

Water Quality Assessment of the Lewis Ginter Botanical Garden Irrigation Pond

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ABSTRACT

Stormwater reuse for irrigation purposes on public and private land is a way to overcome the increasing pressure on finite water resources. Unfortunately, stormwater runoff can contain common pollutants such as nutrients, bacteria and petroleum products. Lewis Ginter Botanical Garden is an 82-acre public garden in Richmond, Virginia that uses stormwater runoff to irrigate garden displays. The objective of this study was to determine levels of *Escherichia coli* (*E. coli*), nitrogen, phosphorous, and total petroleum hydrocarbons in the irrigation water that contains stormwater runoff. Results of the study showed that the irrigation water *E. coli* level of 91mpn/100ml was below both United States Environmental Protection Agency (U.S. EPA) and Virginia Department of Environmental Quality (VA DEQ) recreational freshwater system standards. Total nitrogen of 0.3 mg/L, Total Kjeldahl Nitrogen of 0.28 mg/L, and nitrate + nitrite of <0.1 mg/L indicate that the irrigation water quality is very near U.S. EPA reference conditions. Total ammonia nitrogen of 0.19 mg N/L was well below VA DEQ surface freshwater criteria. Results from two separate testing methods show total phosphorus levels at 0.05 mg/L and 0.16 mg/L which indicates the irrigation water level is above both U.S. EPA reference conditions and VA DEQ water quality criteria levels. Total Petroleum Hydrocarbons-Volatiles (Gas Range Organics) and Total Petroleum Hydrocarbons-Semi-Volatiles (Oil Range Organics) levels of < 0.5 mg/L and 1 mg/L were below Lab Quantitation Limits indicating that results are below applicable limits as established by the U.S. EPA.

KEYWORDS

Stormwater reuse; nitrogen; phosphorus; *E. coli*; total petroleum hydrocarbon.

LIST OF ABBREVIATIONS

| | |
|----------------|---|
| API | Aquarium Pharmaceuticals |
| <i>E. coli</i> | <i>Escherichia coli</i> |
| GRO | Gas Range Organics |
| mpn | most probable number |
| ORO | Oil Range Organics |
| TKN | Total Kjeldahl Nitrogen |
| TPH | Total Petroleum Hydrocarbons |
| U.S. EPA | United States Environmental Protection Agency |
| VA DEQ | Virginia Department of Environmental Quality |

INTRODUCTION

Unpolluted water is a vital biological and economic resource. Its many uses include drinking, fishing, hunting, irrigation, recreation, ecological values, aesthetics and industry. In recent years, water pollutant input levels have increased. The result of this increase has been water quality degradation of many vital water systems including rivers, lakes, streams and ponds (Carpenter et al., 1998). Water shortages are becoming more common, and they are likely to become worse in the future because contaminated water increases the costs of treating water for use, which reduces overall supply (Postel, 1997; Postel et al., 1996).

Water pollution occurs when contaminants such as chemicals and wastes discharge directly into a water body without adequate treatment to remove harmful compounds. Stormwater pollution is caused by untreated contaminated runoff from land uses within a catchment area that drain into waterways. The contaminated runoff can affect the overall health of the receiving water body and can also adversely affect the aquatic habitats and the aesthetics of the water body (Settacharnwit et al., 2003). When contaminated runoff degrades water quality to the point where the water body cannot be utilized for its intended purpose, environmental, economic and social losses can occur (Joliffe, 1995).

According to the U.S. EPA 2000 National Water Quality Inventory, urban runoff is one of the leading sources of water quality impairment in surface waters in the United States. A list of common pollutants found in uncontrolled or untreated

runoff from urban areas includes fertilizers/nutrients, pesticides and herbicides from residential areas; bacteria/pathogens from pet wastes or flawed septic systems; heavy metals and petroleum products such as oil and gas from streets, roadways, and improper disposal of household chemicals; and sediments from construction sites that are not properly managed. (U.S. EPA, 2002)

Stormwater reuse is one way to overcome the increasing pressures on finite water resources (Hatt et al., 2007). Capturing and harvesting stormwater for irrigation use on both public and private lands can reduce potable water demands in urban settings. However, the stormwater pollutant level can effect the overall quality of the irrigation water and impact soil, plants, irrigation systems and public health (He et al., 2008).

Lewis Ginter Botanical Garden is an 82-acre public garden located in the metropolitan Richmond, Virginia area, just north of the Richmond city limits. Established in 1984, the garden consists of approximately 50 public acres of themed garden displays, a classical domed conservatory and several buildings including the E. Claiborne Robins Visitors Center and the Education and Library Complex. The remaining non-public sections of the garden include several maintenance yards and buildings, a small pond, and the Massey Greenhouse. The garden depends on the small pond located on the property, referred to as the Irrigation Pond, to provide irrigation for the gardens. The Irrigation Pond receives its water from a combination of localized runoff, stormwater overflow and from a well located on the property that pumps water to the pond.

The objectives of this study were fourfold. The first objective was to determine which pollutants Lewis Ginter Botanical Garden was concerned about in the Irrigation Pond. The second objective was to test for pollutants of concern to determine their levels. The third objective was to determine if the pollutant levels were high enough to require remediation of the Irrigation Pond water before it is used for irrigation. The fourth objective was to determine and suggest appropriate remedial actions.

WATER QUALITY CONCERNS

The Lewis Ginter Botanical Garden Irrigation Pond is used to irrigate the garden's approximately 50 acres of ornamental plantings as well as edible plant material in the Children's Garden and the Community Kitchen Garden. After several discussions with Lewis Ginter Botanical Garden staff, the most common concerns of using the Irrigation Pond water were public safety, plant material health, and garden aesthetics. Several concerns were voiced about using water with fecal coliform bacteria contamination during visitation hours and on the edible plant material. Another major concern was the excessive algae growth and the associated putrid smell that the pond occasionally emitted. Lastly, there were discussions as to what appeared to be an oily residue on the plant material after irrigation. Based on these discussions and concerns, it was decided that the following chemical and biological parameters would be tested for: pH, fecal coliform bacteria, nitrogen, phosphorous, and TPH.

pH is a measure of the hydrogen ion activity and is equal to $-\log [H^+]$. It ranges from 0 to 14, with a value of 7 being considered neutral. It affects many biological and chemical processes in water, including the solubility of heavy metals and other dissolved constituents. A low pH increases the availability and toxicity of acid soluble metals such as iron, aluminum and manganese, while decreasing phosphorous availability to aquatic plants and animals. High pH increases the toxicity of ammonia in water.

Fecal coliform bacteria such as *E. coli* are found in human and animal wastes. In urban stormwater, fecal coliform bacteria originates from sources such as animal wastes from residential developments, failing sewer and septic systems, area wildlife, and animal manure fertilized areas (Cook & Baker, 2001; Moog & Whiting, 2002; Jameison et al., 2003). Fecal coliform bacteria are considered to be indicator organisms of potential pathogenic microbes (Mallin & Wheeler, 2000). These microbes can pollute area waters, cause human illness and ultimately affect the ability of the water body and area to achieve its intended use (U.S. EPA, 1986; Jones, 1997). Stormwater reuse for irrigating the Lewis Ginter Botanical Garden gardens has the potential to expose the general public to microbially contaminated water and is a major concern. Previous research has shown that pathogenic microorganism transmission through irrigation has resulted in pathophysiological conditions such as skin irritations, ear, eye and wound infections, gastrointestinal illnesses and upper respiratory infections (House et al., 1993).

Nutrients such as nitrogen and phosphorus can originate from fertilizer and

chemical application runoff from area agriculture, residential and commercial developments. Excessive input of these nutrients can cause eutrophication of surface water. The eutrophication cycle consists of:

- Excess nutrients stimulate phytoplankton and submerged aquatic vegetation growth
- Increase in turbidity causes decreased subsurface light penetration
- Death of submerged aquatic vegetation and phytoplankton
- Oxygen demand is accelerated and depleted by organic decomposition and microbe and phytoplankton respiration.
- Low dissolved oxygen kills fish and other aquatic creatures; water smells bad; water cannot fulfill intended use.

Eutrophication is the most common impairment of surface waters in the United States (U.S. EPA, 1990). It negatively affects aquatic ecosystems and commonly makes the water body unsuitable for its designated use (Carpenter et al., 1998).

Petroleum hydrocarbons, including products such as oil and gas, are generated from surrounding area roadways by traffic activity, fluid leakage, component wear, roadway maintenance and pavement degradation (Sansalone & Buchberger, 1997; Shinya et al., 2000). These pollutants contain polycyclic aromatic hydrocarbons which are known to have both carcinogenic and mutagenic properties (Farrington & Meyers, 1975; Farrington, 1980). The volatile and more water soluble petroleum compounds found in these products have been found to have harmful effects on the reproduction and behavior of fish, along with detrimental effects on overall water

quality (Cranwell, 1975).

SITE DESCRIPTION

Lewis Ginter Botanical Garden is an 82-acre public garden located in the metropolitan Richmond, Virginia area, just north of the Richmond city limits.

It is located at the lower part of the North Run Watershed and is further divided into two smaller watersheds called the Thorpe Branch Watershed and the Small Streams Watershed (Figure 1). From a high point on the site near the Garden's main buildings, approximately half the property drains into the Thorpe Branch Watershed and the other half into the Small Streams Watershed. The garden is surrounded by commercial and residential developments to the north, south and west. Lakeside Country Club borders the northeast boundary of the site and Belmont Golf Course and Lakeside Avenue border the southeast boundary. These neighborhoods drain into either the smaller Thorpe Branch or Small Streams Watersheds or directly into the North Run Watershed (Figure 2). It is expected that the runoff from these urban areas carry typical urban pollutants including nitrogen, phosphorus, fecal coliform bacteria and petroleum products.

Three man-made lakes are located on the property and are a contiguous part of the many water features located in the Garden. Sydnor Lake is a focal point of the garden's public area and includes a wetland garden, two small recirculation streams, and a smaller pond located behind the Robins Tea House. It was constructed in 1990 for water storage and has a total capacity of approximately 10 million gallons.

Sydnor Lake receives its water from a combination of localized garden runoff, a deep well known as Well #2 that was drilled on the property in 1987, and Thorpe Branch stormwater. At the location of the intake pipe that carries stormwater overflow to Sydnor Lake, Thorpe Branch drains an approximately 16.1 square mile stormwater runoff area. The 6" intake pipe is capable of delivering up to 250 gpm of floodwater runoff to Sydnor Lake during major storm events. From Sydnor Lake, water is pumped up into another man-made lake on the property known as the Irrigation Pond. The Irrigation Pond was constructed in 2000 as part of the garden's long-term water management plan to provide sustainable and affordable irrigation water for the gardens. The Irrigation Pond is not part of the garden's public display area and its primary function is to store water for garden irrigation. The majority of the water stored in the Irrigation Pond is water pumped from Sydnor Lake, but it also receives drainage water from localized garden runoff. The Irrigation Pond covers an area of approximately 3.5 acres, has a maximum depth of 13', and has an approximate storage capacity of 10 million gallons (Figure 3; Nelson Byrd Woltz Landscape Architects et al., 2007).

MATERIALS AND METHODS

The Irrigation Pond water sampling was conducted during the months of June, July and August 2012. No attempt was made to favor either rain events or dry periods. Water sampling was collected using a clear plastic container once a week in the late afternoon at one of two sampling locations as shown on Figure 4 at a depth of

approximately 20 to 30 cm below the water surface. A total of 12 water samples were obtained.

On the first testing day, the water was transferred to bottles provided by Air, Water and Soil Laboratories, Inc. of Richmond, Virginia and was immediately taken to their laboratory so that they could run the following tests: *E. Coli* [Colilert 18/QT], nitrate + nitrite [SM 18/4500-NO₃ F], total nitrogen [Calc.2], TKN [EPA351.2/R2.0], total phosphorus [SM 18/4500-P E], TPH-Semi-Volatiles (ORO)[SW8015C], and TPH-Volatiles (GRO)[SW8015C]. (Note - test methods are in brackets) Tests conform to the Virginia Environmental Laboratory Accreditation Program, which is overseen by the National Environmental Laboratory Accreditation Conference. All tests are approved by the U.S. EPA and conform to either Standard Methods for the Examination of Water and Wastewater (American Public Health Association, 1998), Guidelines Establishing Test Procedures for the Analysis of Pollutants; Analytical Methods for Biological Pollutants in Ambient Waters; Final Rule (U.S. EPA, 2003) or the Clean Water Act Analytical Methods (U.S. EPA , 2012). The water was also tested on site that day and for the remaining testing dates for pH, total ammonia (NH₃+NH₄⁺), nitrite (NO₂⁻), nitrate (NO₃⁻), and phosphate (PO₄³⁻) using an API (of Chalfont, Pennsylvania) Freshwater Master Test Kit and Phosphate Test Kit.

DATA

The results of the water sample testing performed by Air, Water and Soil Laboratories, Inc. of Richmond, Virginia are shown in full in Appendix A as provided by them.

The data obtained from the 12 water samples taken over the months of June – August 2012 is shown in Appendix B and is organized to show the pH, total ammonia ($\text{NH}_3+\text{NH}_4^+$), nitrite (NO_2^-), nitrate (NO_3^-), and phosphate (PO_4^{3-}) for each date tested.

RESULTS

The Irrigation Pond test results from the analysis done by Air, Water and Soil Laboratories, Inc. of Richmond, Virginia on June 6, 2012 are as follows: *E. Coli* at 91mpn/100ml, TPH-Volatiles (GRO) at < 0.5 mg/L, TPH-Semi-Volatiles (ORO) at < 1 mg/L, total nitrogen at 0.3mg/L, TKN at 0.28mg/L and nitrate + nitrite at < 0.1mg/L and total phosphorous at 0.05 mg/L (See Table 1. Below)

Table 1. Irrigation Pond Test Results – Air, Water and Soil Laboratories, Inc.

| Parameter | Results |
|-------------------------------|---------|
| E. Coli mpn/100ml | 91 |
| TPH-Volatiles (GRO) mg/L | < 0.5 |
| TPH-Semi Volatiles (ORO) mg/L | < 1 |
| Nitrate + Nitrite mg/L | < 0.1 |
| Phosphorus, Total mg/L | 0.05 |
| TKN mg/L | .28 |
| Nitrogen, Total mg/L | 0.3 |

The Irrigation Pond test results from the onsite water testing done using the API Freshwater Master Test Kit and the API Phosphate Test Kit from June – August 2012 are as follows: pH for the Irrigation Pond ranged from a low of 6.4 to a high of 8.4 with a mode of 7.4. Total ammonia (NH₃+NH₄⁺) ranged from 0 to 0.25 mg/L with a mode of 0.25 mg/L. Nitrite (NO₂⁻) and nitrate (NO₃⁻) test results were a constant 0 mg/L. phosphate (PO₄³⁻) test results were a constant 0.5 mg/L. (See Table 2. below)

Table 2. Irrigation Pond Test Results - API Freshwater Master Test Kit and the API Phosphate Test Kit

| | June 2012 | | | | July 2012 | | | | August 2012 | | | |
|---|-----------|------|------|------|-----------|------|-----|-----|-------------|-----|-----|------|
| | 5 | 14 | 22 | 29 | 6 | 13 | 20 | 27 | 10 | 17 | 24 | 31 |
| pH | 7.4 | 7.4 | 7.4 | 7.4 | 7.4 | 7.4 | 6.4 | 6.8 | 8.4 | 7.4 | 7.4 | 7.4 |
| Ammonia NH ₃ +NH ₄ ⁺ mg/L ¹ | 0 | 0.25 | 0.25 | 0.25 | 0.25 | 0.25 | 0 | 0 | 0.25 | 0 | 0 | 0.25 |
| Nitrite NO ₂ ⁻ mg/L ² | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Nitrate NO ₃ ⁻ mg/L ³ | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Phosphate PO ₄ ³⁻ mg/L ⁴ | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 |

¹ Ammonia (NH₃+NH₄⁺) - See Appendix C for API Color Chart. The results in the table reflect the values from the Color Chart. On October 6, 2012, Mars Fishcare Technical Service and Research representative Nathan Fekula noted that an Ammonia value of 0 mg/L might indicate an ammonia range of 0 - 0.125 mg/L and an ammonia value of 0.25 mg/L might indicate an ammonia range of 0.125 - 0.375 mg/L.

² Nitrite (NO₂⁻) - See Appendix C for API Color Chart. The results in the table reflect the values from the Color Chart. On October 6, 2012, Mars Fishcare Technical Service and Research representative Nathan Fekula noted that a nitrite value of 0 mg/L might indicate a nitrite range of 0 -0.125 mg/L .

³ Nitrate (NO₃⁻) - See Appendix C for API Color Chart. The results in the table reflect the values from the Color Chart. On October 6, 2012 Mars Fishcare Technical Service and Research representative Nathan Fekula noted that a nitrate value of 0 mg/L might indicate a nitrate range of 0 - 2.5 mg/L.

⁴ Phosphate (PO_4^{3-}) - See Appendix C for API Color Chart. The results in the table reflect the values from the Color Chart. On October 6, 2012 Mars Fishcare Technical Service and Research representative Nathan Fekula noted that a phosphate value of 0.5 mg/L might indicate a phosphate range of 0.375 - 0.75 mg/L.

DISCUSSION

Neither the U.S. EPA or the VA DEQ has developed irrigation water quality standards for the parameters tested. A combination of U.S. EPA and VA DEQ surface freshwater standards, ambient freshwater standards and recreational surface freshwater standards combined with The Food and Agriculture Organization of the United Nations irrigation water standards were used for the discussion that follows.

Lewis Ginter Botanical Garden falls within Ecoregion IX, level III, ecoregion 45 for U.S. EPA Ambient Water Quality Criteria Recommendations (U.S. EPA, 2000). It falls within ecoregion 9 for the VA DEQ Freshwater Nutrient Criteria (Virginia Water Resources Research Center, 2005).

pH

The pH of the Irrigation Pond ranged from a low of 6.4 on July 20, 2012 to a high of 8.4 on August 10, 2012 with a mode of 7.4. The VA DEQ numerical criteria for surface water pH ranges between 6.0 and 9.0 (Virginia Administrative Code: Virginia Legislative Information System, 2012) and the U.S. EPA national recommended water quality criteria for pH for freshwater aquatic life ranges from 6.5 to 9.0 (U.S. EPA, 1986). The Food and Agriculture Organization of the United

Nations lists the normal pH range for irrigation water between 6.5 and 8.4 (Ayers & Westcot, 1985). The pH of the Irrigation Pond affects the solubility of trace elements and nutrients, and a pH outside of the normal range can cause a nutrient imbalance or a metal toxicity to aquatic life. All pH reading fall within VA DEQ surface water quality criteria. The 6.4 pH reading on July 20, 2012 falls outside of the U.S. EPA water quality criteria and The Food and Agriculture Organization of the United Nations normal pH range for irrigation waters. However, it is only a tenth of a pH unit outside the normal range. Although a pH reading outside the normal limits does not necessarily indicate poor water quality, it is an indication that the water needs further evaluation.

E. Coli

Both the U.S. EPA and VA DEQ use the following *E. coli* water quality standard for recreational freshwater systems: *E. coli* bacteria shall not exceed a monthly geometric mean (a minimum of five samples over a 30 day period for VA DEQ and 2 samples over a 30 day period for U.S. EPA) of 126mpn/100ml. If data is insufficient to calculate the geometric monthly mean, then no more than 10% of the total samples in the assessment period shall exceed 235mpn/100ml. (Virginia Administrative Code: Virginia Legislative Information System, 2012; U.S. EPA, 2003). Only one *E. coli* test was done on the Irrigation Pond on June 5, 2012. The E. Coli level on that date was 91mpn/100ml, which falls well below the single sample maximum of 235mpn/100ml. The EPA accepts the Colilert-18 testing method as an approved method for enumerating *E. coli* in ambient water (U.S. EPA, 2003).

Nutrients -Nitrogen

The U.S. EPA Ambient Water Quality Criteria Recommendations lists reference conditions for nutrients for Lakes and Reservoirs. Reference conditions indicate levels of nutrients that would be in waters that are relatively undisturbed or in least disturbed conditions. The U.S. EPA reference conditions for total nitrogen, TKN and nitrate + nitrite for Ecoregion IX, level III, ecoregion 45 were 0.304 mg/L, 0.245 mg/L and 0.059 mg/L respectively. Results from Air, Water and Soil Laboratories, Inc. show total nitrogen at 0.3mg/L, TKN at 0.28mg/L and nitrate + nitrite at < 0.1mg/L indicating that the Irrigation Pond is very near what the U.S. EPA would consider a reference condition. (U.S. EPA, 2000)

VA DEQ does not have recommended numerical criteria for total nitrogen. The limiting factor in the eutrophication of Virginia's warm water lakes is almost always phosphorus, therefore making criteria for nitrogen unnecessary (VA. DEQ, 2004). However, the Virginia Water Resources Research Center, 2005, studied total nitrogen levels for 41 lakes in ecoregion 9, and the study showed total nitrogen ranging from 0.30 mg/L to 1.08 mg/L in that area. The total nitrogen for the Irrigation Pond was 0.3 mg/L, which is at the low end of the ecoregion 9 total nitrogen range of values, measured in the 41 lakes by Virginia Water Resources Research Center.

The VA DEQ does have surface freshwater criteria for total ammonia nitrogen. Ammonia is toxic to fish and the toxicity is dependent upon pH. According to VA

DEQ, at a pH of 6.4, total ammonia nitrogen should not exceed 50.5 mg N/L; at a pH of 7.4, total ammonia nitrogen should not exceed 23mg N/L; and at a pH of 8.4, total ammonia nitrogen should not exceed 3.88 mg N/L. At pH 8.4, the Irrigation Pond total ammonia was 0.25mg/L. Converting total ammonia to total ammonia nitrogen¹ (multiplying 0.25 mg/L x .7762) results in total ammonia nitrogen of 0.19 mg N/L, which falls well below the VA DEQ criteria. (Virginia Administrative Code: Virginia Legislative Information System, 2012)

Nutrients –Phosphorus

The U.S. EPA Ambient Water Quality Criteria Recommendations indicate that a reference condition for total phosphorus for Ecoregion IX, level III, ecoregion 45 is 0.0225 mg/L (U.S. EPA, 2000). Additionally, VA DEQ recommends total phosphorus levels should be no greater than between 0.03 and 0.04 mg/L for ecoregion 9. (Virginia Administrative Code: Virginia Legislative Information System, 2012). Results from Air, Water and Soil Laboratories, Inc. show total phosphorus at 0.05 mg/L and results from the API Phosphate Test Kit show a total phosphate (PO_4^{3-}) of 0.5 mg/L. Converting total phosphate to total phosphorus² (multiplying PO_4^{3-} by 0.3268) results in total phosphorus of 0.16 mg/L. Both tests clearly show that the Irrigation Pond total phosphorus levels are above both U.S. EPA reference conditions and VA DEQ water quality criteria levels.

¹ The API Freshwater Master Test Kit reads total ammonia ($\text{NH}_3+\text{NH}_4^+$) as an ammonia ion, and is a measure of both nitrogen and hydrogen atoms in the molecule. VA DEQ results are reported as total ammonia nitrogen, which is a measure of only the nitrogen atoms in the molecule.

² The API Freshwater Master Test Kit reads total phosphate (PO_4^{3-}) as a phosphate ion, and is a measure of both phosphorus and oxygen atoms in the molecule. U.S. EPA and VA DEQ results are reported as total phosphorus, which is a measure of only the phosphorus atoms in the molecule.

Total Petroleum Hydrocarbons

Total Petroleum Hydrocarbons is a term that is used to describe a wide variety of chemical compounds derived from crude oil and its by-products. The U.S. EPA indicated in their Quality Criteria for Water 1986, that it is difficult to set criteria for oil and grease because they are not definitive chemical categories and include thousands of organic compounds with properties that vary physically, chemically and toxicologically (U.S. EPA, 1986). Since the Irrigation Pond was tested for TPH-Volatiles (GRO) and TPH-Semi-Volatiles (ORO), and not for particular products, there is no way to analyze the results against the criteria as set forth by the U.S. EPA Quality Criteria for Water 1986. Additionally, the results of TPH- Volatiles (GRO) of < 0.5 mg/L and TPH-Semi-Volatiles (ORO) < 1 mg/L are both below the Lab Quantitation Limits as approved for the testing method by the U.S. EPA, which is an indication that the results are below the applicable limit as established by the U.S. EPA (U.S. EPA, 2007). However, it should be noted that aquatic flora and fauna have shown negative effects to individual oil and gas product levels below the Lab Quantification Limits and further evaluation of this product is needed to make any meaningful conclusions (U.S. EPA, 1986).

CONCLUSIONS AND RECOMMENDATIONS

pH, Nitrogen and E. Coli

The Irrigation Pond pH was within VA DEQ numerical criteria for surface waters and was within or very near water quality criteria for U.S. EPA freshwater aquatic life and The Food and Agriculture Organization of the United Nations normal range for irrigation water. Nitrogen levels in the Irrigation Pond were very near reference

conditions per U.S. EPA Ambient Water Quality Criteria Recommendations and were also at the low end of the ecoregion 9 total nitrogen range of values measured in the 41 lakes by Virginia Water Resources Research Center. Ammonia levels were also within the VA DEQ surface freshwater criteria. *E. coli* bacteria levels were below both U.S. EPA and VA DEQ water quality standards for recreational freshwater systems. The only recommendation for these variables at this time is to continue testing and monitoring the Irrigation Pond year round - on a monthly basis from October to March and weekly from April to September. The test methods can be improved with the use of better and more sensitive test kits. The testing should be expanded to include Sydnor Lake, which is an integral part of the Lewis Ginter Botanical Garden water storage system.

Phosphorus

Phosphorus levels in the Irrigation Pond were above both U.S. EPA Ambient Water Quality Criteria Recommendations and VA DEQ recommended levels. Excessive inputs of phosphorus, in combination with nitrogen, can cause eutrophication of surface water. In the United States, eutrophication is the most common impairment of surface waters, often making the water body unsuitable for its designated use. Weekly visual observation of the Irrigation Pond did not show any substantial algae or other aquatic vegetation growth. It is possible that this was because the total nitrogen to total phosphorus ratio (TN:TP) was less than 7:1, which some studies have shown is indicative of potential N-limitation (Abell et al., 2010). However, since phosphorus is above both U.S. EPA and VA DEQ recommendations, further research needs to be done to determine the cause of the elevated phosphorous levels, and if

at all possible, methods to reduce these levels. Short-term remedies for excessive phosphorus inputs and possible associated eutrophication include:

- the addition of oxygen to waters via aerators. This step has already been done. Four aerators were installed in the Irrigation Pond several years ago to assist in controlling existing eutrophication problems.
- the addition of Ca, Al, or Fe salts to accelerate the precipitation of phosphates (Nichols, 1983; Ryding, 1985).
- The addition of aquatic plants such as *Juncus effuses*, *Iris ensata*, *Scirpus triqueter*, *Iris pseudacorus* and *Zizania latifolia*. These plants, as well as other types of vegetation, have been shown to reduce both nitrogen and phosphorus levels in planted wetlands (Iamchaturapatr et al., 2007; Gumbricht, 1993).

Further discussion with Lewis Ginter Botanical Garden staff regarding the remedial steps to eliminate phosphorus is recommended.

Total Petroleum Hydrocarbons

The U.S. EPA Quality Criteria for Water 1986 for oil and grease establishes limits for particular products, and there is there is no way to analyze the TPH- Volatiles (GRO) and TPH-Semi-Volatiles (ORO) results against those criteria. In addition, the results for TPH-Volatiles (GRO) and TPH-Semi-Volatiles (ORO) were below Lab Quantitation Limits. This indicates that quantities for both items were below the applicable limit as established by the U.S. EPA (U.S. EPA, 2007). However, individual oil and grease products have been shown to be harmful at limits lower than the Lab Quantitation Limits, and further research in this area is needed to establish whether

levels of these products in the Irrigation Pond are safe.

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Figure Captions

Figure 1 - Regional Map of Richmond showing watersheds and counties

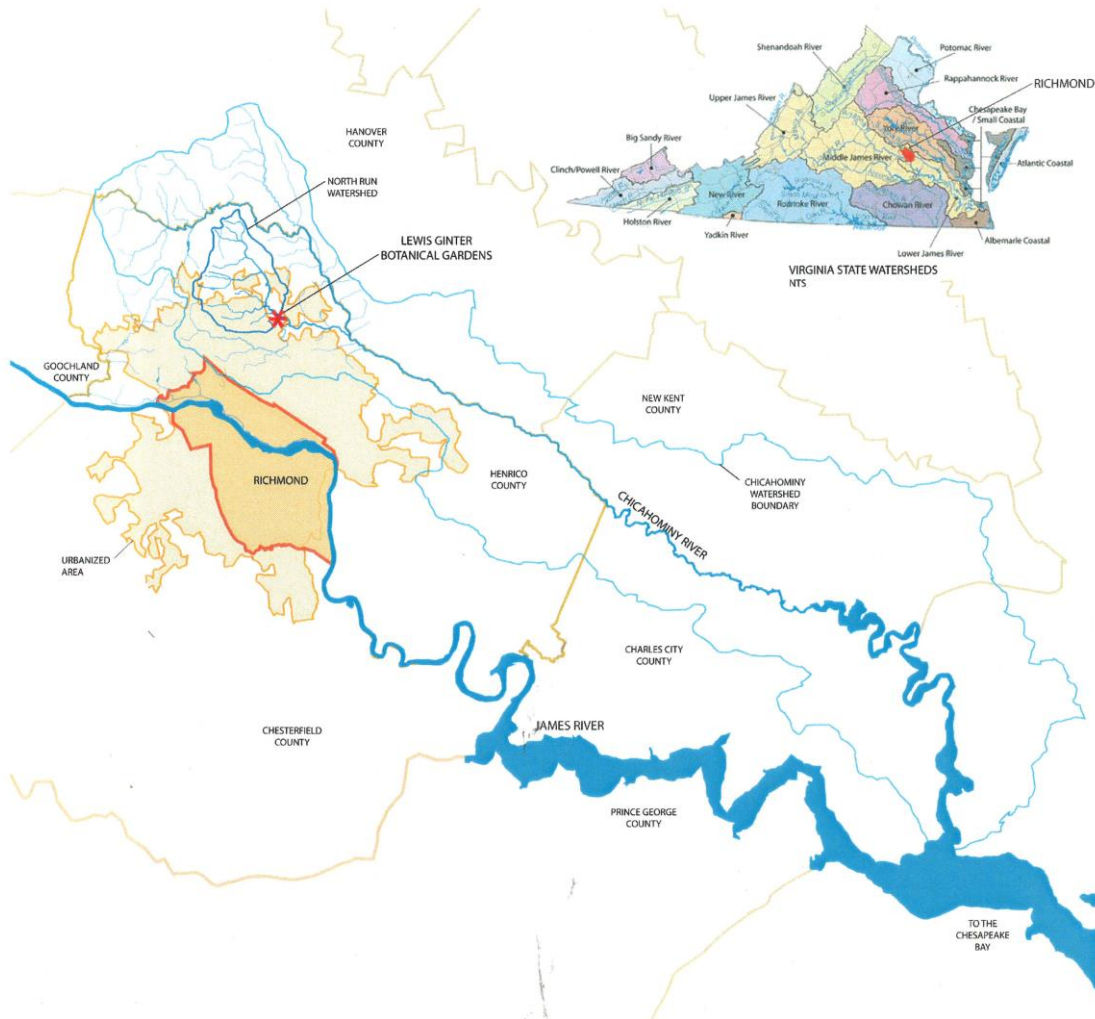
Figure 2 - Local Watersheds in immediate vicinity of LGBG

Figure 3 - Locator Plan of Lewis Ginter Botanical Garden and Existing Conditions

Figure 4 - Irrigation Pond Sampling Locations

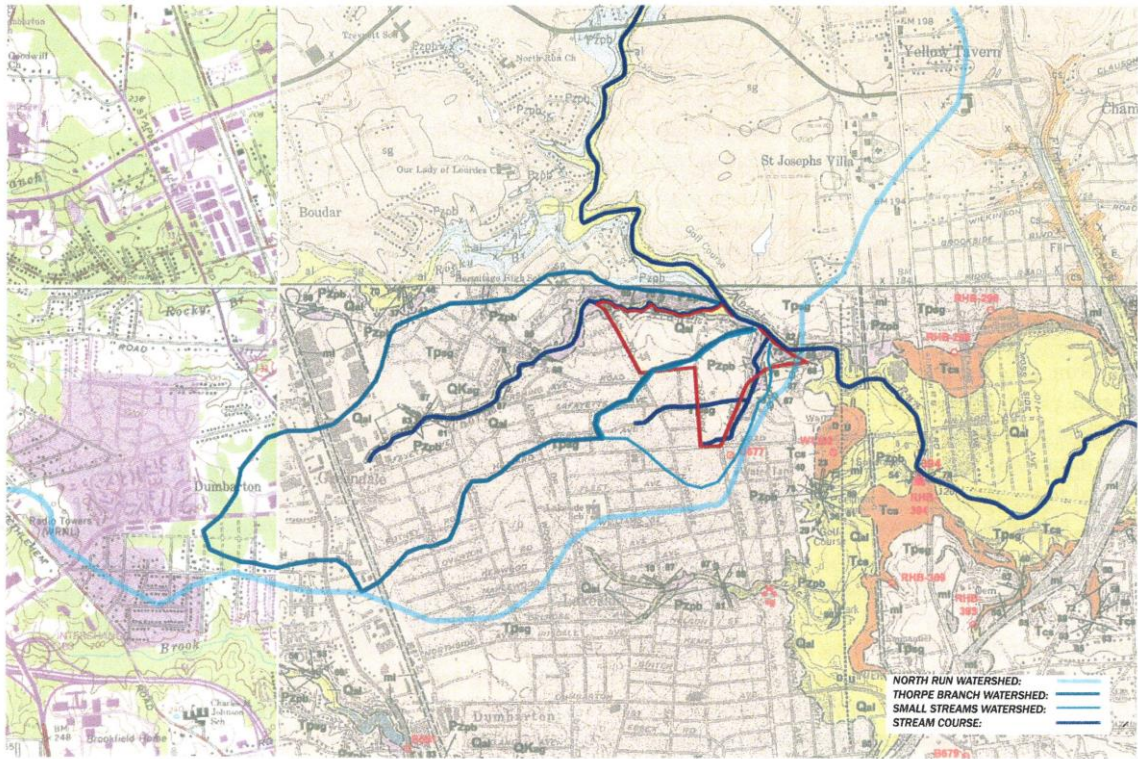
All Figures are from the Lewis Ginter Botanical Garden Hydrologic Master Plan and are used with permission from Shane Tippett, Executive Director, Lewis Ginter Botanical Garden.

Figure 1



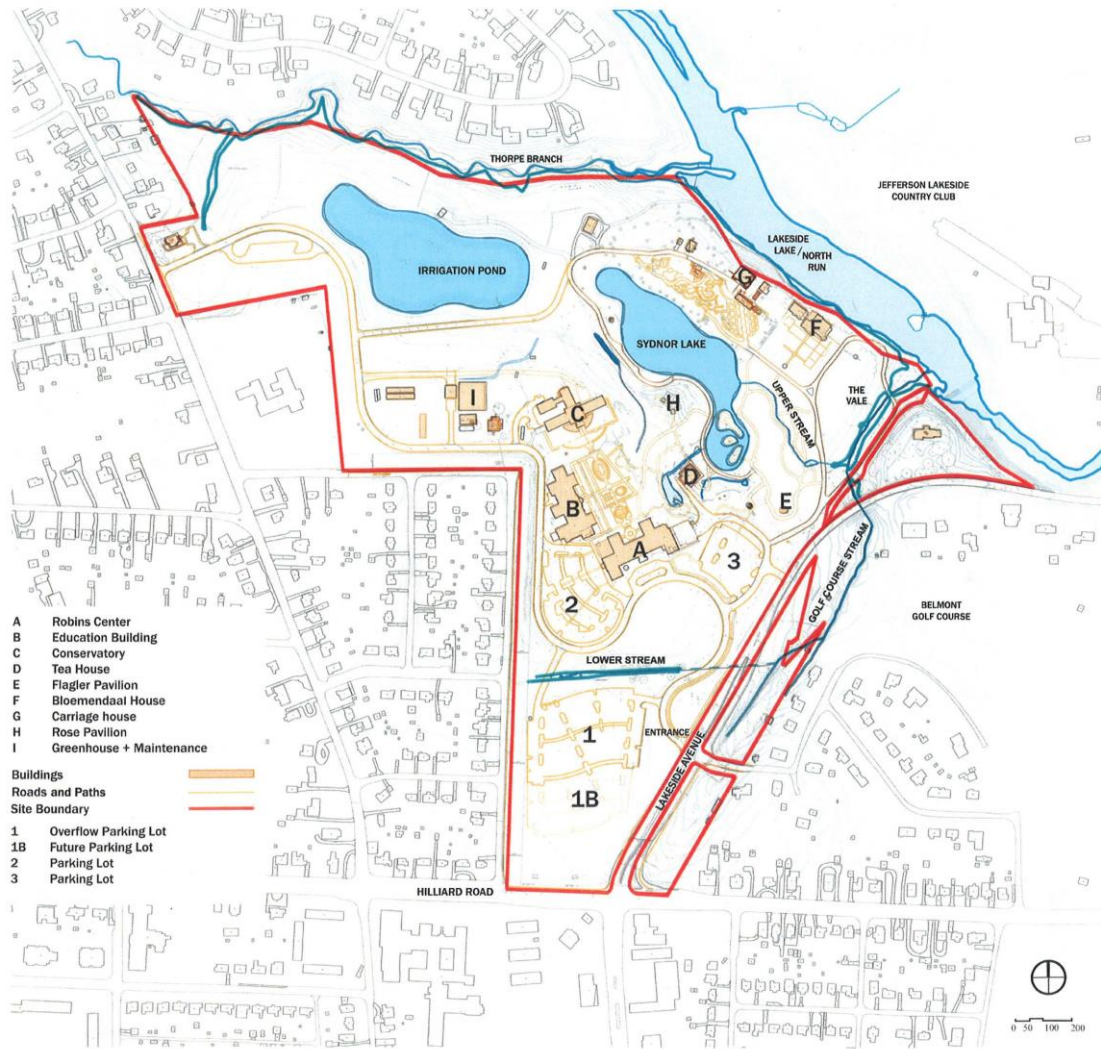
Regional map of Richmond showing watersheds and counties

Figure 2



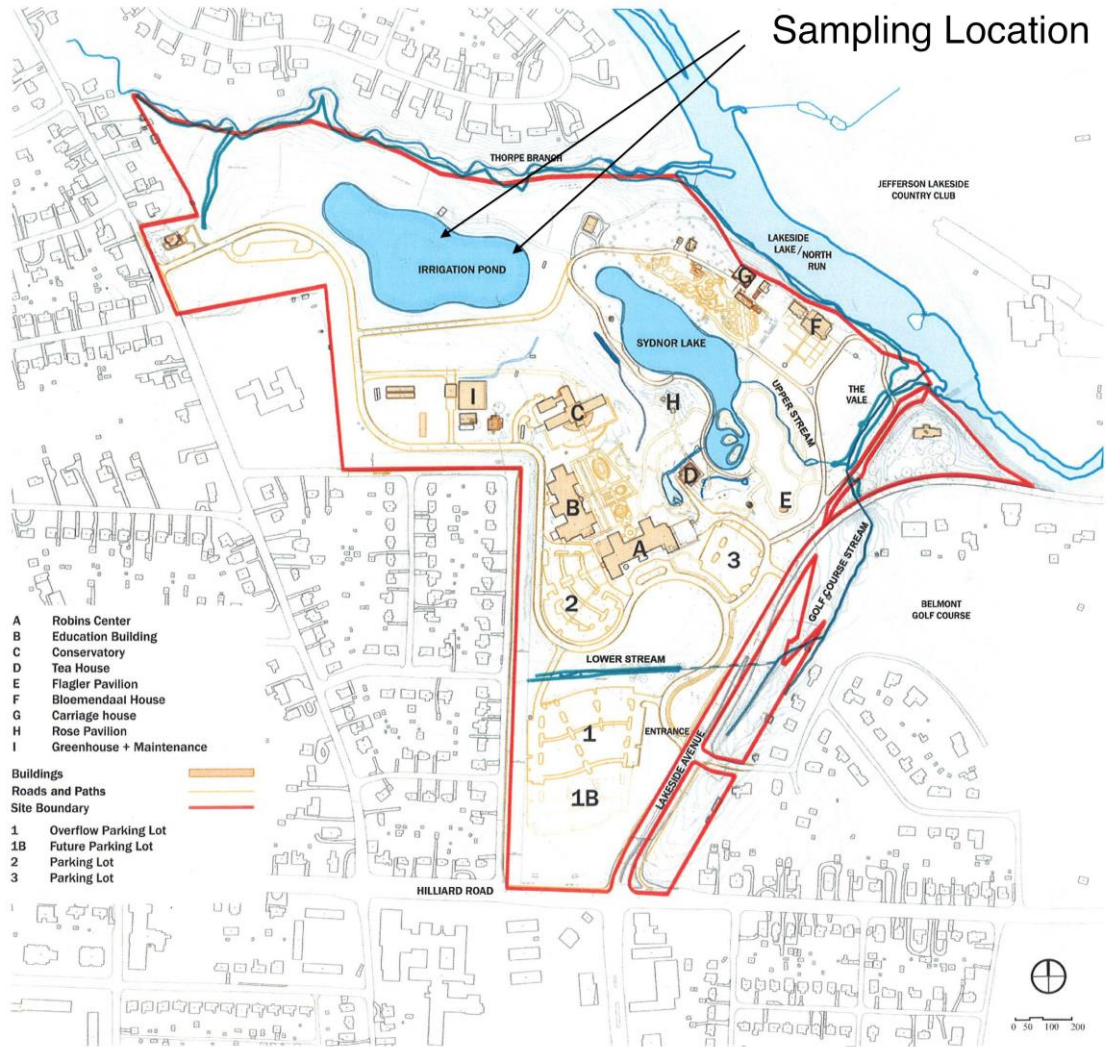
Local watersheds in immediate vicinity of LGBG

Figure 3



Locator Plan of Lewis Ginter Botanical Garden and Existing Conditions

Figure 4



Locator Plan of Lewis Ginter Botanical Garden and Existing Conditions

Irrigation Pond Sampling Locations

Appendix A



2109A North Hamilton Street • Richmond, Virginia 23230 • Tel: (804) 358-8295 Fax: (804) 358-8297

Certificate of Analysis

Final Report

Laboratory Order ID 12060078

| | | |
|--------------------------------|------------------------------|--|
| Client Name: CASH Customer | Date Received: June 05, 2012 | |
| -- | Date Issued: June 12, 2012 | |
| --, -- -- | | |
| Submitted To: Karin Stretchko | Project Number: NA | |
| Client Site I.D.: Lewis Ginter | Purchase Order: NA | |

Sample Summary List

| Laboratory Sample ID | Sample ID | Sample Date | Receive Date |
|-------------------------|----------------|-------------|--------------|
| 12060078-001 | LGBG Irr. Lake | 06/05/2012 | 06/05/2012 |

Ted Soyars
Laboratory Manager

End Notes:

The test results listed in this report relate only to the samples submitted to the laboratory and as received by the Laboratory.

Unless otherwise noted, the test results for solid materials are calculated on a wet weight basis. Analyses for pH, dissolved oxygen, temperature, residual chlorine and sulfite that are performed in the laboratory do not meet NELAC requirements due to extremely short holding times. These analyses should be performed in the field. The results of field analyses performed by the Sampler included in the Certificate of Analysis are done so at the client's request and are not included in the laboratory's fields of certification nor have they been audited for adherence to a reference method or procedure.

The signature on the final report certifies that these results conform to all applicable NELAC standards unless otherwise specified. For a complete list of the Laboratory's NELAC certified parameters please contact customer service.

This report shall not be reproduced except in full without the expressed and written approval of an authorized representative of Air Water & Soil Laboratories, Inc.



061220121806



2109A North Hamilton Street • Richmond, Virginia 23230 • Tel: (804) 358-8295 Fax: (804) 358-8297

Certificate of Analysis

Final Report

Laboratory Order ID 12060078

Client Name: CASH Customer
 --
 --, -- --

Date Received: June 05, 2012
 Date Issued: June 12, 2012

Submitted To: Karin Stretchko
 Client Site I.D.: Lewis Ginter

Project Number: NA
 Purchase Order: NA

Analytical Results

Sample I.D.: LGBG Irr. Lake
 Date/Time Sampled: 06/05/12 16:00

Laboratory Sample I.D.: 12060078-001

| Parameter | Method | Sample Results | Qual | Rep Limit | Samp Prep Date/Time | Analysis Date/Time | Analyst |
|--------------------------|-----------------|----------------|------|-----------|---------------------|--------------------|---------|
| E. Coli | Colilert 18/QT | 91 mpn/100mL | | 1 | 06/05/2012 16:40 | 06/05/2012 16:40 | EML |
| TPH-Volatiles (GRO) | SW8015C | < 0.5 mg/L | | 0.5 | 06/08/2012 14:57 | 06/08/2012 14:57 | AJR |
| TPH-Semi-Volatiles (ORO) | SW8015C | < 1 mg/L | | 1 | 06/06/2012 14:30 | 06/07/2012 13:33 | JHV |
| Nitrate+Nitrite | SM18/4500-NO3 F | < 0.1 mg/L | | 0.1 | 06/08/2012 14:30 | 06/08/2012 14:30 | NMK |
| Phosphorus, Total | SM18/4500-P E | 0.05 mg/L | | 0.01 | 06/08/2012 09:30 | 06/08/2012 09:30 | EML |
| TKN | EPA351.2/R2.0 | 0.28 mg/L | | 0.2 | 06/12/2012 13:24 | 06/12/2012 13:24 | NMK |
| Nitrogen, Total | Calc.2 | 0.3 mg/L | | 0.2 | 06/08/2012 14:30 | 06/08/2012 14:30 | NMK |

Summary of Analytical QC Batches

| QC Batch ID | Method | Sample List |
|-------------|-----------------|--------------|
| QC120606020 | Colilert 18/QT | 12060078-001 |
| QC120608006 | SW8015C | 12060078-001 |
| QC120608018 | SM18/4500-P E | 12060078-001 |
| QC120611007 | SW8015C | 12060078-001 |
| QC120612030 | EPA351.2/R2.0 | 12060078-001 |
| QC120612031 | SM18/4500-NO3 F | 12060078-001 |



061220121806



Air Water & Soil Laboratories, Inc.
 2109 A. North Hamilton Street
 Richmond, Virginia 23230
 (804) 358-8295 - Telephone
 (804) 358-8297 - Fax

Analysis Certifications Report

Client Name: CASH Customer
 Client Site ID: Lewis Ginter
 Submitted To: Karin Stretchko

Date Issued: 06/12/2012

Order ID: 12060078

| Parameter | Method | NC | VA-NP | WVA |
|--------------------------|-----------------|----|-------|-----|
| E. Coli | Colilert 18/QT | | X | |
| Nitrate+Nitrite | SM18/4500-NO3 F | | X | |
| Nitrogen, Total | Calc.2 | | X | |
| Phosphorus, Total | SM18/4500-P E | | X | |
| TKN | EPA351.2/R2.0 | | X | |
| TPH-Semi-Volatiles (ORO) | SW8015C | | X | |
| TPH-Volatiles (GRO) | SW8015C | X | X | X |

"X" denotes that the associated parameter is certified or accredited under the program indicated in the column header.

VA-NP = VELAP Non-Potable Water: Virginia DGS Division of Consolidated Laboratory Services(460021); WVA: West Virginia Department of Environmental Protection(350); NC: North Carolina(495)

Appendix B

API Freshwater Master Test Kit and API Phosphate Test Kit test results for Irrigation Pond

| DATE | NH ₃ +NH ₄ mg/L | NO ₂ ⁻ mg/L | NO ₃ ⁻ mg/l | PO ₄ ³⁻ mg/L | pH |
|---------|---------------------------------------|-----------------------------------|-----------------------------------|------------------------------------|-----|
| 6/5/12 | 0 | 0 | 0 | 0.5 | 7.4 |
| 6/14/12 | 0.25 | 0 | 0 | 0.5 | 7.4 |
| 6/22/12 | 0.25 | 0 | 0 | 0.5 | 7.4 |
| 6/29/12 | 0.25 | 0 | 0 | 0.5 | 7.4 |
| 7/6/12 | 0.25 | 0 | 0 | 0.5 | 7.4 |
| 7/13/12 | 0.25 | 0 | 0 | 0.5 | 7.4 |
| 7/20/12 | 0 | 0 | 0 | 0.5 | 6.4 |
| 7/27/12 | 0 | 0 | 0 | 0.5 | 6.8 |
| 7/10/12 | 0.25 | 0 | 0 | 0.5 | 8.4 |
| 7/17/12 | 0 | 0 | 0 | 0.5 | 7.4 |
| 7/24/12 | 0 | 0 | 0 | 0.5 | 7.4 |
| 7/31/12 | 0.25 | 0 | 0 | 0.5 | 7.4 |

Appendix C

