist of nitrate uptake by the grass and by microorganisms in the soil.

Water input and output volumes for three grass-covered soil chambers were collected for a one year period, allowing evapotranspiration to be calculated through a mass balance. It was also assumed that with the twice a week irrigation schedules, the grass cover did not reach potential ET, thus the measured ET data represent the actual ET. The average ET of the three soil chambers was compared to the predicted ET values from the modified Blaney-Criddle equation on a seasonal and yearly basis. The modiefied Blaney-Criddle Equation was found to be accurate at predicting *actual* ET for St. Augustine grass in Central Florida for the soils and irrigation schedule used.

Using the results concerning the nitrate removal and evapotranspiration, a water balance and nitrogen balance were presented in an example problem. Through the example problem it was shown that by using stormwater for irrigation, a post- versus pre-development volume balance could be achieved. It was also shown that the post-development nitrate emissions were reduced when compared to the pre-development emissions.

To summarize the main conclusions:

a. Irrigating with up to 2 mg/L NO_3-N containing stormwater has minimal effect on nitrate in groundwater at a depth of four feet;
b. The modified Blaney-Criddle equation is accurate for predicting actual ET for irrigated St. Augistine grass in Central Florida;
c. Using excess stormwater as a source for irrigation can be considered a BMP for volume control and nitrate control.
d. A pan evaporation coefficient of 0.42 establishes a relationship between pan evaporation data and evapotranspiration of irrigated St. Augustine grass in Central Florida.

7.3 Recommended Future Research

Some questions about nitrogen and evapotranspiration arose from the research conclusions, which can be topics for future research. Soils with varying nitrogen content and irrigation water with nitrate concentration greater than 2 mg/L could be compared to evaluate the effect on nitrogen leaching and the effect on the nitrogen balance. Also, more research could be performed to ascertain what mechanism is responsible for the nitrate removal as it moves through the soil, what factors influence nitrate removal, and how the removal efficiency can be improved. Also, the effects of excess nitrate emission from a watershed to a receiving water body are documented; however, future research is recommended on the effects on the receiving water of a significant reduction in nitrate emissions. To further understand a watershed's nutrient emissions, a phosphorous balance could be completed around the chambers.

The effect of more available water (increased irrigation and higher water table) on evapotranspiration should be examined and the implications on the accuracy of the Modified Blaney-Criddle. Furthermore, it is recommended to research the accuracy of the Modified Blaney-Criddle for various locations and crops. Also, a long-term study of the pan coefficient would allow for improved ET determination for a geographic area. Finally, to isolate the effect of the vegetation on the results, an identical experiment can be performed without a grass cover.

APPENDIX A – TKN PROCEDURE

Solution Preparation

i. Borate Buffer Solution: add 88 mL of 0.1 N NaOH solution, add 9.5 g $Na_2B_4O_7$*$10H_2O$, dilute to 1L
ii. Sodium Hydroxide – Add 400 mL of 15 N NaOH and dilute to 1 L
iii. Mixed Indicator Solution – Dissolve 200 mg methyl red indicator in 100 mL 95%sopropyl alcohol, dissolve 100 mg methyl blue indicator in 50 mL 95% lsopropyl alcohol, combine two solutions
iv. Boric Acid Indicator – Dissolve 20 g H_3BO_3 in DI water, add 10 mL of mixed indicator solution, dilute to 1 L.
v. 0.02 N Sulfuric Acid Titrant – Add 28 mL of concentrated H_2SO_4 dilute to 1 L, add 20 mL of 1 N H_2SO_4, dilute to 1 L
vi. Digestion Reagent – Add 7.3 gram $CuSO_4$ – start with 800 mL DI water, add 134 g K_2SO_4, add 134 mL of concentrated H_2SO_4, dilute to 1 L.
vii. Sodium Hydroxide / Sodium Thlosulfate Reagent – Dissolve 500 grams NaOH and 25 grams $Na_2S_2O_3$*5H2O in water, dilute to 1 L
viii. Stock Ammonium Solution – Dissolve 3.819 anydrous NH4Cl, dried at 100 °C in water, dilute to 1 L (1 mL = 1 mg N = 1.22 mg NH3)

Inorganic Nitrogen Test

1) C Create TKN data table in log book
e. Use small cylindrical containers to obtain samples
f. Add 20 mL Borate Buffer Solution to each container
g. Add 4 drops 6 N NaOH to each container
h. Turn on burners and condensation water
i. Measure and pour 50 mL Boric Acid Indicator Solution into numbered Erlenmeyer flasks and place in order on distillation apparatus
j. Fill each container to the neck with DI water
k. Pour contents of each container into the corresponding numbered distillation flask and add a few Teflon boiling chips
l. Set distillation flasks on burners being careful to get a good seal with the stoppers
m. Once boiling, distill until 350 mL is collected in the Erlenmeyer flask
n. While samples are boiling, set up titration rign stand with an even numbered volume of 0.02 N sulfuric acid
o. Turn off heat to let flasks cool
p. Titrate all flasks to endpoint, recording titration volumes

Digestion

1) Turn on burners and vacuum system

2) When distillation flasks are cool enough to touch, add 50 mL digestion reagent to each of the 7 sample flasks
3) Place flasks on digestion rack
4) Let contents boil, when white smoke appears, boil for 0.5 hour more and turn off heat
5) Let flasks cool to room temperature

Organic Distillation

1) Turn on heat for the distillation step
2) Add 50 mL Sodium Hydroxide / Sodium Thiosulfate reagent water to each flask
3) Add approximately 350 mL DI water to each flask
4) Follow steps 7 through 13

APPENDIX B – SOIL TEST RESULTS

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Landscape & Vegetable Garden Test

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Orlando, FL 32816-2993
Tel: 407-823-4143

For further information contact:
Wilkins, Deloris H.
Orange County Coop Extn Service
2350 E Michigan St
Orlando, FL 32806-4996
Tel: 407-836-7570
Email: orange@mail.ifas.ufl.edu

Client Identification: 1

Set Number: 5586 Lab Number: 123053

Crop: St. Augustinegrass - South Florida

Report Date: 29-Jun-04

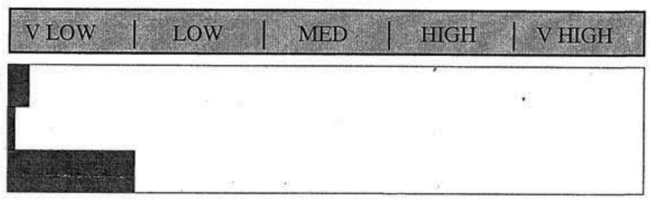
These interpretations and recommendations are based upon soil test results and research/experience with the specified crop under Florida's growing conditions. We do not test soil for N as there is no meaningful soil test for predicting N availability. Thus, the N recommendation was developed from research that measured response of the indicated crop to applied N fertilizer. If you expect significant nutrient release from organic sources such as crop residues or organic amendments, estimate the amount mineralized and subtract that amount from the fertilizer recommendations given below to arrive at crop needs.

SOIL TEST RESULTS AND THEIR INTERPRETATIONS

Target pH:	6.5
pH (1:2 Sample:Water)	4.5
A-E Buffer Value:	7.89

MEHLICH-1 EXTRACTABLE

PHOSPHORUS	(ppm P)	2
POTASSIUM	(ppm K)	1
MAGNESIUM	(ppm Mg)	0
CALCIUM	(ppm Ca)	7



LIME AND FERTILIZER RECOMMENDATIONS

Crop:	St. Augustinegrass Lawn	
Lime:	61.0	lbs per 1000 sq. ft (1 Ton = 2000 Lbs)
Nitrogen:	2	lbs per 1000 sq. ft.
Phosphorus: (P_2O_5)	1	lbs per 1000 sq. ft.
Potassium: (K_2O)	3	lbs per 1000 sq. ft.

Footnotes are printed wherever applicable. These footnotes are an integral part of fertilization recommendations. Please read them carefully.
See Footnote(s): 501

Print Date: 29-Jun-04

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Orlando, FL 32816-2993
Tel: 407-823-4143

For further information contact:
Wilkins, Deloris H.
Orange County Coop Extn Service
2350 E Michigan St
Orlando, FL 32806-4996
Tel: 407-836-7570
Email: orange@mail.ifas.ufl.edu

Client Identification: 2

Set Number: 5586 Lab Number: 123054

Crop: St. Augustinegrass - South Florida

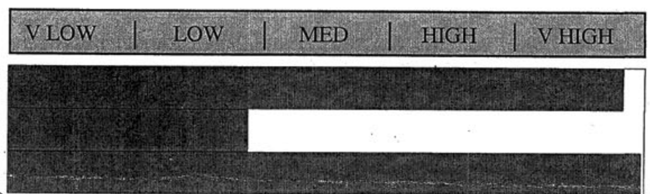
Report Date: 29-Jun-04

These interpretations and recommendations are based upon soil test results and research/experience with the specified crop under Florida's growing conditions. We do not test soil for N as there is no meaningful soil test for predicting N availability. Thus, the N recommendation was developed from research that measured response of the indicated crop to applied N fertilizer. If you expect significant nutrient release from organic sources such as crop residues or organic amendments, estimate the amount mineralized and subtract that amount from the fertilizer recommendations given below to arrive at crop needs.

SOIL TEST RESULTS AND THEIR INTERPRETATIONS

Target pH:	6.5
pH (1:2 Sample:Water)	6.3
A-E Buffer Value:	N/A

MEHLICH-1 EXTRACTABLE		
PHOSPHORUS	(ppm P)	77
POTASSIUM	(ppm K)	33
MAGNESIUM	(ppm Mg)	69
CALCIUM	(ppm Ca)	>1966



LIME AND FERTILIZER RECOMMENDATIONS

Crop:	St. Augustinegrass Lawn	
Lime:	0.0	lbs per 1000 sq. ft (1 Ton = 2000 Lbs)
Nitrogen:	2	lbs per 1000 sq. ft.
Phosphorus: (P_2O_5)	0	lbs per 1000 sq. ft.
Potassium: (K_2O)	3	lbs per 1000 sq. ft.

Footnotes are printed wherever applicable. These footnotes are an integral part of fertilization recommendations. Please read them carefully.
See Footnote(s): 1 501

Print Date: 29-Jun-04

Page 2 of 4

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Tel: 407-836-7570
Email: orange@mail.ifas.ufl.edu

Client Identification: 3

Set Number: 5586 Lab Number: 123055

Crop: St. Augustinegrass - South Florida

Report Date: 29-Jun-04

These interpretations and recommendations are based upon soil test results and research/experience with the specified crop under Florida's growing conditions. We do not test soil for N as there is no meaningful soil test for predicting N availability. Thus, the N recommendation was developed from research that measured response of the indicated crop to applied N fertilizer. If you expect significant nutrient release from organic sources such as crop residues or organic amendments, estimate the amount mineralized and subtract that amount from the fertilizer recommendations given below to arrive at crop needs.

SOIL TEST RESULTS AND THEIR INTERPRETATIONS

Target pH:	6.5
pH (1:2 Sample:Water)	6.5
A-E Buffer Value:	N/A

MEHLICH-1 EXTRACTABLE		
PHOSPHORUS	(ppm P)	72
POTASSIUM	(ppm K)	30
MAGNESIUM	(ppm Mg)	63
CALCIUM	(ppm Ca)	>1500

LIME AND FERTILIZER RECOMMENDATIONS

Crop:	St. Augustinegrass Lawn	
Lime:	0.0	lbs per 1000 sq. ft (1 Ton = 2000 Lbs)
Nitrogen:	2	lbs per 1000 sq. ft.
Phosphorus: (P_2O_5)	0	lbs per 1000 sq. ft.
Potassium: (K_2O)	3	lbs per 1000 sq. ft.

Footnotes are printed wherever applicable. These footnotes are an integral part of fertilization recommendations. Please read them carefully.
See Footnote(s): 1 501

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FootNotes.rpt 06/29/2004

NoteNu	Description
1	Soil test values noted with a ">" sign exceeded the normal working range of our extraction method and are interpreted as high or very high for P, K, or Mg. No positive plant response to addition of the nutrient is likely. In some circumstances, addition of this nutrient to the soil could be detrimental to plant performance or to the environment.
501	For details on fertilization, obtain UF/IFAS publication SL21, "General Recommendations for Fertilization of Turfgrasses on Florida Soils:" The publication is available on the web at http://edis.ifas.ufl.edu/LH014 or from county Extension offices. These rates are for normal, healthy lawns. Double the rates for high maintenance turf. Divide annual rates into 2 to 8 applications depending on location and management levels. Apply no more than 1.0 lb N/1000 sq. ft. per application.

This data report has been issued on the authority of Dr. Rao Mylavarapu, Laboratory Director, Ms. E. Kennelley, Laboratory Coordinator, and Mr. Pete Straub, QA Officer, in support of Florida Cooperative Extnsion Services.

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UCF-Strmwter.
ML 4000 Central Florida Blvd.
Orlando,FL 32816

PO #: n/a
Client Project #: n/a
Date Sampled: Jun 15, 2004; 10:00 AM
Jun 24, 2004; Invoice: 5844F04

Report Summary

Date Received: Jun 15, 2004

Laboratory #	Sample Description	Analysis	Chemist	Location	SampleMatrix
5844	location 1	EPA160.3	NRR	Main Lab	Soil
		EPA351.2	JGK	Main Lab	
		EPA353.1	JGK	Main Lab	
		EPA354.1	JGK	Main Lab	
		EPA365.1	JGK	Main Lab	
		EPA365.4	JGK	Main Lab	
		EPA9045	PCW	Main Lab	
5845	location 2	EPA160.3	NRR	Main Lab	Soil
		EPA351.2	JGK	Main Lab	
		EPA353.1	JGK	Main Lab	
		EPA354.1	JGK	Main Lab	
		EPA365.1	JGK	Main Lab	
		EPA365.4	JGK	Main Lab	
		EPA9045	PCW	Main Lab	

Certificate of Results

Sample integrity was certified prior to analysis. Test results meet all requirements of the NELAC Standards except as noted in the Quality Control Report. Uncertainties for these data are available on request. This report may not be reproduced in part; results relate only to items tested.

ACCREDITED IN ACCORDANCE WITH nelac

Jefferson S. Flowers, Ph.D.
President/Technical Director

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Orlando,FL 32816

PO #: n/a
Client Project #: n/a
Date Sampled: Jun 15, 2004; 10:00 AM
Jun 24, 2004; Invoice: 5844F04

Analysis Report

Laboratory #: 5844	Sample Description: location 1						
Parameter	**Result**	**Units**	**DF**	**MDL**	**QC Batch**	**Method**	**Analyzed**
Total Nitrogen(as N)	778	mg/kg	1	0.0200			
Total_Phosphorous(as P)	194	mg/kg	1	0.0100	10035243	EPA365.4	06/21/04
Total_Solids	100	mg/kg	1	2.50	10035310	EPA160.3	06/18/04
% Moisture	6.07	%H2O	1	0.0100	10035314	EPA160.3	06/18/04
Nitrite(as N)	0.422	mg/kg	1	0.0100	10035351	EPA354.1	06/15/04 04:00 PM
Nitrate(as N)	57.7	mg/kg	1	0.0100	10035353	EPA353.1	06/15/04 04:00 PM
Lab pH (units)	6.55	pH	1	0.0500	10035418	EPA9045	06/24/04 01:06 PM
TKN(as N)	720	mg/kg	1	0.0200	10035419	EPA351.2	06/21/04
Orthophosphate(as P)	1.60	mg/kg	1	0.0100	10035420	EPA365.1	06/24/04 01:20 AM

Laboratory #: 5845	Sample Description: location 2						
Parameter	**Result**	**Units**	**DF**	**MDL**	**QC Batch**	**Method**	**Analyzed**
Total Nitrogen(as N)	822	mg/kg	1	0.0200			
Total_Phosphorous(as P)	190	mg/kg	1	0.0100	10035243	EPA365.4	06/21/04
Total_Solids	100	mg/kg	1	2.50	10035310	EPA160.3	06/18/04
% Moisture	4.25	%H2O	1	0.0100	10035314	EPA160.3	06/18/04
Nitrite(as N)	0.156	mg/kg	1	0.0100	10035351	EPA354.1	06/15/04 04:00 PM
Nitrate(as N)	56.6	mg/kg	1	0.0100	10035353	EPA353.1	06/15/04 04:00 PM
Lab pH (units)	7.10	pH	1	0.0500	10035418	EPA9045	06/24/04 01:06 PM
TKN(as N)	765	mg/kg	1	0.0200	10035419	EPA351.2	06/21/04
Orthophosphate(as P)	1.93	mg/kg	1	0.0100	10035420	EPA365.1	06/24/04 01:20 AM

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Jun 24, 2004; Invoice: 5844F04

Quality Report

Quality Control Batch: 10035243	**Analyst: JGK**							
Blank	**Result**	**Units**						
Total_Phosphorous(as P)	0.0163	mg/kg						
Laboratory Control Sample	**Result**	**Units**	**Spike**	**%REC**	**%REC Lim**			
Total_Phosphorous(as P)	1.92	mg/kg	2.00	96.00	87.50-111.00			
Matrix Spike	**Result**	**Units**	**Spike**	**%REC**	**%REC Lim**	**Sample**		
Total_Phosphorous(as P)	2.05	mg/kg	1.50	130.89	43.05-150.63	0.0867		
Matrix Spike Duplicate	**Result**	**Units**	**Spike**	**%REC**	**%REC Lim**	**Sample**	**RPD**	**RPD Lim**
Total_Phosphorous(as P)	2.15	mg/kg	1.50	137.55	43.05-150.63	0.0867	4.76	24.60

Quality Control Batch: 10035310	**Analyst: NRR**	
Blank	**Result**	**Units**
Total_Solids	0.0002U	%TS

Quality Control Batch: 10035351	**Analyst: JGK**					
Blank	**Result**	**Units**				
Nitrite(as N)	0.00001U	%DW				
Laboratory Control Sample	**Result**	**Units**	**Spike**	**%REC**	**%REC Lim**	
Nitrite(as N)	0.788	%DW	0.800	98.50	84.50-114.12	
Matrix Spike	**Result**	**Units**	**Spike**	**%REC**	**%REC Lim**	**Sample**
Nitrite(as N)	0.511	%DW	0.500	102.20	58.60-136.20	0.0000100U

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Matrix Spike Duplicate	**Result**	**Units**	**Spike**	**%REC**	**%REC Lim**	**Sample**	**RPD**	**RPD Lim**
Nitrite(as N)	0.500	%DW	0.500	100.00	58.60-136.20	0.0000100U	2.18	23.80

Quality Control Batch: 10035353 **Analyst: JGK**

Blank	**Result**	**Units**
Nitrate(as N)	0.00235	%DW

Laboratory Control Sample	**Result**	**Units**	**Spike**	**%REC**	**%REC Lim**
Nitrate(as N)	0.813	%DW	0.800	101.62	80.50-116.87

Matrix Spike	**Result**	**Units**	**Spike**	**%REC**	**%REC Lim**	**Sample**
Nitrate(as N)	0.574	%DW	0.500	104.98	53.36-147.88	0.0491

Matrix Spike Duplicate	**Result**	**Units**	**Spike**	**%REC**	**%REC Lim**	**Sample**	**RPD**	**RPD Lim**
Nitrate(as N)	0.622	%DW	0.500	114.58	53.36-147.88	0.0491	8.03	28.80

Quality Control Batch: 10035419 **Analyst: JGK**

Blank	**Result**	**Units**
TKN(as N)	0.02U	mg/kg

Laboratory Control Sample	**Result**	**Units**	**Spike**	**%REC**	**%REC Lim**
TKN(as N)	1.96	mg/kg	2.00	98.00	79.00-107.50

Matrix Spike	**Result**	**Units**	**Spike**	**%REC**	**%REC Lim**	**Sample**
TKN(as N)	2.49	mg/kg	1.50	127.93	36.70-157.89	0.571

Matrix Spike Duplicate	**Result**	**Units**	**Spike**	**%REC**	**%REC Lim**	**Sample**	**RPD**	**RPD Lim**
TKN(as N)	2.52	mg/kg	1.50	129.93	36.70-157.89	0.571	1.20	48.00

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Date Sampled: Jun 15, 2004; 10:00 AM
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Quality Control Batch: 10035420	Analyst: JGK							
Blank	**Result**	**Units**						
Orthophosphate(as P)	0.01U	mg/kg						
Laboratory Control Sample	**Result**	**Units**	**Spike**	**%REC**	**%REC Lim**			
Orthophosphate(as P)	0.490	mg/kg	0.500	98.00	78.00-112.40			
Matrix Spike	**Result**	**Units**	**Spike**	**%REC**	**%REC Lim**	**Sample**		
Orthophosphate(as P)	0.483	mg/kg	0.500	91.74	40.43-153.16	0.0243		
Matrix Spike Duplicate	**Result**	**Units**	**Spike**	**%REC**	**%REC Lim**	**Sample**	**RPD**	**RPD Lim**
Orthophosphate(as P)	0.470	mg/kg	0.500	89.14	40.43-153.16	0.0243	2.73	30.40

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Narrative Report

Sample Handling
Sample handling and holding time criteria were met for all samples. Samples collected by submitter. No unusual events occurred during analysis. Results are reported on a wet weight basis for aqueous matrices and on a dry weight basis for sludge and soil matrices unless otherwise noted.

Quality Control
Enclosed analyses met method or FCL criteria, unless otherwise denoted on the sample results. Applied data qualifiers are defined below.

Attachments
Chain of Custody

Qualifier	Meaning
U	Compound was analyzed for but not detected.
J	One or more QC samples associated with this data value exceeded QC limits.
J1	Surrogate recovery limits have been exceeded.
J2	No known quality control criteria exist for the component.
J3	Reported value failed to meet established quality control criteria for either precision or accuracy.
J4	Sample matrix interfered with the ability to make an accurate determination on the spiked sample.
Q	Sample held beyond the accepted holding time.
L	Off-scale high; reported concentration exceeds the highest standard.
V	Analyte was detected in both the sample and the associated method blank.
TNTC	Too numerous to count.
A	Absent
P	Present
T	Value reported is less than the statistical method detection limit. Reported for informational purposes only.
M	Value reported is greater than the statistical method detection limit, but less than the reported MDL.
G	The greatest of three dilutions did not yield sufficient oxygen depletion for valid data.
S	The least of three dilutions did not yield sufficient oxygen residual for valid data.
O	Result is greater than (over) the specified value.
I	Reported value is between reported MDL (low calibration standard) and laboratory determined MDL (EPA 40 CFR 136, App. B).

APPENDIX C – DATA

Table 18 - Precipitation Data

Date	Volume (in)	Volume per chamber (mL)	NO_3^- + NO_2^- (mg/L)	NO_2^- (mg/L)	NH_3 (mg/L)	Alkalinity (mg/L as $CaCO_3$)	pH
6/4/2004	0.90	7934.62	1.20	0.06			
6/6/2004	0.02	176.32					
6/7/2004	3.05	26889.54	0.15	0.00			
6/10/2004	0.30	2644.87					
6/11/2004	0.56	4937.10	0.47	0.02			
6/12/2004	0.06	528.97					
6/15/2004	0.29	2556.71					
6/16/2004	0.59	5201.58	0.18	0.03	0.08	0.00	4.78
6/20/2004	0.97	8551.76	0.26	0.02			
6/21/2004	0.96	8463.59	0.19			0.00	4.51
6/22/2004	0.20	1763.25	0.84	0.07	0.12	0.00	4.35
6/26/2004	1.78	15692.91					
6/28/2004	0.21	1851.41	1.20	0.11		15.00	8.04
7/3/2004	0.45	3967.31	0.65	0.08			8.40
7/4/2004	1.84	16221.89	0.26	0.00			8.10
7/5/2004	0.17	1498.76	0.41	0.01		10.00	8.01
7/12/2004	2.28	20101.03	0.29			36.00	7.30
7/19/2004	0.17	1498.76	0.72		0.3	32.00	7.09
7/29/2004	0.30	2644.87	0.75	0.09			6.99
8/1/2004	0.06	528.97					
8/2/2004	0.13	1146.11	0.40			28.00	7.33
8/4/2004	0.05	440.81					
8/5/2004	0.41	3614.66	0.34			17.00	7.67
8/7/2004	0.95	8375.43	0.29	0.02			5.78
8/8/2004	2.22	19572.06	0.05				6.00
8/9/2004	1.17	10315.00	0.07				5.71
8/10/2004	0.23	2027.74	0.40				5.78
8/11/2004	0.21	1851.41	0.95			6.00	5.74
8/13/2004	2.76	24332.83	0.04		0.25		6.08
8/15/2004	2.54	22393.26	0.13			2.00	4.83
8/16/2004	0.13	1146.11	0.32				4.99
8/17/2004	0.10	881.62	0.69				4.57
8/22/2004	0.61	5377.91	0.38			0.00	4.77
8/23/2004	0.50	4408.12	0.52			0.00	4.30
8/25/2004	1.00	8816.24	0.51	0.06		0.00	4.32
8/26/2004	0.84	7405.64	0.36			0.00	4.13
8/28/2004	0.41	3614.66	0.41			0.00	4.43

Date	Volume (in)	Volume Per Chamber (mL)	NO_3^- + NO_2^- (mg/L)	NO_2^- (mg/L)	NH_3 (mg/L)	Alkalinity (mg/L as $CaCO_3$)	pH
8/30/2004	0.25	2204.06	0.22		0.21	6.50	5.64
9/1/2004	2.18	19219.41	0.29			0.00	4.43
9/7/2004	6.29	55454.17	0.04	0.00		3.00	5.50
9/10/2004	0.15	1322.44	0.76			4.25	5.54
9/13/2004	1.68	14811.29	0.05				5.24
9/17/2004	0.15	1322.44			0		
9/20/2004	0.77	6788.51				11.00	6.55
9/21/2004	1.15	10138.68	0.04				5.84
9/22/2004	0.16	1410.60	0.08				5.16
9/27/2004	4.72	41612.67				0.00	4.82
10/5/2004	0.58	5113.42	0.48	0.01			
10/13/2004	0.58	5113.42	0.16				6.47
10/15/2004	0.54	4760.77	0.12				7.32
10/20/2004	0.52	4584.45	0.22		0.03	14.00	6.82
11/5/2004	0.10	881.62	1.01				7.40
11/11/2004	0.22	1939.57					10.02
11/14/2004	0.16	1410.60	0.07		0		
11/29/2004	1.10	9697.87	0.04		0.11	8.50	7.58
12/10/2004	0.27	2380.39	0.22		0.06		2.45
12/26/2004	1.45	12783.55	0.07	0.00		0.00	4.27
1/13/2005	0.09	793.46	0.32				7.84
1/14/2005	2.29	20189.20	0.04		0.07		7.71
1/16/2005	0.13	1146.11	0.04			12.00	7.60
2/3/2005	0.18	1586.92	0.75				
2/4/2005	0.10	881.62	0.65				
2/24/2005	1.13	9962.35	0.55		0.06	2.00	4.85
2/28/2005	1.21	10667.65	0.02			11.00	6.66
3/6/2005	0.14	1234.27					
3/8/2005	0.37	3262.01	0.41				6.53
3/9/2005	0.50	4408.12	0.38		0.11		6.70
3/14/2005	0.06	528.97					
3/16/2005	0.23	2027.74	0.68				7.45
3/17/2005	1.66	14634.96	0.13				7.49
3/21/2005	0.16	1410.60					
3/23/2005	1.20	10579.49	0.23				5.31
3/27/2005	0.78	6876.67	0.22	0.04	0.08		7.59
3/28/2005	0.12	1057.95	0.54	0.12			6.65
3/31/2005	0.06	528.97					
4/8/2005	0.48	4231.80	0.37		0.96		7.47
4/13/2005	0.09	793.46					

Date	Volume (in)	Volume Per Chamber (mL)	NO_3^- + NO_2^- (mg/L)	NO_2^- (mg/L)	NH_3 (mg/L)	Alkalinity (mg/L as $CaCO_3$)	pH
4/24/2005	0.04	352.65					
4/27/2005	0.27	2380.39	1.88				7.55
5/1/2005	0.75	6612.18					
5/4/2005	0.69	6083.21			0.11		5.70
5/8/2005	0.42	3702.82					
5/11/2005	0.11	969.79					
6/1/2005	1.57	13841.50					6.52

Table 19 - Irrigation Source Data

Date	NO_3^- + NO_2^- (mg/L)	NO_2^- (mg/L)	NH_3 (mg/L)	pH	Alkalinity (mg/L as $CaCO_3$)
6/4/2004	0.04	0			
6/9/2004	0.02	0		7.75	
6/16/2004	0.02	0		7.35	
6/20/2004	0.03			7.02	60.00
6/21/2004	0.03	0		7.11	40.00
6/22/2004	0.04			7.05	
6/25/2004	0.02	0		7.14	
7/2/2004	0.02			7.36	
7/5/2004	0.01	0		7.14	60.00
7/9/2004	0.02			7.02	
7/13/2004	0.03		0.1	7.14	
7/17/2004	0.02			6.94	
7/20/2004	0.02			6.95	
7/23/2004	0.01		0.08	7.05	
7/26/2004	0.02			7.01	53.00
7/30/2004	0.04	0.01		6.90	
8/3/2004	0.02	0		7.08	43.00
8/20/2004	0.04	0	0.75	7.05	42.00
9/3/2004	0.01			7.37	
9/10/2004	0.02	0		7.06	35.00
9/28/2004	0.02			7.13	
10/1/2004	0.03			7.22	40.00
10/8/2004	0.03		0.11	7.05	

Date	NO_3^- + NO_2^- (mg/L)	NO_2^- (mg/L)	NH_3 (mg/L)	pH	Alkalinity (mg/L as $CaCO_3$)
10/13/2004	0.03		0.16	6.92	35.00
10/26/2004	0.02		0.04	7.02	
11/12/2004	0.02			7.16	50.00
11/24/2004	0.03		0.02	7.24	
11/30/2004	0.02			7.20	44.00
12/10/2004	0.02		0.11	7.21	
1/4/2005	0.02			7.33	
1/7/2005	0.02			7.15	
1/14/2005	0.03		0.05	7.20	38.00
1/21/2005	0.02			7.25	
2/8/2005	0.02		0.08	7.41	55.00
3/11/2005	0.02	0		7.04	
3/18/2005	0.01	0	0.11	6.77	35.00
3/25/2005	0.01			7.06	
4/1/2005	0.00		0.02	7.15	
4/8/2005	0.01			7.15	
4/15/2005	0.00		0.16	7.09	22.00
5/3/2005	0.00		0.21	9.31	
5/13/2005	0.00			7.56	

Table 20 - Irrigation Event Data

Date	Irrigation Amount per Chamber (in)	Irrigation Amount per Chamber (L)	NO_3^- Conc. Chamber 1 Irrigation (mg/L)	NO_3^- Conc. Chamber 2 Irrigation (mg/L)	NO_3^- Conc. Chamber 3 Irrigation (mg/L)
6/3/2004	0.34	3.00	0.03	0.03	0.03
6/4/2004	0.34	3.00	0.03	0.03	0.03
6/5/2004	0.23	2.00	0.03	0.03	0.03
6/8/2004	0.34	3.00	0.03	0.03	0.03
6/9/2004	0.34	3.00	0.03	0.03	0.03
6/13/2004	0.43	3.80	1.00	2.00	0.03
6/17/2004	0.43	3.80	1.02	2.02	0.02
6/24/2004	0.43	3.80	1.03	2.03	0.03
6/27/2004	0.43	3.80	1.02	2.02	0.02
7/1/2004	0.36	3.20	1.04	2.04	0.04
7/8/2004	0.36	3.20	1.02	2.02	0.02

Date	Irrigation Amount per Chamber (in)	Irrigation Amount per Chamber (L)	NO_3^- Conc. Chamber 1 Irrigation (mg/L)	NO_3^- Conc. Chamber 2 Irrigation (mg/L)	NO_3^- Conc. Chamber 3 Irrigation (mg/L)
7/14/2004	0.36	3.20	1.01	2.02	0.01
7/18/2004	0.36	3.20	1.02	2.02	0.02
7/22/2004	0.36	3.20	1.03	2.03	0.03
7/29/2004	0.36	3.20	1.02	2.02	0.02
8/1/2004	0.59	5.20	1.01	2.01	0.01
8/8/2004	0.59	5.20	1.04	2.04	0.04
8/22/2004	0.41	3.60	1.02	2.02	0.02
8/29/2004	0.41	3.60	1.04	2.04	0.04
9/12/2004	0.34	3.00	1.01	2.02	0.01
9/19/2004	0.34	3.00	1.02	2.02	0.02
10/7/2004	0.34	3.00	1.02	2.02	0.02
10/10/2004	0.34	3.00	1.03	2.03	0.03
10/17/2004	0.34	3.00	1.02	2.02	0.02
10/21/2004	0.34	3.00	1.03	2.03	0.03
10/24/2004	0.28	2.50	1.03	2.03	0.03
11/1/2004	0.34	3.00	1.03	2.03	0.03
11/4/2004	0.28	2.50	1.02	2.02	0.02
11/7/2004	0.28	2.50	1.02	2.02	0.02
11/18/2004	0.28	2.50	1.02	2.02	0.02
11/21/2004	0.28	2.50	1.02	2.02	0.02
11/24/2004	0.28	2.50	1.02	2.02	0.02
12/2/2004	0.23	2.00	1.02	2.02	0.02
12/5/2004	0.23	2.00	1.03	2.03	0.03
12/9/2004	0.23	2.00	1.03	2.03	0.03
12/12/2004	0.23	2.00	1.02	2.02	0.02
12/16/2004	0.23	2.00	1.02	2.02	0.02
12/19/2004	0.23	2.00	1.02	2.02	0.02
12/22/2004	0.23	2.00	1.02	2.02	0.02
12/30/2004	0.23	2.00	1.02	2.02	0.02
1/2/2005	0.23	2.00	1.02	2.02	0.02
1/5/2005	0.23	2.00	1.02	2.02	0.02
1/9/2005	0.23	2.00	1.02	2.02	0.02
1/13/2005	0.23	2.00	1.02	2.02	0.02
1/20/2005	0.23	2.00	1.00	2.00	0.03
1/23/2005	0.23	2.00	1.00	2.00	0.03
1/27/2005	0.23	2.00	1.00	2.00	0.03
1/30/2005	0.23	2.00	1.00	2.00	0.03
2/6/2005	0.23	2.00	1.00	2.00	0.02

Date	Irrigation Amount per Chamber (in)	Irrigation Amount per Chamber (L)	NO_3^- Conc. Chamber 1 Irrigation (mg/L)	NO_3^- Conc. Chamber 2 Irrigation (mg/L)	NO_3^- Conc. Chamber 3 Irrigation (mg/L)
2/10/2005	0.23	2.00	1.00	2.00	0.02
2/13/2005	0.23	2.00	1.00	2.00	0.02
2/17/2005	0.23	2.00	1.00	2.00	0.02
2/20/2005	0.23	2.00	1.00	2.00	0.02
3/3/2005	0.23	2.00	1.00	2.00	0.00
3/7/2005	0.23	2.00	1.00	2.00	0.02
3/13/2005	0.23	2.00	1.00	2.00	0.01
3/17/2005	0.23	2.00	1.00	2.00	0.00
3/20/2005	0.23	2.00	1.02	2.02	0.02
3/27/2005	0.28	2.50	1.01	2.01	0.01
4/3/2005	0.32	2.80	1.00	2.00	0.00
4/6/2005	0.32	2.80	1.01	2.01	0.01
4/10/2005	0.32	2.80	1.00	2.00	0.00
4/14/2005	0.32	2.80	1.00	2.00	0.00
4/17/2005	0.32	2.80	1.00	2.00	0.00
4/21/2005	0.32	2.80	1.00	2.00	0.00
4/24/2005	0.32	2.80	1.00	2.00	0.00
4/28/2005	0.33	2.90	1.00	2.00	0.00
5/8/2005	0.59	5.20	1.00	2.00	0.00
5/12/2005	0.59	5.20	1.00	2.00	0.00
5/19/2005	0.59	5.20	1.00	2.00	0.00
5/26/2005	0.59	5.20	1.00	2.00	0.00
5/30/2005	0.59	5.20	1.00	2.00	0.00

Table 21 - Chamber 1 Soil Moisture Data

Date	Root Zone 1 (%)	Root Zone 2 (%)	Root Zone 3 (%)	Root Zone Average (%)	Soil 1 (%)	Soil 2 (%)	Soil 3 (%)	Soil Average (%)
6/2/2004	96.5	96.2	96.4	96.4	96.3	96.0	95.0	95.8
6/3/2004	96.3	96.1	96.1	96.2	96.1	95.8	94.8	95.6
6/4/2004	96.8	96.3	96.6	96.6	96.3	96.1	95.3	95.9
6/5/2004	97.4	97.7	97.5	97.5	96.4	96.2	95.5	96.0
6/6/2004	97.5	97.8	97.6	97.6	96.3	96.3	95.6	96.1
6/7/2004	97.2	96.5	97.0	96.9	96.4	96.2	95.8	96.1
6/8/2004	98.0	97.2	97.6	97.6	97.0	97.1	96.6	96.9
6/9/2004	97.2	96.6	97.0	96.9	96.6	96.7	96.5	96.6
6/10/2004	97.0	96.3	96.6	96.6	96.4	96.6	97.0	96.7
6/11/2004	96.8	96.6	96.8	96.7	96.8	97.2	97.4	97.1
6/12/2004	96.9	96.6	96.8	96.8	96.7	97.5	97.6	97.3
6/13/2004	96.7	96.5	96.6	96.6	96.6	97.4	97.4	97.1
6/14/2004	96.7	96.6	96.6	96.6	96.8	97.5	97.5	97.3
6/15/2004	96.7	96.6	96.7	96.7	97.0	97.5	97.4	97.3
6/16/2004	96.6	96.5	96.6	96.6	97.1	97.5	97.5	97.4
6/17/2004	96.6	96.6	96.7	96.6	97.4	97.5	97.4	97.4
6/18/2004	96.4	96.4	96.6	96.5	97.4	97.4	97.4	97.4
6/19/2004	96.6	96.6	96.8	96.7	97.6	97.6	97.5	97.6
6/20/2004	96.5	96.6	96.8	96.6	97.7	97.7	97.6	97.7
6/21/2004	96.4	96.5	96.6	96.5	97.5	97.5	97.6	97.5
6/22/2004	96.3	96.4	96.5	96.4	97.5	97.5	97.6	97.5
6/23/2004	96.4	96.5	96.6	96.5	97.5	97.6	97.7	97.6
6/24/2004	96.5	96.6	96.7	96.6	97.6	97.6	97.8	97.7
6/25/2004	96.3	96.4	96.5	96.4	97.5	97.3	97.5	97.4
6/26/2004	96.6	96.6	96.9	96.7	97.9	97.7	98.0	97.9

Date	Root Zone 1 (%)	Root Zone 2 (%)	Root Zone 3 (%)	Root Zone Average (%)	Soil 1 (%)	Soil 2 (%)	Soil 3 (%)	Soil Average (%)
6/27/2004	96.7	96.7	96.8	96.7	97.8	97.7	97.9	97.8
6/28/2004	96.6	96.8	96.7	96.7	97.6	97.7	97.9	97.7
6/29/2004	96.9	96.9	97.0	96.9	97.7	97.7	97.9	97.8
6/30/2004	96.9	96.9	96.9	96.9	97.5	97.7	97.8	97.7
7/1/2004	96.8	96.9	96.9	96.9	97.7	97.8	97.9	97.8
7/2/2004	96.2	96.3	96.4	96.3	97.1	97.3	97.3	97.2
7/3/2004	96.5	96.5	96.5	96.5	97.4	97.5	97.6	97.5
7/4/2004	96.5	96.3	96.4	96.4	97.2	97.3	97.3	97.3
7/5/2004	96.4	96.3	96.5	96.4	97.1	97.2	97.3	97.2
7/6/2004	96.5	96.5	96.5	96.5	97.2	97.3	97.2	97.2
7/7/2004	96.4	96.5	96.6	96.5	97.0	97.2	97.3	97.2
7/8/2004	96.4	96.5	96.6	96.5	97.2	97.4	97.3	97.3
7/9/2004	96.4	96.3	96.5	96.4	97.0	97.2	97.2	97.1
7/10/2004	96.5	96.5	96.7	96.6	97.2	97.3	97.4	97.3
7/11/2004	96.5	96.3	96.6	96.5	97.1	97.3	97.2	97.2
7/12/2004	96.3	96.3	96.4	96.3	97.0	97.2	97.2	97.1
7/13/2004	96.4	96.3	96.4	96.4	96.9	97.2	97.1	97.1
7/14/2004	96.4	96.3	96.4	96.4	96.9	97.2	97.0	97.0
7/15/2004	96.3	96.3	96.4	96.3	96.9	97.1	96.9	97.0
7/16/2004	96.5	96.5	96.6	96.5	97.0	97.2	97.0	97.1
7/17/2004	96.8	96.7	96.8	96.8	97.3	97.5	97.5	97.4
7/18/2004	96.5	96.4	96.5	96.5	96.9	97.2	97.1	97.1
7/19/2004	96.3	96.3	96.4	96.3	96.9	97.1	97.0	97.0
7/20/2004	96.3	96.2	96.4	96.3	96.9	97.1	97.0	97.0
7/21/2004	96.4	96.3	96.4	96.4	96.9	97.1	97.0	97.0
7/22/2004	96.3	96.3	96.4	96.3	96.9	97.1	97.0	97.0
7/23/2004	96.6	96.5	96.7	96.6	97.0	97.3	97.4	97.2
7/24/2004	96.4	96.2	96.3	96.3	96.8	97.1	97.0	97.0

Date	Root Zone 1 (%)	Root Zone 2 (%)	Root Zone 3 (%)	Root Zone Average (%)	Soil 1 (%)	Soil 2 (%)	Soil 3 (%)	Soil Average (%)
7/25/2004	96.3	96.2	96.4	96.3	97.1	97.1	96.9	97.0
7/26/2004	96.6	96.5	96.7	96.6	96.9	97.4	97.2	97.2
7/27/2004	96.5	96.4	96.6	96.5	96.8	97.2	97.1	97.0
7/28/2004	96.4	96.3	96.5	96.4	96.8	97.1	97.0	97.0
7/29/2004	96.4	96.2	96.4	96.3	96.8	97.1	96.9	96.9
7/30/2004	96.3	96.1	96.4	96.3	96.8	97.1	97.0	97.0
7/31/2004	96.6	96.3	96.5	96.5	96.8	97.1	97.0	97.0
8/1/2004	96.5	96.4	96.5	96.5	96.9	97.1	97.0	97.0
8/2/2004	96.6	96.4	96.5	96.5	96.8	97.0	96.9	96.9
8/4/2004	96.4	96.2	96.3	96.3	96.7	96.9	96.8	96.8
8/5/2004	96.6	96.3	96.5	96.5	96.7	96.9	96.9	96.8
8/7/2004	96.5	96.4	96.5	96.5	96.9	97.1	96.9	97.0
8/8/2004	96.5	96.3	96.4	96.4	96.8	97.0	96.9	96.9
8/9/2004	96.4	96.2	96.4	96.3	96.9	97.1	96.9	97.0
8/10/2004	96.5	96.4	96.5	96.5	96.8	97.0	96.9	96.9
8/11/2004	96.6	96.3	96.4	96.4	96.7	96.9	96.7	96.8
8/12/2004	96.5	96.4	96.5	96.5	96.8	97.0	96.9	96.9
8/13/2004	96.6	96.4	96.6	96.5	96.8	97.1	97.0	97.0
8/14/2004	96.5	96.2	96.4	96.4	96.7	97.0	96.7	96.8
8/15/2004	96.4	96.2	96.3	96.3	96.7	97.0	96.7	96.8
8/16/2004	96.3	96.1	96.3	96.2	96.5	96.8	96.7	96.7
8/17/2004	96.3	96.2	96.4	96.3	96.5	96.7	96.7	96.6
8/18/2004	96.4	96.2	96.3	96.3	96.5	96.8	96.6	96.6
8/19/2004	96.3	96.2	96.3	96.3	96.5	96.8	96.6	96.6
8/20/2004	96.5	96.2	96.4	96.4	96.5	96.8	96.7	96.7
8/22/2004	96.5	96.2	96.4	96.4	96.6	96.9	96.7	96.7
8/23/2004	96.4	96.2	96.4	96.3	96.6	96.9	96.7	96.7
8/24/2004	96.4	96.2	96.3	96.3	96.5	96.8	96.6	96.6

Date	Root Zone 1 (%)	Root Zone 2 (%)	Root Zone 3 (%)	Root Zone Average (%)	Soil 1 (%)	Soil 2 (%)	Soil 3 (%)	Soil Average (%)
8/25/2004	96.4	96.1	96.3	96.3	96.5	96.8	96.6	96.6
8/26/2004	96.6	96.2	96.2	96.3	96.6	96.9	96.7	96.7
8/27/2004	96.5	96.1	96.3	96.3	96.5	96.8	96.6	96.6
8/28/2004	96.4	96.2	96.4	96.3	96.6	96.8	96.6	96.7
8/29/2004	96.5	96.4	96.5	96.5	96.6	97.1	96.9	96.9
8/30/2004	96.5	96.2	96.4	96.4	96.5	96.8	96.5	96.6
8/31/2004	96.5	96.2	96.3	96.3	96.6	96.8	96.6	96.7
9/7/2004	97.0	97.0	97.0	97.0	97.0	97.4	96.5	97.0
9/13/2004	96.4	96.3	96.3	96.3	96.4	96.6	96.5	96.5
9/17/2004	96.4	96.0	96.1	96.2	96.3	96.5	96.3	96.4
9/22/2004	96.3	96.2	96.2	96.2	96.5	96.7	96.5	96.6
9/30/2004	96.2	95.9	96.0	96.0	96.2	96.4	96.2	96.3
10/5/2004	96.3	96.2	95.9	96.1	96.4	96.7	96.4	96.5
10/8/2004	96.5	96.1	93.5	95.4	96.4	96.7	96.4	96.5
10/13/2004	96.4	96.0	96.3	96.2	96.4	96.8	96.4	96.5
10/17/2004	96.3	95.9	96.1	96.1	96.4	96.7	96.5	96.5
10/21/2004	96.3	96.0	96.2	96.2	96.4	96.6		96.5
10/24/2004	96.3	95.9	96.1	96.1	96.3	96.6		96.5
10/27/2004	96.2	95.8	96.1	96.0	96.4	96.6		96.5
11/1/2004	96.5	95.8	96.0	96.1	96.3	96.5		96.4
11/8/2004	96.1	95.6	95.9	95.9	96.3	96.6		96.5
11/11/2004	96.1	95.6	95.9	95.9	96.2	96.5		96.4
11/15/2004	96.1	95.6	95.9	95.9	96.2	96.5		96.4
11/19/2004	96.1	95.6	95.9	95.9	96.3	96.5		96.4
11/24/2004	96.2	95.7	96.0	96.0	96.3	96.4		96.4
11/29/2004	96.1	95.7	96.0	95.9	96.4	96.6		96.5
12/2/2004	96.2	95.8	96.2	96.1	96.4	96.6		96.5
12/5/2004	96.0	95.4	95.8	95.7	96.2	96.5	96.2	96.3

Date	Root Zone 1 (%)	Root Zone 2 (%)	Root Zone 3 (%)	Root Zone Average (%)	Soil 1 (%)	Soil 2 (%)	Soil 3 (%)	Soil Average (%)
12/8/2004	96.3	95.8	96.2	96.1	96.5	96.6	96.4	96.5
12/10/2004	96.3	95.8	96.1	96.1	96.5	96.6	96.3	96.5
12/14/2004	96.1	95.4	95.4	95.6	96.1	96.3	96.2	96.2
12/17/2004	95.8	96.2	95.5	95.8	95.9	96.2	95.9	96.0
12/19/2004	96.0	95.3	95.7	95.7	96.0	96.3	96.1	96.1
12/22/2004	96.5	95.1	95.4	95.7	95.3	95.2	96.0	95.5
12/26/2004	95.6	95.2	95.4	95.4	95.9	96.2	95.9	96.0
12/30/2004	95.9	95.3	95.5	95.6	95.9	96.2	96.0	96.0
1/10/2005	96.3	95.7	95.8	95.9	96.2	96.5	96.2	96.3
1/11/2005	96.2	95.7	95.9	95.9	96.1	96.5	96.1	96.2
1/13/2005	96.2	95.7	96.0	96.0	96.2	96.5	96.2	96.3
1/16/2005	95.8	95.7	95.9	95.8	96.1	96.4	96.1	96.2
1/18/2005	95.3	95.2	95.4	95.3	95.8	96.1	95.9	95.9
1/20/2005	95.4	95.2	95.4	95.3	95.8	96.1	95.8	95.9
1/23/2005	96.0	95.6	95.8	95.8	96.0	96.3	95.9	96.1
1/25/2005	95.5	95.1	95.3	95.3	95.6	96.0	95.7	95.8
1/30/2005	96.1	95.5	95.1	95.6	96.0	96.3	95.9	96.1
2/3/2005	95.9	95.5	95.7	95.7	96.0	96.3	96.0	96.1
2/6/2005	95.9	95.3	95.6	95.6	96.2	96.2	95.9	96.1
2/10/2005	96.0	95.4	95.7	95.7	96.1	96.3	96.0	96.1
2/13/2005	95.9	95.1	95.4	95.5	95.9	96.2	95.9	96.0
2/15/2005	95.8	95.4	95.6	95.6	95.9	96.3	96.0	96.1
2/20/2005	95.9	95.4	95.6	95.6	95.9	96.3	96.1	96.1
2/22/2005	96.2	95.5	95.9	95.9	96.1	96.4	96.1	96.2
2/24/2005	96.1	95.7	95.9	95.9	96.2	96.5	96.1	96.3
2/28/2005	96.1	95.9	96.0	96.0	96.2	96.5	96.2	96.3
3/3/2005	95.8	95.4	95.6	95.6	96.0	96.3	96.0	96.1
3/8/2005	96.0	95.5	95.8	95.8	96.1	96.4	96.0	96.2

Date	Root Zone 1 (%)	Root Zone 2 (%)	Root Zone 3 (%)	Root Zone Average (%)	Soil 1 (%)	Soil 2 (%)	Soil 3 (%)	Soil Average (%)
3/15/2005	96.0	95.6	95.8	95.8	96.1	96.4	96.1	96.2
3/18/2005	96.0	95.8	95.9	95.9	96.2	96.4	96.1	96.2
3/21/2005	96.1	95.8	95.8	95.9	95.9	96.4	96.1	96.1
3/24/2005	96.0	96.0	96.0	96.0	96.1	96.4	96.2	96.2
3/27/2005	96.3	95.8	96.0	96.0	96.2	96.4	96.1	96.2
3/31/2005	96.1	95.6	95.9	95.9	96.1	96.4	96.1	96.2
4/4/2005	96.2	95.7	95.9	95.9	96.3	96.5	96.2	96.3
4/7/2005	96.4	95.7	96.0	96.0	96.2	96.5	96.3	96.3
4/10/2005	96.3	95.9	96.1	96.1	96.4	96.5	96.4	96.4
4/14/2005	96.2	95.8	96.1	96.0	96.3	96.6	96.4	96.4
4/19/2005	96.2	95.7	96.1	96.0	96.2	96.6	96.3	96.4
4/22/2005	96.3	95.9	96.2	96.1	96.5	96.7	96.5	96.6
4/27/2005	96.4	95.9	96.2	96.2	96.6	96.8	96.6	96.7
5/1/2005	96.6	96.0	96.1	96.2	96.3	96.6	96.3	96.4
5/4/2005	96.5	96.0	96.2	96.2	96.5	96.7	96.5	96.6
5/8/2005	96.5	95.9	96.1	96.2	96.4	96.6	96.4	96.5
5/12/2005	96.6	96.1	96.3	96.3	96.4	96.7	96.5	96.5
5/15/2005	96.4	96.0	96.2	96.2	96.5	96.8	96.6	96.6
5/19/2005	96.4	96.0	96.2	96.2	96.3	96.5	96.3	96.4
5/24/2005	96.8	96.2	96.3	96.4	96.5	96.8	96.6	96.6
6/1/2005	96.8	96.2	96.3	96.4	96.5	96.8	96.6	96.6

Table 22 - Chamber 2 Soil Moisture Data

Date	Root Zone 1 (%)	Root Zone 2 (%)	Root Zone 3 (%)	Root Zone Average (%)	Soil 1 (%)	Soil 2 (%)	Soil 3 (%)	Soil Average (%)
6/2/2004	96.9	96.6	96.8	96.8	97.2	97.0	96.8	97.0
6/3/2004	96.6	96.3	96.4	96.4	96.8	96.9	96.5	96.7
6/4/2004	97.1	96.7	96.7	96.8	97.0	97.1	96.6	96.9
6/5/2004	97.0	97.9	97.3	97.4	97.1	97.1	96.5	96.9
6/6/2004	97.2	97.7	97.5	97.5	97.0	97.1	96.6	96.9
6/7/2004	96.9	97.1	96.8	96.9	97.0	97.1	97.1	97.1
6/8/2004	97.4	97.7	97.4	97.5	97.6	98.5	98.1	98.1
6/9/2004	96.9	97.1	96.9	97.0	97.3	98.1	97.8	97.7
6/10/2004	96.7	96.9	96.7	96.8	97.2	98.0	97.6	97.6
6/11/2004	96.7	97.0	96.8	96.8	97.6	98.1	98.0	97.9
6/12/2004	96.8	96.9	96.7	96.8	97.7	98.0	97.7	97.8
6/13/2004	96.7	96.8	96.6	96.7	97.6	97.8	97.6	97.7
6/14/2004	96.8	96.9	96.7	96.8	97.8	97.8	97.7	97.8
6/15/2004	96.8	96.9	96.8	96.8	97.9	97.8	97.7	97.8
6/16/2004	96.7	97.0	96.8	96.8	97.8	97.8	97.6	97.7
6/17/2004	96.8	96.9	96.9	96.9	97.9	97.8	97.8	97.8
6/18/2004	96.9	96.8	96.7	96.8	97.9	97.7	97.6	97.7
6/19/2004	96.9	96.9	96.7	96.8	98.0	97.6	97.7	97.8
6/20/2004	96.9	97.0	96.9	96.9	98.1	97.7	97.7	97.8
6/21/2004	96.6	96.9	96.6	96.7	98.0	97.6	97.7	97.8
6/22/2004	96.5	96.8	96.5	96.6	97.8	97.6	97.5	97.6
6/23/2004	96.7	96.7	96.5	96.6	97.8	97.6	97.5	97.6
6/24/2004	96.8	97.0	96.6	96.8	97.8	97.7	97.5	97.7
6/25/2004	96.6	96.8	96.6	96.7	97.6	97.5	97.3	97.5

Date	Root Zone 1 (%)	Root Zone 2 (%)	Root Zone 3 (%)	Root Zone Average (%)	Soil 1 (%)	Soil 2 (%)	Soil 3 (%)	Soil Average (%)
6/26/2004	96.1	96.9	96.8	96.6	97.9	97.9	97.7	97.8
6/27/2004	96.2	97.0	96.8	96.7	97.9	97.8	97.6	97.8
6/28/2004	96.2	97.0	96.7	96.6	97.8	97.8	97.5	97.7
6/29/2004	96.5	97.1	97.0	96.9	97.8	97.9	97.6	97.8
6/30/2004	96.5	97.0	96.8	96.8	97.5	97.6	97.4	97.5
7/1/2004	96.6	97.0	96.9	96.8	97.7	97.8	97.6	97.7
7/2/2004	96.1	96.6	96.4	96.4	97.2	97.2	97.1	97.2
7/3/2004	96.5	96.7	96.6	96.6	97.5	97.5	97.5	97.5
7/4/2004	96.4	96.7	96.5	96.5	97.3	97.3	97.1	97.2
7/5/2004	96.3	96.6	96.4	96.4	97.3	97.3	97.0	97.2
7/6/2004	96.4	96.7	96.5	96.5	97.2	97.4	97.1	97.2
7/7/2004	96.4	96.7	96.5	96.5	97.2	97.4	97.1	97.2
7/8/2004	96.6	96.9	96.6	96.7	97.4	97.5	97.3	97.4
7/9/2004	96.2	96.6	96.4	96.4	97.2	97.2	97.0	97.1
7/10/2004	94.8	97.0	96.9	96.2	97.3	97.6	97.4	97.4
7/11/2004	94.0	96.8	96.5	95.8	97.2	97.3	97.2	97.2
7/12/2004	95.9	96.6	96.5	96.3	97.3	97.4	97.1	97.3
7/13/2004	95.8	96.6	96.5	96.3	97.2	97.3	97.0	97.2
7/14/2004	95.9	96.7	96.5	96.4	97.1	97.3	96.9	97.1
7/15/2004	95.9	96.6	96.5	96.3	97.0	97.2	96.9	97.0
7/16/2004	96.0	96.8	96.6	96.5	97.1	97.3	97.1	97.2
7/17/2004	96.3	97.1	97.0	96.8	97.5	97.6	97.5	97.5
7/18/2004	95.5	96.7	96.6	96.3	97.1	97.3	97.1	97.2
7/19/2004	96.5	96.7	96.5	96.6	97.1	97.2	97.1	97.1
7/20/2004	96.0	96.7	96.5	96.4	96.9	97.3	97.2	97.1
7/21/2004	96.0	96.7	96.4	96.4	97.0	97.1	97.0	97.0
7/22/2004	95.7	96.5	96.4	96.2	96.7	97.0	96.8	96.8
7/23/2004	95.6	97.2	97.0	96.6	97.3	97.5	97.4	97.4

Date	Root Zone 1 (%)	Root Zone 2 (%)	Root Zone 3 (%)	Root Zone Average (%)	Soil 1 (%)	Soil 2 (%)	Soil 3 (%)	Soil Average (%)
7/24/2004	94.4	96.7	96.6	95.9	96.9	97.0	96.9	96.9
7/25/2004	93.0	96.7	96.5	95.4	96.9	97.0	96.9	96.9
7/26/2004	91.8	96.9	96.8	95.2	97.1	97.2	97.0	97.1
7/27/2004	88.4	96.7	96.8	94.0	97.1	97.1	97.0	97.1
7/28/2004	85.7	96.6	96.7	93.0	96.9	96.9	96.9	96.9
7/29/2004	83.1	96.5	96.6	92.1	96.9	96.9	96.9	96.9
7/30/2004	85.7	96.7	96.7	93.0	96.9	96.9	96.9	96.9
7/31/2004	88.5	96.6	96.7	93.9	96.8	96.8	96.8	96.8
8/1/2004	91.1	96.6	96.7	94.8	96.8	96.8	96.9	96.8
8/2/2004	96.4	96.6	96.5	96.5	96.8	96.8	96.7	96.8
8/4/2004	96.5	96.6	96.6	96.6	96.7	96.8	96.8	96.8
8/5/2004	96.7	96.9	96.8	96.8	96.7	96.8	96.9	96.8
8/7/2004	96.5	96.7	96.6	96.6	96.8	96.8	96.8	96.8
8/8/2004	96.4	96.6	96.4	96.5	96.8	96.8	96.8	96.8
8/9/2004	96.3	96.6	96.5	96.5	96.8	96.8	96.8	96.8
8/10/2004	96.6	96.8	96.7	96.7	96.9	96.9	97.0	96.9
8/11/2004	96.5	96.5	96.6	96.5	96.8	96.7	96.3	96.6
8/12/2004	96.6	96.6	96.6	96.6	97.0	96.9	96.9	96.9
8/13/2004	96.5	96.6	96.4	96.5	96.9	96.7	96.8	96.8
8/14/2004	96.4	96.4	96.3	96.4	96.8	96.8	96.8	96.8
8/15/2004	96.6	96.5	96.5	96.5	96.9	96.7	96.7	96.8
8/16/2004	96.4	96.4	96.3	96.4	96.5	96.7	96.7	96.6
8/17/2004	96.5	96.5	96.5	96.5	96.7	96.7	96.7	96.7
8/18/2004	96.4	96.4	96.4	96.4	96.7	96.6	96.6	96.6
8/19/2004	96.4	96.4	96.3	96.4	96.7	96.7	96.6	96.7
8/20/2004	96.5	96.5	96.4	96.5	96.8	96.7	96.7	96.7
8/22/2004	96.6	96.5	96.4	96.5	96.8	96.9	96.8	96.8
8/23/2004	96.5	96.6	96.5	96.5	96.9	96.9	96.8	96.9

Date	Root Zone 1 (%)	Root Zone 2 (%)	Root Zone 3 (%)	Root Zone Average (%)	Soil 1 (%)	Soil 2 (%)	Soil 3 (%)	Soil Average (%)
8/24/2004	96.4	96.6	96.5	96.5	96.8	96.7	96.7	96.7
8/25/2004	96.6	96.6	96.4	96.5	96.8	96.8	96.7	96.8
8/26/2004	96.5	96.6	96.0	96.4	96.8	96.7	96.8	96.8
8/27/2004	96.6	96.5	96.4	96.5	96.7	96.7	96.7	96.7
8/28/2004	96.5	96.5	96.4	96.5	96.7	96.9	96.8	96.8
8/29/2004	96.8	96.7	96.8	96.8	96.9	97.1	97.0	97.0
8/30/2004	96.5	96.4	96.4	96.4	96.7	96.7	96.7	96.7
8/31/2004	96.5	96.4	96.3	96.4	96.8	96.4	96.6	96.6
9/7/2004			97.2	97.2	97.2	97.2	97.3	97.2
9/13/2004			96.3	96.3	96.6	96.7	96.6	96.6
9/17/2004			96.2	96.2	96.6	96.5	96.5	96.5
9/22/2004			96.2	96.2	96.5	96.7	96.6	96.6
9/30/2004			96.0	96.0	96.3	96.3	96.4	96.3
10/5/2004			96.2	96.2	96.6	96.7	96.8	96.7
10/8/2004			96.1	96.1	96.5	96.7	96.8	96.7
10/13/2004			96.2	96.2	96.5	96.7	96.7	96.6
10/17/2004			96.1	96.1	96.6	96.6	96.6	96.6
10/20/2004			96.1	96.1	96.4	96.6	96.5	96.5
10/24/2004			96.1	96.1	96.5	96.6	96.5	96.5
11/1/2004			96.0	96.0	96.4	96.4	96.4	96.4
11/8/2004			95.9	95.9	96.3	96.4	96.4	96.4
11/11/2004			96.0	96.0	96.3	96.4	96.4	96.4
11/15/2004			95.9	95.9	96.3	96.4	96.3	96.3
11/19/2004			95.9	95.9	96.4	96.5	96.5	96.5
11/24/2004			96.0	96.0	96.3	96.4	96.3	96.3
11/29/2004			95.9	95.9	96.4	96.5	96.5	96.5
12/2/2004			96.1	96.1	96.5	96.5	96.5	96.5
12/5/2004			95.7	95.7	96.3	96.3	96.3	96.3

Date	Root Zone 1 (%)	Root Zone 2 (%)	Root Zone 3 (%)	Root Zone Average (%)	Soil 1 (%)	Soil 2 (%)	Soil 3 (%)	Soil Average (%)
12/8/2004			96.0	96.0	96.5	96.6	96.2	96.4
12/10/2004			96.1	96.1	96.3	96.4	96.4	96.4
12/14/2004			95.6	95.6	96.2	96.2	96.2	96.2
12/17/2004			95.4	95.4	96.0	96.1	96.0	96.0
12/19/2004			95.6	95.6	96.1	96.2	96.2	96.2
12/22/2004			95.4	95.4	95.9	96.0	96.0	96.0
12/26/2004			95.3	95.3	95.8	95.9	95.7	95.8
12/30/2004			95.5	95.5	95.9	96.1	96.0	96.0
1/10/2005			95.9	95.9	96.0	96.2	96.3	96.2
1/11/2005			95.9	95.9	96.2	96.3	96.3	96.3
1/13/2005			96.0	96.0	96.3	96.3	96.1	96.2
1/16/2005			95.7	95.7	96.0	96.1	96.1	96.1
1/18/2005			95.2	95.2	95.8	95.9	95.9	95.9
1/20/2005			95.2	95.2	95.8	95.8	95.8	95.8
1/23/2005			95.5	95.5	96.0	96.0	95.9	96.0
1/25/2005			95.1	95.1	95.7	95.9	95.9	95.8
1/30/2005			95.7	95.7	96.0	96.2	96.2	96.1
2/3/2005			95.6	95.6	96.0	96.1	96.0	96.0
2/6/2005			95.4	95.4	95.9	96.0	96.0	96.0
2/10/2005			95.7	95.7	96.1	96.1	96.1	96.1
2/13/2005			95.4	95.4	95.8	96.1	96.0	96.0
2/15/2005			95.6	95.6	95.9	96.1	96.1	96.0
2/20/2005			95.7	95.7	96.2	96.2	96.2	96.2
2/22/2005			95.9	95.9	96.1	96.3	96.2	96.2
2/24/2005			95.9	95.9	96.2	96.3	96.2	96.2
2/28/2005			96.0	96.0	96.3	96.3	96.3	96.3
3/3/2005			95.5	95.5	96.0	96.2	96.1	96.1
3/8/2005			95.7	95.7	96.1	96.2	96.1	96.1

Date	Root Zone 1 (%)	Root Zone 2 (%)	Root Zone 3 (%)	Root Zone Average (%)	Soil 1 (%)	Soil 2 (%)	Soil 3 (%)	Soil Average (%)
3/15/2005			95.8	95.8	96.1	96.1	96.1	96.1
3/18/2005			95.8	95.8	96.1	96.1	96.1	96.1
3/21/2005			95.8	95.8	96.1	96.2	96.1	96.1
3/24/2005			96.0	96.0	96.1	96.3	96.2	96.2
3/27/2005			96.0	96.0	96.3	96.3	96.3	96.3
3/31/2005			95.9	95.9	96.1	96.3	96.3	96.2
4/4/2005			96.0	96.0	96.3	96.5	96.3	96.4
4/7/2005			96.0	96.0	96.3	96.3	96.4	96.3
4/10/2005			96.1	96.1	96.4	96.4	96.4	96.4
4/14/2005			96.0	96.0	96.4	96.4	96.5	96.4
4/19/2005			96.1	96.1	96.3	96.4	96.4	96.4
4/22/2005			96.2	96.2	96.6	96.6	96.7	96.6
4/27/2005			96.5	96.5	96.8	95.8	96.7	96.4
5/1/2005			96.3	96.3	96.3	95.8	96.3	96.1
5/4/2005			96.3	96.3	96.3	96.6	96.6	96.5
5/8/2005			96.4	96.4	96.6	96.7	96.6	96.6
5/12/2005			96.4	96.4	96.6	96.6	96.5	96.6
5/15/2005			96.3	96.3	96.5	96.3	96.5	96.4
5/19/2005			96.3	96.3	96.4	96.5	96.5	96.5
5/25/2005			96.6	96.6	96.7	96.7	96.8	96.7
6/1/2005			96.6	96.6	96.7	96.7	96.8	96.7

Table 23 - Chamber 3 Soil Moisture Data

Date	Root Zone 1 (%)	Root Zone 2 (%)	Root Zone 3 (%)	Root Zone Average (%)	Soil 1 (%)	Soil 2 (%)	Soil 3 (%)	Soil Average (%)
6/2/2004	96.9	96.7	97.0	96.9	96.8	95.4	97.3	96.5
6/3/2004	96.7	96.3	96.7	96.6	96.6	95.3	97.1	96.3
6/4/2004	97.0	96.7	96.9	96.9	96.8	95.7	97.2	96.6
6/5/2004	98.1	98.1	97.7	98.0	96.9	95.9	97.1	96.6
6/6/2004	98.0	98.1	97.6	97.9	96.8	96.1	97.0	96.6
6/7/2004	97.1	97.2	97.4	97.2	97.0	97.6	97.9	97.5
6/8/2004	97.7	97.5	97.8	97.7	97.8	98.1	98.7	98.2
6/9/2004	97.1	97.0	97.3	97.1	97.6	97.8	98.4	97.9
6/10/2004	96.9	96.8	97.1	96.9	97.5	97.5	98.0	97.7
6/11/2004	97.1	97.0	97.1	97.1	98.0	97.8	98.4	98.1
6/12/2004	97.1	96.8	97.1	97.0	97.8	97.6	98.2	97.9
6/13/2004	97.0	96.9	96.9	96.9	97.6	97.4	98.2	97.7
6/14/2004	97.0	96.9	96.9	96.9	97.6	97.4	98.0	97.7
6/15/2004	96.9	96.8	97.0	96.9	97.7	97.4	98.0	97.7
6/16/2004	97.0	97.0	96.9	97.0	97.8	97.3	98.0	97.7
6/17/2004	97.1	97.0	97.0	97.0	97.8	97.5	98.1	97.8
6/18/2004	96.9	96.8	97.0	96.9	97.6	97.3	97.9	97.6
6/19/2004	97.0	97.0	97.2	97.1	97.7	97.4	97.8	97.6
6/20/2004	97.2	97.0	97.2	97.1	97.8	97.5	98.1	97.8
6/21/2004	97.0	96.8	96.9	96.9	97.7	97.6	98.0	97.8
6/22/2004	96.8	96.7	96.7	96.7	97.5	97.4	97.8	97.6
6/23/2004	96.9	96.8	96.8	96.8	97.6	97.4	97.8	97.6
6/24/2004	97.0	97.0	97.0	97.0	97.6	97.6	97.7	97.6

Date	Root Zone 1 (%)	Root Zone 2 (%)	Root Zone 3 (%)	Root Zone Average (%)	Soil 1 (%)	Soil 2 (%)	Soil 3 (%)	Soil Average (%)
6/25/2004	96.9	96.8	96.9	96.9	97.3	97.4	97.6	97.4
6/26/2004	97.1	97.0	97.1	97.1	97.9	97.9	98.0	97.9
6/27/2004	97.0	97.0	97.0	97.0	97.6	97.6	98.0	97.7
6/28/2004	97.0	96.9	96.8	96.9	97.6	97.6	97.8	97.7
6/29/2004	97.1	97.0	97.1	97.1	97.7	97.6	98.0	97.8
6/30/2004	96.9	96.9	96.9	96.9	97.4	97.4	97.7	97.5
7/1/2004	97.0	97.0	97.1	97.0	97.6	97.5	97.8	97.6
7/2/2004	96.7	96.6	96.7	96.7	97.2	97.1	97.3	97.2
7/3/2004	96.9	96.9	96.9	96.9	97.5	97.4	97.7	97.5
7/4/2004	96.8	96.7	96.9	96.8	97.3	97.4	97.6	97.4
7/5/2004	96.7	96.6	96.8	96.7	97.2	97.1	97.4	97.2
7/6/2004	96.7	96.7	96.7	96.7	97.1	97.0	97.3	97.1
7/7/2004	96.7	96.6	96.8	96.7	97.1	97.0	97.4	97.2
7/8/2004	97.0	97.0	97.1	97.0	97.4	97.2	97.5	97.4
7/9/2004	96.7	96.7	96.8	96.7	97.1	97.1	97.4	97.2
7/10/2004	97.1	97.0	97.1	97.1	97.3	97.3	97.6	97.4
7/11/2004	96.7	96.5	96.9	96.7	97.2	97.1	97.2	97.2
7/12/2004	96.8	96.6	96.9	96.8	97.2	97.2	97.5	97.3
7/13/2004	96.6	96.6	96.8	96.7	97.1	97.2	97.4	97.2
7/14/2004	96.6	96.6	96.8	96.7	97.0	97.0	97.3	97.1
7/15/2004	96.6	96.7	96.8	96.7	97.0	96.9	97.2	97.0
7/16/2004	97.0	96.9	96.9	96.9	97.1	97.1	97.3	97.2
7/17/2004	97.2	97.2	97.3	97.2	97.5	97.4	97.7	97.5
7/18/2004	96.8	96.8	97.0	96.9	97.1	97.0	97.4	97.2
7/19/2004	96.8	96.8	96.9	96.8	96.9	97.0	97.2	97.0
7/20/2004	96.9	96.9	96.9	96.9	96.9	97.1	97.3	97.1
7/21/2004	96.7	96.7	96.8	96.7	96.9	96.8	97.1	96.9
7/22/2004	96.7	96.6	96.7	96.7	96.7	96.8	97.1	96.9

Date	Root Zone 1 (%)	Root Zone 2 (%)	Root Zone 3 (%)	Root Zone Average (%)	Soil 1 (%)	Soil 2 (%)	Soil 3 (%)	Soil Average (%)
7/23/2004	97.3	97.2	97.3	97.3	97.4	97.4	97.7	97.5
7/24/2004	96.9	96.7	96.9	96.8	97.0	97.0	97.2	97.1
7/25/2004	96.7	96.7	96.8	96.7	97.0	96.9	97.2	97.0
7/26/2004	97.0	96.8	97.0	96.9	97.1	97.2	97.3	97.2
7/27/2004	97.0	96.9	97.0	97.0	97.1	97.1	97.4	97.2
7/28/2004	96.7	96.7	96.8	96.7	96.9	96.9	97.2	97.0
7/29/2004	97.0	96.8	97.0	96.9	97.1	97.0	97.4	97.2
7/30/2004	96.9	96.8	96.9	96.9	97.0	97.0	97.2	97.1
7/31/2004	97.0	96.7	96.9	96.9	96.8	96.8	97.0	96.9
8/1/2004	96.9	96.8	96.9	96.9	96.8	96.9	97.1	96.9
8/2/2004	96.7	96.6	96.6	96.6	96.8	96.8	97.0	96.9
8/4/2004	96.8	96.7	96.8	96.8	96.8	96.7	97.1	96.9
8/5/2004	97.0	96.9	97.0	97.0	97.1	97.0	97.3	97.1
8/7/2004	96.8	96.6	96.8	96.7	96.8	96.8	96.9	96.8
8/8/2004	96.8	96.7	96.8	96.8	96.7	96.8	97.0	96.8
8/9/2004	96.8	96.6	96.8	96.7	96.9	96.9	97.0	96.9
8/10/2004	96.9	96.8	96.9	96.9	97.1	97.1	97.2	97.1
8/11/2004	96.8	96.7	96.7	96.7	96.8	97.0	97.2	97.0
8/12/2004	97.0	96.6	96.9	96.8	96.9	97.1	97.2	97.1
8/13/2004	96.9	96.6	96.7	96.7	96.9	97.0	97.2	97.0
8/14/2004	96.7	96.5	96.5	96.6	96.8	96.8	96.7	96.8
8/15/2004	96.8	96.4	96.6	96.6	96.9	97.0	97.0	97.0
8/16/2004	96.7	96.5	96.5	96.6	96.7	96.8	97.0	96.8
8/17/2004	96.9	96.7	96.7	96.8	96.8	96.9	97.0	96.9
8/18/2004	96.8	96.5	96.6	96.6	96.7	96.8	96.8	96.8
8/19/2004	96.7	96.5	96.6	96.6	96.8	96.8	97.0	96.9
8/20/2004	96.8	96.6	96.7	96.7	96.9	96.8	97.1	96.9
8/22/2004	96.8	96.5	96.7	96.7	96.9	96.9	97.1	97.0

Date	Root Zone 1 (%)	Root Zone 2 (%)	Root Zone 3 (%)	Root Zone Average (%)	Soil 1 (%)	Soil 2 (%)	Soil 3 (%)	Soil Average (%)
8/23/2004	96.8	96.6	96.6	96.7	96.8	96.9	97.1	96.9
8/24/2004	96.9	96.6	96.6	96.7	96.8	96.9	96.9	96.9
8/25/2004	96.7	96.5	96.5	96.6	96.7	96.8	97.1	96.9
8/26/2004	96.8	96.6	96.7	96.7	96.9	96.9	97.1	97.0
8/27/2004	96.7	96.5	96.5	96.6	96.7	96.7	97.0	96.8
8/28/2004	96.8	96.5	96.6	96.6	96.9	97.0	97.2	97.0
8/29/2004	97.1	96.9	96.9	97.0	97.1	97.0	97.3	97.1
8/30/2004	96.7	96.5	96.5	96.6	96.7	96.8	97.0	96.8
8/31/2004	96.6	96.4	96.4	96.5	96.6	96.8	96.8	96.7
9/7/2004	87.0	97.3	96.9	93.7	97.2	97.3	97.4	97.3
9/13/2004	96.8	96.5	96.5	96.6	96.7	96.9	97.0	96.9
9/17/2004	97.0	96.9	96.6	96.8	96.9	97.0	97.3	97.1
9/22/2004	96.6	96.5	96.5	96.5	96.7	96.8	96.9	96.8
9/30/2004	96.4	96.3	96.2	96.3	96.3	96.4	96.6	96.4
10/5/2004	96.5	96.3	96.3	96.4	96.6	96.7	96.8	96.7
10/8/2004	96.6	96.3	96.3	96.4	96.6	96.8	96.9	96.8
10/13/2004	96.6	96.3	96.4	96.4	96.7	96.9	97.0	96.9
10/17/2004	96.4	96.1	96.2	96.2	96.7	96.9	96.9	96.8
10/20/2004	96.4	96.1	96.1	96.2	96.5	96.7	96.7	96.6
10/24/2004	96.3	96.1	96.1	96.2	96.6	96.7	96.9	96.7
10/27/2004	96.2	95.9	96.0	96.0	96.4	96.6	96.7	96.6
11/1/2004	96.2	95.0	96.2	95.8	96.5	96.6	96.7	96.6
11/8/2004	96.0	95.8	95.8	95.9	96.1	96.5	96.6	96.4
11/11/2004	96.2	95.9	96.0	96.0	96.3	96.6	96.7	96.5
11/15/2004	96.1	95.9	96.0	96.0	96.4	96.6	96.8	96.6
11/19/2004	96.1	95.9	96.0	96.0	96.5	96.6	96.8	96.6
11/24/2004	96.3	96.1	96.1	96.2	96.4	96.6	96.8	96.6
11/29/2004	96.2	95.9	96.0	96.0	96.6	96.8	96.8	96.7

Date	Root Zone 1 (%)	Root Zone 2 (%)	Root Zone 3 (%)	Root Zone Average (%)	Soil 1 (%)	Soil 2 (%)	Soil 3 (%)	Soil Average (%)
12/2/2004	96.3	96.0	96.1	96.1	96.4	96.5	96.7	96.5
12/5/2004	96.0	95.7	95.9	95.9	96.3	96.6	96.8	96.6
12/8/2004	96.3	96.0	96.1	96.1	96.6	96.7	96.9	96.7
12/10/2004	96.2	96.0	96.1	96.1	96.5	96.6	96.6	96.6
12/14/2004	95.8	95.5	95.7	95.7	96.2	96.5	96.6	96.4
12/17/2004	96.6	95.3	95.5	95.8	96.0	96.2	96.3	96.2
12/19/2004	95.9	95.6	95.7	95.7	96.1	96.3	96.4	96.3
12/22/2004	95.7	95.4	95.5	95.5	96.1	96.3	96.5	96.3
12/26/2004	95.5	95.2	95.2	95.3	95.7	96.0	96.0	95.9
12/30/2004	95.8	94.7	95.6	95.4	96.0	96.2	96.3	96.2
1/10/2005	96.3	95.9	95.9	96.0	96.2	96.5	96.5	96.4
1/11/2005	96.3	95.9	96.6	96.3	96.3	96.6	96.6	96.5
1/13/2005	96.2	96.0	96.0	96.1	96.3	96.6	96.6	96.5
1/16/2005	96.0	95.7	95.6	95.8	96.0	96.2	96.2	96.1
1/18/2005	95.6	95.3	95.2	95.4	95.8	95.9	96.1	95.9
1/20/2005	95.6	95.3	95.2	95.4	95.7	95.9	96.0	95.9
1/23/2005	96.0	95.6	95.6	95.7	95.7	96.1	96.2	96.0
1/25/2005	95.1	95.3	95.2	95.2	95.8	95.8	95.9	95.8
1/30/2005	96.1	95.8	95.1	95.7	96.0	96.1	96.4	96.2
2/3/2005	95.9	95.6	95.6	95.7	95.9	96.0	96.2	96.0
2/6/2005	95.7	95.5	95.5	95.6	95.9	96.2	96.3	96.1
2/10/2005	96.0	95.7	95.7	95.8	96.0	96.3	96.4	96.2
2/13/2005	95.8	95.5	95.6	95.6	95.9	96.2	96.2	96.1
2/15/2005	95.9	95.6	95.7	95.7	96.0	96.2	96.3	96.2
2/20/2005	96.0	95.6	95.8	95.8	96.2	96.4	96.4	96.3
2/22/2005	96.1	95.7	95.8	95.9	96.2	96.4	96.4	96.3
2/24/2005	96.2	95.9	95.9	96.0	96.3	96.4	96.4	96.4
2/28/2005	96.3	95.9	96.0	96.1	96.4	96.4	96.5	96.4

Date	Root Zone 1 (%)	Root Zone 2 (%)	Root Zone 3 (%)	Root Zone Average (%)	Soil 1 (%)	Soil 2 (%)	Soil 3 (%)	Soil Average (%)
3/3/2005	95.9	95.6	95.6	95.7	96.0	96.2	96.0	96.1
3/8/2005	96.0	95.8	95.8	95.9	96.2	96.4	96.1	96.2
3/15/2005	96.0	95.7	95.8	95.8	96.1	96.2	96.4	96.2
3/18/2005	96.0	95.6	95.7	95.8	96.1	96.0	96.2	96.1
3/21/2005	96.3	95.9	95.8	96.0	96.1	96.2	96.3	96.2
3/24/2005	96.3	96.0	95.8	96.0	96.2	96.4	96.4	96.3
3/27/2005	96.4	96.1	96.1	96.2	96.3	96.5	96.3	96.4
3/31/2005	96.3	95.9	96.0	96.1	96.2	96.3	96.4	96.3
4/4/2005	96.4	96.1	96.2	96.2	96.3	96.0	96.1	96.1
4/7/2005	96.2	95.9	96.2	96.1	96.2	96.5	96.6	96.4
4/10/2005	96.4	96.1	96.2	96.2	96.3	96.5	96.7	96.5
4/14/2005	96.2	96.1	96.1	96.1	96.2	96.6	96.6	96.5
4/19/2005	96.4	96.0	96.1	96.2	96.2	96.4	96.8	96.5
4/22/2005	96.6	96.2	96.6	96.5	96.3	96.6	96.7	96.5
4/27/2005	96.6	96.5	96.5	96.5	96.7	97.0	97.0	96.9
5/1/2005	96.4	96.2	96.4	96.3	96.3	96.6	96.1	96.3
5/4/2005	96.6	96.1	96.2	96.3	96.4	96.7	96.8	96.6
5/8/2005	96.3	96.2	96.4		96.6	97.0	96.9	
5/12/2005	96.6	96.3	96.6		96.4	96.8	96.7	
5/15/2005	96.5	96.3	96.4		96.4	96.8	96.3	
5/19/2005	96.6	96.3	96.5		96.2	96.7	96.6	
5/25/2005	96.5	96.4	96.7		96.5	96.8		
6/1/2005	96.5	96.4	96.7		96.5	96.8	96.3	

Table 24 - Chamber 1 Filtrate Data

Date	Volume (mL)	NO_3^- + NO_2^- (mg/L)	NO_2- (mg/L)	NH_3 (mg/L)	Alkalinity (mg/L as $CaCO_3$)	pH
6/4/2004	577	0.05	0			
6/5/2004	430	0.06				
6/6/2004	570					
6/7/2004	1825					
6/8/2004	1800	0.05	0			
6/9/2004	1565	0.04				6.90
6/10/2004	2855	0.04				6.43
6/11/2004	1870					6.17
6/12/2004	2865	0.04	0			6.94
6/13/2004	2020					6.63
6/14/2004	2600	0.05				6.63
6/15/2004	2340	0.04				6.58
6/16/2004	2540	0.03	0			6.70
6/17/2004	2490	0.04			420	6.97
6/18/2004	2380	0.04			300	6.65
6/19/2004	1270	0.04	0			6.73
6/20/2004	2330				540	6.80
6/21/2004	4290	0.03			420	6.83
6/22/2004	2660	0.03				6.79
6/23/2004	2490	0.03				
6/24/2004	1360	0.04			800	6.90
6/25/2004	1340	0.04	0		720	6.81
6/26/2004	3690	0.03				6.77
6/27/2004	1900	0.04				6.76
6/28/2004	2980				520	6.77
6/29/2004	1310	0.03				6.93
6/30/2004	1540	0.04				6.93
7/1/2004	1930	0.05				6.83
7/2/2004	1250	0.04				6.75
7/3/2004	1610	0.04				6.69
7/4/2004	3560					6.59
7/5/2004	3440	0.05			320	6.52
7/6/2004	2500	0.04		10.20		6.56
7/7/2004	1670	0.04	0			6.56
7/8/2004	1710	0.03				6.57
7/9/2004	1665	0.03				6.56
7/10/2004	1640	0.05		11.56		6.63
7/11/2004	1730					6.57

Date	Volume (mL)	NO_3^- + NO_2^- (mg/L)	NO_2^- (mg/L)	NH_3 (mg/L)	Alkalinity (mg/L as $CaCO_3$)	pH
7/12/2004	3620	0.03				6.54
7/13/2004	1770	0.03				6.54
7/14/2004	1740	0.03		14.80		6.57
7/15/2004	3095	0.03			400	6.55
7/16/2004	1530	0.04				6.64
7/17/2004	1570	0.03				6.62
7/18/2004	1680	0.03				6.67
7/19/2004	1720	0.03	0	15.00		6.67
7/20/2004	1610	0.02				6.40
7/21/2004	1210	0.03			433	6.68
7/22/2004	1000	0.03		11.90		6.83
7/23/2004	980	0.03				6.88
7/24/2004	865	0.03				6.68
7/25/2004	820	0.03				6.67
7/26/2004	860	0.03		14.30	425	6.63
7/27/2004	850	0.04				6.75
7/28/2004	640					6.91
7/29/2004	500					
7/30/2004	780	0.03		9.01		6.90
7/31/2004	1000	0.03				6.74
8/1/2004	875	0.03				6.80
8/2/2004	1740	0.03				6.59
8/4/2004	620	0.04	0.00	8.23	550	6.71
8/5/2004	910	0.03				6.42
8/7/2004	1800	0.03				6.50
8/8/2004	2000	0.03				6.55
8/9/2004	2000	0.04				6.54
8/10/2004	5730	0.02				6.58
8/11/2004	2880	0.03				6.49
8/12/2004	3575	0.03			600	6.39
8/13/2004	1440					6.63
8/14/2004	420	0.02		7.86	475	6.74
8/15/2004	4060	0.03		5.61	450	6.64
8/16/2004	3605	0.02		7.86	380	6.60
8/17/2004	2410	0.03	0	9.27		6.69
8/18/2004	2550	0.03				6.73
8/19/2004	2175	0.03		7.25		6.75
8/20/2004	1980	0.03		8.82		6.05
8/22/2004	2380	0.02		7.10		6.74
8/23/2004	3840	0.05		5.65	380	6.67
8/24/2004	1705	0.03				6.71

Date	Volume (mL)	NO_3^- + NO_2^- (mg/L)	NO_2^- (mg/L)	NH_3 (mg/L)	Alkalinity (mg/L as $CaCO_3$)	pH
8/25/2004	4120	0.04		5.87		6.67
8/26/2004	2930	0.03		7.80		6.63
8/27/2004	2820	0.03		7.75		6.70
8/28/2004	2930	0.03		12.40	350	6.67
8/29/2004	2700	0.04		7.30		6.76
8/30/2004	1870	0.04	0			6.76
8/31/2004	2620	0.02		4.56	400	6.73
9/1/2004	7215					6.64
9/2/2004	2865					
9/7/2004	8550	0.05	0	8.77		6.69
9/8/2004	1340					
9/9/2004	1150			5.86		6.66
9/10/2004	1590	0.03				6.67
9/12/2004	1535				480	6.66
9/13/2004	3710					
9/14/2004	1290			6.78		
9/15/2004	3600	0.02				6.63
9/16/2004	1535					6.61
9/17/2004	1570			6.37		
9/19/2004	2530	0.03		4.16		6.66
9/20/2004	2730					
9/21/2004	3790	0.03				6.54
9/22/2004	1330					
9/24/2004	2785				450	6.61
9/25/2004	1360					
9/27/2004	5700					
9/28/2004	3530			4.20		6.59
9/29/2004	1555					
9/30/2004	1380					6.67
10/1/2004	1160	0.03				6.71
10/4/2004	1750					
10/5/2004	1350	0.02				6.71
10/6/2004	1130					
10/7/2004	1235			8.76		6.70
10/8/2004	1155					
10/10/2004	1140					
10/13/2004	1470			5.78	440	6.72
10/15/2004	1540					6.67
10/17/2004	1460	0.02				6.62
10/18/2004	1110					
10/19/2004	1790					

Date	Volume (mL)	NO_3^- + NO_2^- (mg/L)	NO_2^- (mg/L)	NH_3 (mg/L)	Alkalinity (mg/L as $CaCO_3$)	pH
10/21/2004	1210			4.65		
10/22/2004	1130	0.02			400	6.70
10/24/2004	1345					6.69
10/25/2004	1290			6.98	340	6.67
10/26/2004	870					
10/27/2004	710					
11/1/2004	540					
11/2/2004	1270	0.03		4.32	370	6.75
11/5/2004	990					6.36
11/8/2004	790					
11/9/2004	650	0.02		8.97		6.76
11/10/2004	720					6.63
11/11/2004	840					6.75
11/12/2004	890			4.65		
11/14/2004	780	0.02			400	6.84
11/15/2004	1010					
11/18/2004	800			6.45		
11/21/2004	550	0.02				6.81
11/24/2004	520			6.79		6.85
11/29/2004	1040	0.03				6.77
11/30/2004	830			7.04	415	6.78
12/2/2004	1210	0.02				6.82
12/3/2004	835					6.68
12/5/2004	850					
12/6/2004	980	0.02		7.08		6.80
12/8/2004	825	0.02				6.74
12/9/2004	730					
12/10/2004	640					6.78
12/14/2004	910	0.03		6.89	450	6.73
12/16/2004	770					
12/17/2004	930					
12/19/2004	890	0.02				6.76
12/22/2004	780	0.02		6.88		6.78
12/26/2004	1490	0.02				6.54
12/30/2004	1400					
12/31/2004	1485				390	6.77
1/10/2005	2450	0.02		7.77		6.77
1/11/2005	1000	0.02				6.74
1/13/2005	1120					6.77
1/14/2005	1560					6.63
1/16/2005	1660				420	6.71

Date	Volume (mL)	NO_3^- + NO_2^- (mg/L)	NO_2^- (mg/L)	NH_3 (mg/L)	Alkalinity (mg/L as $CaCO_3$)	pH
1/18/2005	1480	0.02		4.96		6.75
1/20/2005	1400	0.02				6.75
1/23/2005	1360	0.03				6.68
1/24/2005	1130					6.65
1/25/2005	1100					
1/26/2005	1140					
1/27/2005	2140	0.02		2.58	450	6.71
1/30/2005	1300					
2/1/2005	1320	0.02				6.63
2/3/2005	2870					6.65
2/4/2005	1110					
2/6/2005	1230	0.02		5.03		6.71
2/8/2005	1080				435	6.71
2/9/2005	740					
2/10/2005	1030					
2/13/2005	1030					
2/15/2005	990	0.02		5.22		6.63
2/17/2005	860				480	6.71
2/20/2005	980					
2/22/2005	790	0.03				6.63
2/24/2005	1470	0.02		7.27		6.61
2/28/2005	4220					6.72
3/1/2005	3620	0.02				6.71
3/3/2005	1350	0.02				6.74
3/6/2005	2790					6.78
3/7/2005	1310	0.01		2.06		6.81
3/8/2005	1510				410	6.72
3/9/2005	1290					
3/10/2005	1490	0.02				
3/15/2005	1520					6.62
3/16/2005	1475					6.84
3/17/2005	1490	0.02				6.72
3/18/2005	4550					6.79
3/20/2005	2850					
3/21/2005	1400					
3/22/2005	2860	0.01		6.42		6.7
3/23/2005	6430					6.72
3/24/2005	2980					6.8
3/25/2005	2930	0.02				6.76
3/27/2005	3100					6.7
3/28/2005	2750	0.00				6.73

Date	Volume (mL)	NO_3^- + NO_2^- (mg/L)	NO_2^- (mg/L)	NH_3 (mg/L)	Alkalinity (mg/L as $CaCO_3$)	pH
3/29/2005	1420					
3/30/2005	1120					
3/31/2005	1420			3.45		6.8
4/1/2005	2510					
4/3/2005	1280	0.01				6.77
4/4/2005	1150					6.69
4/5/2005	1030					
4/6/2005	830					
4/7/2005	1290					6.79
4/8/2005	1050					
4/10/2005	1150	0.00		3.89		
4/11/2005	930					
4/12/2005	720					6.87
4/14/2005	960			1.12		
4/15/2005	1050					
4/17/2005	900					
4/19/2005	700					6.82
4/21/2005	580			7.56		6.9
4/22/2005	510					
4/27/2005	550					
5/1/2005	1100			4.75		6.88
5/4/2005	1280					6.86
5/8/2005	1460					
5/12/2005	1130					
5/18/2005	1300	0.00				6.86
5/19/2005	1100					
5/22/2005	1000					6.33
5/25/2005	1120			3.09		
5/26/2005	1680			7.38		
6/1/2005	1700					6.78

Table 25 - Chamber 2 Filtrate Data

Date	Volume (mL)	NO_3^- + NO_2^- (mg/L)	NO_2^- (mg/L)	NH_3 (mg/L)	Alkalinity (mg/L as $CaCO_3$)	pH
6/4/2004	631	0.05	0.00			
6/5/2004	1090					
6/6/2004	2125					
6/7/2004	1850					6.60
6/8/2004	1860	0.08				6.88
6/9/2004	1957	0.06				6.90
6/10/2004	3525	0.06	0.00			6.80
6/11/2004	1845					6.12
6/12/2004	3925	0.08				6.63
6/13/2004	1705					6.43
6/14/2004	1690	0.05				6.38
6/15/2004	1780	0.06				6.49
6/16/2004	1520					6.60
6/17/2004	1670	0.05			400	6.81
6/18/2004	1750	0.05	0.00		420	6.60
6/19/2004	1780	0.04				6.65
6/20/2004	1650				360	6.65
6/21/2004	3200	0.05			380	6.71
6/22/2004	3130	0.06				6.64
6/23/2004	3400	0.04				
6/24/2004	1730	0.05			600	6.58
6/25/2004	1880	0.04			600	6.50
6/26/2004	3620	0.04	0.00			6.55
6/27/2004	2020	0.04				6.65
6/28/2004	3200				400	6.71
6/29/2004	1760	0.05				6.75
6/30/2004	2040	0.04				6.70
7/1/2004	1860	0.05				6.63
7/2/2004	1890	0.04				6.64
7/3/2004	1860					6.87
7/4/2004	3760	0.04	0.00			6.64
7/5/2004	3570	0.04			300	6.56
7/6/2004	1850	0.04		8.65		6.57
7/7/2004	1840	0.04				6.57
7/8/2004	1930	0.04				6.59
7/9/2004	1850	0.03				6.62
7/10/2004	1840	0.04	0.00	9.56		6.64
7/11/2004	1820					6.63

Date	Volume (mL)	NO_3^- + NO_2^- (mg/L)	NO_2^- (mg/L)	NH_3 (mg/L)	Alkalinity (mg/L as $CaCO_3$)	pH
7/12/2004	3970	0.03				6.63
7/13/2004	2030	0.03				6.61
7/14/2004	1775	0.03	0.00	16.20		6.66
7/15/2004	1840	0.04			390	6.66
7/16/2004	1880	0.04				6.68
7/17/2004	1730	0.03				6.71
7/18/2004	1965					6.67
7/19/2004	1830	0.04		12.20		6.66
7/20/2004	1870	0.03				6.53
7/21/2004	1840				365	6.69
7/22/2004	1830	0.04	0.00	8.76		6.72
7/23/2004	1950	0.04				6.72
7/24/2004	1990	0.03				6.67
7/25/2004	1840					6.63
7/26/2004	1360	0.04	0.00	5.89	390	6.63
7/27/2004	780					7.08
7/28/2004	51	0.02				
7/29/2004	0					7.69
7/30/2004	160	0.03		6.88		
7/31/2004	8					
8/1/2004	7					
8/2/2004	10.5					
8/5/2004	40	0.05	0.00			
8/7/2004	1950	0.03				6.46
8/8/2004	2101	0.06	0.00			6.51
8/9/2004	2170	0.05				6.43
8/10/2004	6760	0.03				6.68
8/11/2004	1770	0.03				6.70
8/12/2004	5500	0.03			430	6.52
8/13/2004	1640					6.80
8/14/2004	1650	0.03		9.88	400	6.68
8/15/2004	5030	0.02		12.70	330	6.74
8/16/2004	4970	0.02		11.50	300	6.69
8/17/2004	3535	0.03		7.29		6.72
8/18/2004	3680	0.02				6.74
8/19/2004	3765	0.02		13.59		6.73
8/20/2004	3550	0.03		7.29		6.54
8/22/2004	3460	0.02		8.70		6.77
8/23/2004	5580	0.02		4.76	290	6.73
8/24/2004	1890	0.02				6.75
8/25/2004	5440	0.02		7.56		6.78

Date	Volume (mL)	NO_3^- + NO_2^- (mg/L)	NO_2^- (mg/L)	NH_3 (mg/L)	Alkalinity (mg/L as $CaCO_3$)	pH
8/26/2004	3520	0.03		6.54		6.75
8/27/2004	2880	0.02		5.93		6.72
8/28/2004	3640	0.02		8.90	300	6.74
8/29/2004	3830	0.03		9.80		6.77
8/30/2004	1810	0.03				6.75
8/31/2004	3690	0.02		10.50	330	6.76
9/1/2004	7855					6.70
9/2/2004	3720					
9/7/2004	9480	0.02	0.02	6.45		6.80
9/8/2004	1150					
9/9/2004	1135			7.18		6.66
9/10/2004	1700	0.03				6.67
9/12/2004	1570				425	6.66
9/13/2004	4000					
9/14/2004	1950			5.67		
9/15/2004	3680	0.02				6.20
9/16/2004	2110					6.68
9/17/2004	1880			3.87		
9/19/2004	3590	0.03		10.56		6.62
9/20/2004	4390					
9/21/2004	5370					6.51
9/22/2004	2000					
9/24/2004	3425	0.02			440	6.60
9/25/2004	1765					
9/27/2004	7460					
9/28/2004	3390			2.81		6.53
9/29/2004	1700					
9/30/2004	1935					6.59
10/1/2004	1290	0.02				6.63
10/4/2004	1900					
10/5/2004	1610	0.02				6.63
10/6/2004	1125					
10/7/2004	1340	0.02		6.89		6.78
10/8/2004	1400					
10/10/2004	1125					
10/13/2004	1810			7.48	395	6.64
10/15/2004	1760					6.63
10/17/2004	1450	0.03				6.61
10/18/2004	1125					
10/19/2004	1530					
10/21/2004	1860			5.06		

Date	Volume (mL)	NO_3^- + NO_2^- (mg/L)	NO_2^- (mg/L)	NH_3 (mg/L)	Alkalinity (mg/L as $CaCO_3$)	pH
10/22/2004	1375	0.02			410	6.58
10/24/2004	1080					6.63
10/25/2004	1180			7.45	310	6.67
10/26/2004	990					
10/27/2004	790					
11/1/2004	540					
11/2/2004	1180	0.02		8.32	300	6.68
11/5/2004	1150					6.46
11/8/2004	710					
11/9/2004	680	0.02		7.60		6.75
11/10/2004	910					6.51
11/11/2004	1020					6.68
11/12/2004	870			14.30		
11/14/2004	1000	0.02			380	6.73
11/15/2004	1220					
11/18/2004	950			11.23		
11/21/2004	600	0.02				6.75
11/24/2004	630			9.67		6.78
11/29/2004	980	0.03				6.67
11/30/2004	905			6.75	405	6.69
12/2/2004	1125	0.02				6.72
12/3/2004	850					6.68
12/5/2004	610					
12/6/2004	790	0.02		7.00		6.70
12/8/2004	930					6.68
12/9/2004	830					
12/10/2004	610	0.02				6.74
12/14/2004	990	0.02		7.35	430	6.66
12/16/2004	890					
12/17/2004	1320					
12/19/2004	1120	0.02				6.64
12/22/2004	1170	0.02		8.80		6.63
12/26/2004	1710	0.02				6.50
12/30/2004	1630					
12/31/2004	1590				400	6.63
1/10/2005	2455	0.02		8.06		6.63
1/11/2005	980	0.01				6.62
1/13/2005	1150					6.63
1/14/2005	1640					6.63
1/16/2005	1460				370	6.59
1/18/2005	1590	0.02		2.05		6.59

Date	Volume (mL)	NO_3^- + NO_2^- (mg/L)	NO_2^- (mg/L)	NH_3 (mg/L)	Alkalinity (mg/L as $CaCO_3$)	pH
1/20/2005	1670	0.02				5.57
1/23/2005	1440	0.01				6.59
1/24/2005	1230					6.54
1/25/2005	1140					
1/26/2005	1230					
1/27/2005	1380	0.02		3.40	390	6.59
1/30/2005	1340					
2/1/2005	1390	0.01				6.53
2/3/2005	3190					6.50
2/4/2005	1100	0.02				
2/5/2005						
2/6/2005	1290			6.99		6.60
2/8/2005	1120	0.02			480	6.60
2/9/2005	700					
2/10/2005	1050					
2/13/2005	1650					
2/15/2005	1030			3.80		6.55
2/17/2005	850				420	6.60
2/20/2005	1020					
2/22/2005	740					6.69
2/24/2005	1630	0.02		7.98		6.54
2/28/2005	4580					6.66
3/1/2005	3310					6.61
3/3/2005	1430	0.01				6.60
3/6/2005	2960					6.65
3/7/2005	1360			8.26		6.70
3/8/2005	1410				330	6.65
3/9/2005	1290					
3/10/2005	1590	0.01				
3/15/2005	1610					6.63
3/16/2005	1485					
3/17/2005	1470	0.02				6.75
3/18/2005	4880					6.61
3/20/2005	3200					6.72
3/21/2005	1520					
3/22/2005	3050	0.02		7.80		6.56
3/23/2005	5770					6.70
3/24/2005	3280					6.72
3/25/2005	4480	0.02				6.70
3/27/2005	2800					6.70
3/28/2005	2950	0.01				

Date	Volume (mL)	NO_3^- + NO_2^- (mg/L)	NO_2^- (mg/L)	NH_3 (mg/L)	Alkalinity (mg/L as $CaCO_3$)	pH
3/29/2005	2770					
3/30/2005	1120					6.82
3/31/2005	1490			7.71		6.79
4/1/2005	2580					
4/3/2005	1350	0.01				
4/4/2005	1150					6.80
4/5/2005	1180					
4/6/2005	870					
4/7/2005	1370					6.76
4/8/2005	960					
4/10/2005	1190	0.01		3.24		
4/11/2005	900					
4/12/2005	760					6.83
4/14/2005	1000			4.99		
4/17/2005	1020					
4/19/2005	760					6.82
4/21/2005	680					
4/22/2005	530	0.00		3.50		6.88
4/27/2005	830					6.88
5/1/2005	1730			5.20		6.82
5/4/2005	1580					
5/8/2005	1430					
5/12/2005	1130					6.80
5/18/2005	1000	0.00				6.85
5/19/2005	960					
5/22/2005	730					
5/25/2005	830			6.10		6.99
5/26/2005	2390			5.17		
6/1/2005	850					6.59

Table 26 - Chamber 3 Filtrate Data

Date	Volume (mL)	NO_3^- + NO_2^- (mg/L)	NO_2^- (mg/L)	NH_3 (mg/L)	Alkalinity (mg/L as $CaCO_3$)	pH
6/4/2004	400	0.06	0.00			
6/5/2004	435					
6/6/2004	455	0.07				
6/7/2004	5060					
6/8/2004	600	0.08	0.00			
6/9/2004	555					
6/10/2004	1265					
6/13/2004	195	0.05				6.94
6/14/2004	3620	0.05	0.00			6.58
6/15/2004	1700	0.05				6.62
6/16/2004	3375					6.66
6/17/2004	3295	0.05			400	6.88
6/18/2004	1400	0.06			410	6.91
6/19/2004	1530					6.88
6/20/2004	1500	0.03			300	6.82
6/21/2004	1600	0.05			290	6.78
6/22/2004	1730	0.05				6.57
6/23/2004	3310	0.04				
6/24/2004	1660	0.04	0.00		400	6.87
6/25/2004	1590	0.03			370	6.64
6/26/2004	4030	0.03				6.63
6/27/2004	1910					6.65
6/28/2004	1840				350	6.71
6/29/2004	1800	0.04				6.74
6/30/2004	1910	0.04				6.79
7/1/2004	1740	0.04				6.77
7/2/2004	1910	0.03	0.00			6.80
7/3/2004	1810					6.80
7/4/2004	3570					6.72
7/5/2004	3400	0.04			300	6.73
7/6/2004	2050	0.03	0.00	10.45		6.73
7/7/2004	1860	0.04				6.76
7/8/2004	2150	0.03				6.75
7/9/2004	1850	0.03				6.81
7/10/2004	1860			9.87		6.86
7/11/2004	1900					6.86
7/12/2004	3580	0.03				6.86

Date	Volume (mL)	NO_3^- + NO_2^- (mg/L)	NO_2^- (mg/L)	NH_3 (mg/L)	Alkalinity (mg/L as $CaCO_3$)	pH
7/13/2004	1840	0.03				6.82
7/14/2004	1860	0.03		9.19		6.82
7/15/2004	1900	0.03			380	6.89
7/16/2004	1850	0.03	0.00			6.87
7/17/2004	1875	0.03				6.89
7/18/2004	2000					6.90
7/19/2004	1900	0.04		6.89		6.88
7/20/2004	1850	0.03	0.00			6.65
7/21/2004	640	0.04			415	7.13
7/22/2004	48	0.11		6.32		
7/23/2004	55					
7/24/2004	21					
7/29/2004	0					
7/30/2004	50	0.06	0.00	6.03		8.12
7/31/2004	11					
8/1/2004	6.5					
8/2/2004	6					
8/5/2004	2					
8/7/2004	2200	0.03	0.00			6.56
8/10/2004	7020	0.03				6.69
8/12/2004	4460	0.03			390	6.58
8/13/2004	1475					6.97
8/14/2004	1320	0.02		8.10	350	6.75
8/15/2004	5035	0.03		7.51	300	6.78
8/16/2004	5435	0.03		5.75	310	6.70
8/17/2004	3510	0.03		6.34		6.75
8/18/2004	3400	0.02				6.78
8/19/2004	3150	0.02		7.58		6.80
8/20/2004	2830	0.02		6.42		6.18
8/22/2004	3845	0.02		2.90		6.83
8/23/2004	5320	0.02		3.85	320	6.78
8/24/2004	1840	0.03				6.81
8/25/2004	4605	0.03		5.85		6.78
8/26/2004	3195	0.03		6.15		6.80
8/27/2004	3310	0.03		6.14		6.75
8/28/2004	3100	0.02		3.50	300	6.79
8/29/2004	3135	0.03		3.59		6.83
8/30/2004	1770	0.03				6.84
8/31/2004	3010	0.03		5.70	365	6.79
9/1/2004	7250					6.76
9/2/2004	3090					

Date	Volume (mL)	NO_3^- + NO_2^- (mg/L)	NO_2^- (mg/L)	NH_3 (mg/L)	Alkalinity (mg/L as $CaCO_3$)	pH
9/7/2004	10470	0.03		5.25		6.75
9/8/2004	1280					
9/9/2004	1300			4.57		6.74
9/10/2004	1640	0.03				6.76
9/12/2004	1490				340	6.74
9/13/2004	3720					
9/14/2004	2020			7.56		
9/15/2004	4160	0.02				6.70
9/16/2004	1870					6.70
9/17/2004	1950			2.57		
9/19/2004	3180	0.03		6.86		6.74
9/20/2004	5280					
9/21/2004	6470					6.64
9/22/2004	3065					
9/24/2004	3440				385	6.80
9/25/2004	1680					
9/27/2004	4700					
9/28/2004	3690			2.20		6.71
9/29/2004	1830					
9/30/2004	1760	0.02				6.74
10/1/2004	1430					6.78
10/5/2004	1830					6.77
10/6/2004	1450					
10/7/2004	1670			4.34		6.82
10/8/2004	1430					
10/10/2004	620					
10/13/2004	2250	0.02		5.67	350	6.67
10/15/2004	1815					6.73
10/17/2004	1860					6.72
10/18/2004	1275					
10/20/2004	2125					
10/21/2004	1795			4.60		
10/22/2004	1510				380	6.70
10/24/2004	1240	0.05				6.88
10/25/2004	1110			6.88	360	6.86
10/26/2004	990					
10/27/2004	780					
11/1/2004	550					
11/2/2004	1270	0.02		7.67	360	6.75
11/5/2004	740					6.49
11/8/2004	535					

Date	Volume (mL)	NO_3^- + NO_2^- (mg/L)	NO_2^- (mg/L)	NH_3 (mg/L)	Alkalinity (mg/L as $CaCO_3$)	pH
11/9/2004	1610	0.02		8.65		6.76
11/10/2004	2000					6.53
11/11/2004	780					6.85
11/12/2004	1680			3.57		
11/14/2004	740	0.02			410	6.89
11/15/2004	1860					
11/18/2004	670			8.51		
11/21/2004	380	0.01				6.90
11/24/2004	370			4.86		6.96
11/29/2004	790	0.01				6.77
11/30/2004	810			6.40	360	6.76
12/2/2004	1030	0.02				6.80
12/3/2004	760					6.74
12/5/2004	540					
12/6/2004	770	0.02		5.87		6.78
12/8/2004	810					6.76
12/9/2004	760	0.02				6.83
12/14/2004	930	0.02		7.32	330	6.77
12/16/2004	800					
12/19/2004	940	0.02				6.75
12/22/2004	800	0.01		7.23		6.78
12/26/2004	1555	0.02				6.68
12/30/2004	1590					
12/31/2004	1620				360	6.73
1/10/2005	1430			7.02		6.74
1/11/2005	900	0.02				6.71
1/13/2005	1150					6.73
1/14/2005	1630					
1/15/2005						6.66
1/16/2005	1540				400	
1/17/2005						6.69
1/18/2005	1530	0.03		3.09		6.69
1/19/2005						
1/20/2005	1510	0.03				6.65
1/23/2005	1340	0.01				6.68
1/24/2005	1080					6.61
1/25/2005	1000					
1/26/2005	1170					
1/27/2005	1320	0.01		6.12	380	6.68
1/30/2005	1250					
2/1/2005	2740					6.67

Date	Volume (mL)	NO_3^- + NO_2^- (mg/L)	NO_2^- (mg/L)	NH_3 (mg/L)	Alkalinity (mg/L as $CaCO_3$)	pH
2/3/2005	3000	0.02				
2/4/2005	970	0.02				
2/6/2005	1160			3.47		6.69
2/7/2005						
2/8/2005	990	0.02			370	6.68
2/9/2005	670					
2/10/2005	970					
2/13/2005	980					
2/15/2005	1040			4.07		6.63
2/17/2005	770				340	6.68
2/20/2005	1020					6.79
2/22/2005	750					
2/24/2005	1565			3.98		6.61
2/28/2005	4370					6.76
3/1/2005	3600					6.71
3/3/2005	1400	0.02				6.69
3/6/2005	3090					6.68
3/7/2005	1310			5.75		6.78
3/8/2005	1590				320	6.73
3/9/2005	1330					
3/10/2005	1610					
3/15/2005	1610					6.68
3/16/2005	1550					6.82
3/17/2005	1510	0.02				6.73
3/18/2005	4670					6.82
3/20/2005	3000					
3/21/2005	1420					
3/22/2005	3140	0.02		6.00		6.64
3/23/2005	6650					6.76
3/24/2005	3410					6.78
3/25/2005	4810	0.01				6.81
3/27/2005	3290					6.78
3/28/2005	2820					
3/29/2005	4110					
3/30/2005	1100	0.01		7.81		6.93
3/31/2005	1260					6.80
4/1/2005	2650					
4/3/2005	1280	0.00				6.80
4/4/2005	1220					6.78
4/5/2005	1140					
4/6/2005	800					

Date	Volume (mL)	NO_3^- + NO_2^- (mg/L)	NO_2^- (mg/L)	NH_3 (mg/L)	Alkalinity (mg/L as $CaCO_3$)	pH
4/7/2005	1450					6.82
4/8/2005	980					
4/10/2005	1190	0.00		3.40		
4/11/2005	1590					6.90
4/12/2005	730					
4/14/2005	1020			3.06		
4/15/2005	1030					
4/17/2005	780					
4/19/2005	650					
4/21/2005	390					
4/22/2005	470			5.62		6.94
4/27/2005	600					6.93
5/1/2005	1050			4.65		
5/4/2005	1080					6.94
5/8/2005	1200					
5/12/2005	930					6.94
5/18/2005	1000	0.00				6.95
5/19/2005	1020					
5/22/2005	1740					7.01
5/25/2005	870			5.05		
5/26/2005	1650			6.11		
6/1/2005	1530					6.91

APPENDIX D – QUALITY CONTROL DATA

Table 27 - Precipitation Quality Control

Date	NO_3^- + NO_2^- (mg/L)	Duplicate NO_3^- + NO_2^- (mg/L)	RPD (%)	$C_{spiked\ matrix}$ (mg/L) [a]	% Recovery	NH_3 (mg/L)	Duplicate NH_3 (mg/L)	RPD (%)	$C_{spiked\ matrix}$ (mg/L) [b]	% Recovery
6/22/2004	0.60	0.64	6.45	1.67	108.67	0.00	0.00	0.00	9.87	99.69
6/29/2004	1.26	1.23	2.41							
7/12/2004	0.20	0.21	4.88	1.12	93.12					
7/19/2004						0.30	0.27	10.53	10.23	100.32
8/2/2004	0.28	0.23	19.61	1.30	103.30					
8/13/2004						0.25	0.25	0.00	8.97	88.10
8/17/2004	0.49	0.47	4.17							
8/30/2004	0.15	0.15	0.00			0.21	0.23	9.09	11.03	109.30
9/7/2004	0.02	0.02	0.00	0.92	90.92					
9/17/2004						0.00	0.00	0.00	10.43	105.34
9/22/2004	0.05	0.06	18.18							
10/13/2004	0.11	0.10	9.52	1.21	111.21					
10/20/2004						0.03	0.02	40.00	10.87	109.49
11/5/2004	0.72	0.74	2.74							
11/14/2004						0.00	0.00	0.00	11.68	117.97
12/10/2004	0.15			1.01	87.01	0.06	0.12	66.67	10.12	101.61
1/13/2005	0.22	0.20	9.52	0.98	76.98					
1/14/2005						0.07	0.08	13.33	10.00	100.30
2/24/2005	0.39	0.37	5.26	1.26	88.26	0.06	0.09	40.00	7.87	78.89
3/9/2005					0.00	0.11	0.11	0.00	11.21	112.12
3/16/2005	0.68	0.60	12.50	1.50	83.50					
3/27/2005	0.22			0.78	56.99	0.08	0.03	90.91	11.23	112.62

Date	NO_3^- + NO_2^- (mg/L)	Duplicate NO_3^- + NO_2^- (mg/L)	RPD (%)	$C_{spiked\ matrix}$ (mg/L) [a]	% Recovery	NH_3 (mg/L)	Duplicate NH_3 (mg/L)	RPD (%)	$C_{spiked\ matrix}$ (mg/L) [b]	% Recovery
4/8/2005	0.37	0.36	2.74							
4/27/2005	1.88			2.57	71.57					
5/4//2005						0.11	0.09	20.00	11.97	119.80

[a] V_{spm} = 101 mL, V_{sol} = 100 mL, C_{spike} = 100 ppm NO_3-N, [b] V_{spm} = 101 mL, V_{sol} = 100 mL, C_{spike} = 1000 ppm NH_3-N

Table 28 - Irrigation Quality Control

Date	NO_3^- + NO_2^- (mg/L)	Duplicate NO_3^- + NO_2^- (mg/L)	RPD (%)	$C_{spiked\ matrix}$ (mg/L) [a]	% Recovery	NH_3 (mg/L)	Duplicate NH_3 (mg/L)	RPD (%)	$C_{spiked\ matrix}$ (mg/L) [b]	% Recovery
7/22/2004						0.10	0.08	22.22	10.09	100.91
7/26/2004	0.02	0.00	200.00	123.24						
8/1/2004						0.08	0.10	22.22	8.8	88.08
8/4/2004	0.02			0.97	95.97					
8/29/2004						0.75	0.66	12.77	15.87	152.79
9/12/2004	0.01	0.02	66.67							
10/10/2004	0.03	0.03	0.00	1.06	104.06					
10/17/2004						0.11	0.03	114.29	9.45	94.35
10/22/2004						0.16	0.25	43.90	7.67	75.87
11/4/2004	0.02	0.02	0.00			0.04	0.03	28.57	9.33	93.83
12/3/2004	0.03			0.89	86.89	0.02	0.04	66.67	11.23	113.22
1/13/2005	0.02	0.02	0.00							
1/23/2005	0.03			0.93	90.93	0.05				
3/27/2005	0.01	0.02	66.67			0.11	0.09	20.00	11.97	119.80
4/10/2005	0.00	0.00	0.00			0.02			10.20	102.82
512/2005	0.00			1.02	103.02	0.21	0.18	15.38	9.78	96.68

[a] V_{spm} = 101 mL, V_{sol} = 100 mL, C_{spike} = 100 ppm NO_3-N, [b] V_{spm} = 101 mL, V_{sol} = 100 mL, C_{spike} = 1000 ppm NH_3-N

Table 29 - Chamber 1 Groundwater Quality Control

Date	NO_3^- + NO_2^- (mg/L)	Duplicate NO_3^- + NO_2^- (mg/L)	RPD (%)	$C_{spiked\ matrix}$ (mg/L) [a]	% Recovery	NH_3 (mg/L)	Duplicate NH_3 (mg/L)	RPD (%)	$C_{spiked\ matrix}$ (mg/L) [b]	% Recovery
7/12/2004	0.03	0.03	0.00							
7/14/2004	0.03			1.00	98.00					
7/19/2004						15.00	13.76	8.62	20.10	53.01
7/21/2004	0.03	0.03	0.00	0.92	89.92					
7/30/2004	0.03	0.02	40.00							
8/16/2004	0.02	0.02	0.00	0.89	87.89					
8/19/2004						15.50	13.98	10.31	24.89	96.37
8/23/2004						5.65	6.00	6.01		
8/31/2004	0.02			0.86	84.86					
9/7/2004	0.05	0.04	22.22							
9/15/2004	0.02	0.02	0.00							
9/17/2004						6.37	6.03	5.48	18.01	118.22
9/21/2004	0.03			0.94	91.94					
9/28/2004						4.20	3.66	13.74	15.42	113.74
10/17/2004	0.02	0.02	0.00	1.05	104.05					
11/1/2004						12.32	11.80	4.31	20.31	81.94
11/9/2004	0.02	0.01	66.67							
12/2/2004	0.02									
12/14/2005						6.89	6.88	0.15	14.05	73.01
1/10/2005	0.02	0.01	66.67	1.25	124.25	7.77				
2/6/2005						5.03	6.9	31.35	13.68	87.87
2/15/2005						1.22			10.07	89.51
2/24/2005	0.02	0.02	0.00	0.99	97.99	7.27	5.96	19.80	15.24	81.22

Date	NO_3^- + NO_2^- (mg/L)	Duplicate NO_3^- + NO_2^- (mg/L)	RPD (%)	$C_{spiked\ matrix}$ (mg/L)[a]	% Recovery	NH_3 (mg/L)	Duplicate NH_3 (mg/L)	RPD (%)	$C_{spiked\ matrix}$ (mg/L)[b]	% Recovery
3/10/2005	0.02			0.79	77.79					
3/17/2005	0.02			0.72	70.72					
3/22/2005	0.01	0.01	0.00	0.64	63.64	6.42	6.09	5.28		
3/31/2005						5.98			17.03	112.20
4/3/2005	0.01			0.31	30.31					
4/10/2005	0	0	0.00	0.3	30.30					
4/27/2005	0			0.89	89.89					
5/1/2005						4.75			13.2	85.82
5/8/2005	0.02			0.23	21.23					
5/18/2005	0			0.16	16.16					

[a] V_{spm} = 101 mL, V_{sol} = 100 mL, C_{spike} = 100 ppm NO_3-N, [b] V_{spm} = 101 mL, V_{sol} = 100 mL, C_{spike} = 1000 ppm NH_3-N

Table 30 - Chamber 2 Groundwater Quality Control

Date	NO_3^- + NO_2^- (mg/L)	Duplicate NO_3^- + NO_2^- (mg/L)	RPD (%)	$C_{spiked\ matrix}$ (mg/L) [a]	% Recovery	NH_3 (mg/L)	Duplicate NH_3 (mg/L)	RPD (%)	$C_{spiked\ matrix}$ (mg/L) [b]	% Recovery
7/14/2004	0.03	0.03	0.00	1.07	105.07	16.20	14.12	13.72		
7/19/2004						12.20			24.90	129.49
7/22/2004						8.76	10.49	17.97	15.10	64.91
7/26/2004	0.04	0.03	28.57							
8/5/2004	0.05			0.95	90.95					
8/11/2004	0.03	0.03	0.00							
8/15/2004						12.70	11.80	7.35	20.70	82.07
8/20/2004						7.29	8.66	17.18	15.73	86.00
8/26/2004	0.03	0.03	0.00	1.03	101.03					
8/31/2004						10.50	10.01	4.78		
9/7/2004	0.02	0.02	0.00							
9/9/2004						7.18			15.74	87.17
9/17/2004						3.87	4.60	17.24		
9/24/2004	0.02			1.00	99.00					
9/28/2004						2.81	3.03	7.53	14.51	118.45
10/1/2004	0.02	0.02	0.00							
10/7/2004	0.02			0.88	86.88					
10/17/2004	0.02	0.03	40.00							
11/2/2004						8.32	9.05	8.41	19.04	109.10
11/9/2004	0.02	0.02	0.00							
11/14/2004	0.02			0.97	95.97					
12/14/2004	0.02	0.01	66.67	0.69	67.69	7.35	7.09		12.89	56.69

Date	NO_3^- + NO_2^- (mg/L)	Duplicate NO_3^- + NO_2^- (mg/L)	RPD (%)	$C_{spiked\ matrix}$ (mg/L)[a]	% Recovery	NH_3 (mg/L)	Duplicate NH_3 (mg/L)	RPD (%)	$C_{spiked\ matrix}$ (mg/L)[b]	% Recovery
1/10/2005						8.06		100.00		
1/20/2005	0.02	0.02	0.00	0.89	87.89					
2/6/2005						6.99	7.01	0.29	15.7	88.67
2/24/2005	0.02			1.13	112.13	7.98	5.95	29.15	15.01	71.80
3/7/2005						8.26	7.98	3.45	19.56	114.96
3/17/2005	0.02	0.01	66.67	0.69	67.69					
3/22/2005	0.02			0.55	53.55	7.8	7.7	1.29	16.03	83.90
3/31/2005						7.71			16.78	92.38
4/14/2005	0			0.31	31.31	4.99			12.82	79.58
4/22/2005	0			0.92	92.92	2.83	3.43	19.17	11.21	84.92
4/27/2005	0.02			0.1	8.10					
5/12/2005	0			0.11	11.11					

[a] V_{spm} = 101 mL, V_{sol} = 100 mL, C_{spike} = 100 ppm NO_3-N, [b] V_{spm} = 101 mL, V_{sol} = 100 mL, C_{spike} = 1000 ppm NH_3-N

Table 31 - Chamber 3 Groundwater Quality Control

Date	NO_3^- + NO_2^- (mg/L)	Duplicate NO_3^- + NO_2^- (mg/L)	RPD (%)	$C_{spiked\ matrix}$ (mg/L) [a]	% Recovery	NH_3 (mg/L)	Duplicate NH_3 (mg/L)	RPD (%)	$C_{spiked\ matrix}$ (mg/L) [b]	% Recovery
7/14/2004	0.03	0.03	0.00	0.98	95.98					
7/22/2004	0.11	0.03	114.29	0.70	59.70	6.32	5.89	7.04	15.30	91.33
7/27/2004	0.06			1.15	110.15					
8/7/2004	0.03	0.02	40.00							
8/15/2004						10.80	9.03	17.85		
8/18/2004	0.02	0.02	0.00	1.06	105.06					
8/22/2004						2.90	3.65	22.90	14.18	114.22
8/29/2004						3.59	3.73	3.83		
8/30/2004	0.03	0.03	0.00							
9/7/2004	0.03	0.03	0.00							
9/9/2004						4.57	5.00	8.96	13.62	91.85
9/15/2004	0.02	0.02	0.00	0.85	83.85					
9/28/2004						2.20	2.35	6.59	9.87	77.69
10/13/2004	0.02	0.02	0.00	1.08	107.08					
10/25/2004						6.88	7.98	14.80		
11/2/2004	0.02	0.01	66.67							
11/12/2004						14.30	11.48	21.88	22.63	85.56
11/14/2004	0.02	0.02	0.00	0.96	94.96					
11/24/2004						4.86			19.80	151.38
12/6/2004	0.02			0.77	75.77	5.87	5.58	5.07	15.01	92.90
12/19/2004	0.02	0.02	0.00							
1/10/2005						7.02			13.89	70.09
1/27/2005	0.01			0.90	89.90	6.12	5.98	2.31	14.70	87.27

Date	NO_3^- + NO_2^- (mg/L)	Duplicate NO_3^- + NO_2^- (mg/L)	RPD (%)	$C_{spiked\ matrix}$ (mg/L)[a]	% Recovery	NH_3 (mg/L)	Duplicate NH_3 (mg/L)	RPD (%)	$C_{spiked\ matrix}$ (mg/L)[b]	% Recovery
3/3/2005	0.02	0.02	0.00							
3/17/2005	0.02	0.02	0.00	0.68	66.68					
3/22/2005	0.02			0.75	73.75	6.00	5.56	7.61	17.90	120.79
3/31/2005						6.23			16.00	99.30
4/3/2005	0.00			0.66	66.66					
4/4/2005	0.01	0.01	0.00	0.20	19.20					
4/10/2005						3.40			15.89	126.49
4/27/2005	0.01			0.18	17.18					
5/1/2005						4.65	1.80	88.37	13.66	91.47
5/12/2005	0.02			0.86	84.86					
5/18/2005	0.00			0.09	9.09					
5/22/2005	0.00			0.12	12.12					

[a] V_{spm} = 101 mL, V_{sol} = 100 mL, C_{spike} = 100 ppm NO_3-N, [b] V_{spm} = 101 mL, V_{sol} = 100 mL, C_{spike} = 1000 ppm NH_3-N

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