Publication No. 03-136-209

PILOT PROJECT TO TEST NATURAL WATER TREATMENT CAPACITY OF WETLAND AND TAILING SAND FILTRATION ON MINED PHOSPHATE LANDS

Prepared by
SCHREUDER, INC.

under a grant sponsored by

FIPR
Florida Institute of Phosphate Research

March 2005

The Florida Institute of Phosphate Research was created in 1978 by the Florida Legislature (Chapter 378.101, Florida Statutes) and empowered to conduct research supportive to the responsible development of the state's phosphate resources. The Institute has targeted areas of research responsibility. These are: reclamation alternatives in mining and processing, including wetlands reclamation, phosphogypsum storage areas and phosphatic clay containment areas; methods for more efficient, economical and environmentally balanced phosphate recovery and processing; disposal and utilization of phosphatic clay; and environmental effects involving the health and welfare of the people, including those effects related to radiation and water consumption.

FIPR is located in Polk County, in the heart of the central Florida phosphate district. The Institute seeks to serve as an information center on phosphate-related topics and welcomes information requests made in person, or by mail, email, or telephone.

Florida Institute of Phosphate Research
1855 West Main Street
Bartow, Florida 33830
(863) 534-7160
Fax: (863) 534-7165
http://www.fipr.state.fl.us

PILOT PROJECT TO TEST NATURAL WATER TREATMENT CAPACITY OF WETLAND AND TAILING SAND FILTRATION ON MINED PHOSPHATE LANDS

FINAL REPORT

Peter J. Schreuder, CPG
Principal Investigator

SCHREUDER, INC.
110 West Country Club Drive
Tampa, Florida 33612 USA

Prepared for

FLORIDA INSTITUTE OF PHOSPHATE RESEARCH
1855 West Main Street
Bartow, Florida 33830 USA

Project Manager: Steven G. Richardson
FIPR Contract Number: 98-03-136

and

SOUTHWEST FLORIDA WATER MANAGEMENT DISTRICT
2379 Broad Street
Brooksville, Florida 34609 USA

Contract Manager: Mark D. Barcelo, P.E.
Manager of the Hydrologic Section
SWFWMD Agreement Number: 99C0NN0008

March 2005

DISCLAIMER

The contents of this report are reproduced herein as received from the contractor. The report may have been edited as to format in conformance with the FIPR *Style Manual*.

The opinions, findings and conclusions expressed herein are not necessarily those of the Florida Institute of Phosphate Research, nor does mention of company names or products constitute endorsement by the Florida Institute of Phosphate Research.

PERSPECTIVE

Demand for water in central Florida is increasing while the availability of groundwater is dwindling. Lowered aquifer levels from municipal and industrial pumping have increased the threat of saltwater intrusion in coastal areas and have affected spring flows in more inland areas. The Southwest Florida Water Management District (SWFWMD) is proposing to cut back on the permitted quantities of water pumped from the Floridan Aquifer in the Southern Water Use Caution Area (SWUCA) so as to be closer to sustainable yield levels. This will have a significant impact on current, and especially future, water users. To meet the growing demands of development, alternative sources of water must be sought. Possible sources are reclaimed wastewater, the capture of storm water, the capture of "excess" surface water, development of the surficial aquifer, and desalinization of seawater.

The idea of storing water in reservoirs created from mine pits has been around for some time; however, that water is subject to evaporative losses, must be piped to the users, and must be treated before use. Getting the water into the ground as rapidly as possible would reduce evaporative losses, would help restore a depleted aquifer, and the aquifer itself could be used as the "pipeline" if the production well was some distance from the injection well. To avoid degradation of the aquifer, the injected water must be of equal or better quality than the water already in the aquifer. This project is part of an effort to examine the feasibility of temporarily storing wastewater or excess surface water in small surge reservoirs on mined lands, purifying the water with wetland treatment and sand tailings filtration, and then injecting the treated water into the Floridan Aquifer. The project reported here was a field test of a treatment wetland and a sand tailings filtration basin conducted on former phosphate mined lands at the Progress Energy Florida, Hines Energy Complex in Polk County, Florida. FIPR and SWFWMD (including its associated Basin Boards) equally shared the cost of this study, while Progress Energy Florida provided the site and some "in-kind" services.

The goals of the project were to:

- Demonstrate in a pilot-scale project on mined lands the effectiveness of wetland treatment followed by tailing sand filtration for purifying surface waters to meet drinking water quality standards.
- Collect water quality and design data that could be used in developing full-scale projects.

A 1.5-acre tailing sand filtration bed was constructed and an existing wetland in a "U-shaped" ditch, 8400 feet in length, was used. Waters from two sources were tested in the system: water from the power plant cooling pond (August 2002 to March 2003) and waste water from the city of Bartow (April 2003 to December 2003).

The main purpose of the sand filter was to remove particulates and microorganisms, and the sand filter did indeed drastically reduce bacterial counts, although water coming through the sand filter in the field test sometimes exceeded drinking water standards for coliform bacteria. In an earlier laboratory study (FIPR Publication No. 03-124-153), microorganism removal was very effective when a sufficient unsaturated zone was maintained at the surface of the sand columns. It is thought that situations that caused greater saturation of sand at or near the surface of the sand filter may be related to the occasional exceedance of the drinking water standard for coliform bacteria in the field demonstration. Better water level control (i.e., better control of the inflow and outflow pumps) may solve this problem. Additionally, a steadier flow of water (in contrast with frequent pump shutdowns due to lightning, etc.) will likely promote the development of a biologically active surface film (or "schmutzdecke") that should aid bacterial removal. The authors also suggest that a UV system could be added to kill bacteria that may occasionally get through the sand filter.

For many parameters, the cooling pond water was of fairly good quality to begin with. The sand filter reduced coliform bacterial counts, but iron and manganese concentrations actually increased after the water passed through the wetland and sand filter, probably due mainly to dissolution of iron and manganese mineral impurities in the sand. The lowering of TDS, sodium and chloride by the system was attributed to dilution by rainfall, but sulfate concentrations were lowered to a greater extent than could be accounted for by dilution, suggesting biological reduction of the sulfate in the wetland. Wetlands typically have low redox potentials, and the chemically reduced water from a treatment wetland may lower the risk of pyrite oxidation and the resulting arsenic release that has been observed in some cases when highly oxygenated water (high redox potential) has been injected into the Floridan aquifer.

The effluent had higher concentrations of nitrate and total phosphorus than the cooling pond water, and wetland treatment was effective in lowering these concentrations. Fluoride was increased by passing the effluent water through the wetland and sand filter, but it was below the drinking water standard. Iron increased slightly after the effluent water passed through the wetland and sand filter, but manganese did not. Lower levels of Fe and Mn when effluent water passed through the sand filter than when cooling pond water passed through the sand filter may have been due to those metals being leached to lower levels in the sand by the time the effluent water was applied (waste water was tested after the cooling pond water test). Other tests have shown that cleaner sands (lower levels of clay or apatite minerals) have much lower levels of iron or manganese in the leachate.

Other FIPR-funded projects on this topic include:

- *Potential Use of Phosphate Mining Tailing Sand for Water Filtration: Leaching Tests* (FIPR Publication No. 03-113-154). This report addressed the leaching of sand tailings in barrels as a first step in determining the effects of sand tailing filtration on water quality.

- *An Investigation of the Capacity of Tailing Sand to Remove Microorganisms from Surficial Waters* (FIPR Publication No. 03-124-153). This was a laboratory column leaching study to examine microorganism removal by sand tailing filtration. Sufficient depth of the surface unsaturated zone and lower relative permeability of the sand were important factors in the effective removal of microorganisms.

- *Feasibility of Natural Treatment and Aquifer Recharge of Wastewater and Surface Waters Using Mined Phosphate Lands: A Concept to Expand Regional Water Resource Availability* (FIPR Publication No. 03-113-186). This project examined the feasibility, including costs, of several potential real world possibilities for water treatment and storage on mined lands.

- *Water Quality Investigation of In-Situ Tailing Sand Deposits Under Natural Environmental Conditions* (FIPR Publication No. 03-129-185). Examined water quality in several sand tailings deposits in the field. Iron was greater than the 0.3 mg/l standard in nine of the 12 sites, but three were below. Manganese was higher than the 0.05 mg/l standard at seven of the twelve sites, but five were below. In all cases, fluoride was below the 4.0 mg/l standard, and sulfate was below the 250 mg/l standard.

Steven G. Richardson
FIPR Reclamation Research Director

ABSTRACT

This project involves the treatment of flood surface waters by and reclaimed water treatment through natural processes on lands previously mined by phosphate mining companies. As a result of the mining process, the phosphate companies produce open mine pits, clay settling areas (CSA) and tailing sand deposits, which the companies are required to reclaim as land and lakes, wetlands, pastures, and agricultural lands.

The basis for this project was the premise that the natural systems, in particular, wetlands created on CSAs followed by tailing sand filtration, will remove the organic, inorganic and microbiological contaminants from the waters, resulting in water that will meet drinking water standards. After collecting and analyzing a total of 725 water samples from the end point of the natural treatment system at the tailing sand filter basin, all EPA and State of Florida mandated Primary and Secondary Drinking Water Standards (PDWS/SDWS) were met except for a few parameters. The parameters that exceeded SDWS were iron, manganese, fluoride, color, and odor, which are parameters that commonly occur in natural groundwater at concentrations exceeding the secondary drinking water standards. There were two exceedances of chloroform, which is found in the Group 2 Unregulated drinking water standards, but all other parameters found in PDWS, Volatile Organic Compounds, Synthetic Organic Contaminants (pesticides and herbicides), Group 1 Unregulated, Group 3 Unregulated, and Radionuclide parameters were either undetected in the laboratory analyses or were detected, but at concentrations lower than the drinking water standard for that parameter. During the study, *Cryptosporidium* and *Giardia* were never found present in the filter basin, but both microorganisms were found present in the wetland and in the water from the cooling pond and effluent discharge. In varying concentrations, fecal and total coliform were found present in the wetland, cooling pond, and effluent discharge on a regular basis; however, total coliform concentrations exceeded the recommended limit of 4 colonies per unit of 100 milliliters less than 30 percent of the time in the water pumped from the filter basin. SI attributes the presence of total coliform to high water levels within the filter basin because of several, re-occurring operational impacts and very rainy periods. There is also a hypothesis that the very low nutrient and very low total dissolved solids concentration in the water pumped from the treatment wetland in combination with the very high vertical hydraulic conductivity of the filter bed tailing sands prevented the formation of a biologically active layer at the sand/water interface commonly referred to as the “schmutzdecke”. The function of the “schmutzdecke” is (among others) to remove coliform bacteria. In addition to these constraints, the periodic nature of the wetland pumpage did not help to promote the development of this biofilm.

An additional important finding is a reduction in surface water temperature averaging 5.4° C with a maximum of 8.5° C while flowing through the wetland. Additionally, during filtration through the tailing sand filter the temperature increased by an average of 1.3° C. The average net difference in temperature of the water flowing into the wetland and the treated and filtered water flowing from the filter basin is 3.9° C, with a maximum of 9.8° C.

Another significant discovery is that the concentrations of sulfate were reduced in the surface water more than could be accounted for by dilution of rainfall. In addition, the pH of the cooling pond water was reduced by approximately two units during the flow through the wetland, indicating a reducing environment. This observation, in combination with the observation of the hydrogen sulfide odor coming from the wetland water as it was delivered to the surface of the filter basin, leads to a qualitative observation that sulfate concentrations in the water flowing into the wetland are being reduced. No field data were collected to determine the sulfide concentrations in water pumped from the wetland or water pumped from the basin. It is reasonable to infer a correlation between hydrogen sulfide smell and the odor measurements. If this correlation holds then the odor data suggests that the water pumped from the basin may also be in a reducing state. Recharging water into the aquifer that is low or depleted in oxygen and in a reducing state could reduce the probability or prevent the dissolution of metals from the limestone matrix.

The project envisions the treated water from the basin will be used to be recharged to the underlying Floridan Aquifer through a recharge well that will be installed on-site as part of the overall feasibility test of the Aquifer Recharge and Recovery Project (ARRP) concept. This concept envisions recharging naturally treated surface, storm and waste waters to the underlying Floridan Aquifer, an extensive confined groundwater system capable of storing and transmitting large quantities of water, for later retrieval through another (pumping) well at some distance away and at a different time.

The Florida Institute of Phosphate Research (FIPR) and the Southwest Florida Water Management District (SWFWMD) have funded this pilot project to assess the natural treatment capacity of previously mined phosphate lands in support of the ARRP concept. The installation of the recharge well is funded cooperatively by the SWFWMD and Progress Energy Florida.

ACKNOWLEDGEMENTS

The principal investigator wishes to acknowledge the valuable support he has received during the conduct of this project from the FIPR Research Director Dr. Steven Richardson, from the SWFWMD representative Mark Barcelo, P.E. and from the representatives of Progress Energy Florida (PEF), Mr. Kent Hedrick, P.E. and Randy Melton, CEP. He also gratefully acknowledges the in-kind contribution from PEF, which provided the site, constructed the electric power supply lines and provided the electrical service free of charge. The constant watch of PEF's security detail was an important factor in the safety and constancy of the operation. The success of such a project is directly related to the attention to detail for the field operations as well as the data and sample collection that was given by the hydrologic field technician Dana Gaydos. She also assisted in the recording and management of the large database and along with Julie K. Earls, in the preparation of this report. John M. Dumeyer, P.E., P.G., Holly L. Regar, and Nicholas C. Schrier provided additional contributions to the successful implementation of the project.

TABLE OF CONTENTS

TABLE OF CONTENTS (CONT.)

TABLE OF CONTENTS (CONT.)

TABLE OF CONTENTS (CONT.)

LIST OF FIGURES

Figure **Page**

APPENDIX FIGURES

LIST OF FIGURES (CONT.)

Figure **Page**

LIST OF TABLES

Table **Page**

APPENDIX TABLES

LIST OF TABLES (CONT.)

Table **Page**

EXECUTIVE SUMMARY

The economic development of an area depends on the availability of reasonably priced water of suitable quality to meet the public water supply, industrial, agricultural and mining needs of the region. In the Florida peninsula, all fresh water is derived from rainfall, and as such, the supply is limited. In the past, the water demands were easily met by incoming rainfall. The aquifer system underlying the area is quite large and can store significant quantities of groundwater. However, the pumpage of groundwater in local areas of the peninsula has exceeded the rate of recharge to the underlying aquifer systems. This has led to significant depletions of the groundwater storage in the overlying surficial aquifer, causing lakes and wetlands to go dry.

In 1995, the Board of Directors of FIPR approved a two-year study (Project 94-03-113) to assess the feasibility of the use of mined phosphate lands to store excess surface water and wastewater for later use to help meet the future projected agricultural, industrial and public water supply demands. After the completion of the first year of study, it was determined that significant dependable long-term excess surface water supplies could not be obtained. A change in the scope of the study to concentrate on aquifer recharge was proposed and approved by FIPR. The change involved the use of mined lands to naturally treat wastewater and excess surface water so that it would meet drinking water standards to enable the water to be stored in the underlying Floridan Aquifer for later retrieval. In this manner, the large evaporative losses and water quality changes incurred by surface water storage facilities would not occur.

The phosphate mining operations result in two key post-mining features of particular interest to this water treatment approach; these are the clay settling areas (CSA) and the production of large quantities of tailing sands. The study investigated temporary storage of excess surface water, wastewater, or storm water in a reservoir; and then releasing the water to a manmade wetland (former CSA) for treatment by biological processes; followed by filtration by tailing sands. The sand filtration step would further reduce total suspended solids and improve water quality to drinking water standards. After filtration, this water can either be stored in the Floridan Aquifer for future use or pumped directly for consumer use. This integrated natural treatment and recharge is called the Aquifer Recharge and Recovery (ARRP) concept.

In 1997, the FIPR authorized a study to evaluate the feasibility of applying the ARRP concept in the Bone Valley phosphate-mining district for increasing potential water supplies for the future. The investigators have prepared conceptual engineering plans including descriptions of the estimated capital and operating and maintenance costs of five (5) ARRP project sites in the Bone Valley phosphate-mining district. Their findings are documented in a report "Feasibility of Natural Treatment and Recharge of Waste Water and Surface Waters Using Mined Phosphate Lands, A Concept to Expand Regional Water Resource Availability" that was prepared for FIPR in 2002. This publication Number 03-113-186 is available from FIPR.

The above-mentioned publication number 03-113-186 contains a paragraph "Permitting Requirements for Implementation (of ARRP)" on page 14 providing a synopsis of the regulatory requirements to obtain a permit to construct and operate an ARRP system. The Florida Department of Environmental Protection (FDEP) will be responsible for the reservoirs, dams, clay settling areas, wetlands and the recharge well(s). Diversion of surface water and the recovery of recharged water is primarily the responsibility of the Southwest Florida Water Management District (SWFWMD), along with wetland issues. The US Army Corps of Engineers (USACOE) will also be involved in reservoirs as well as wetland issues.

While this report documents the feasibility of implementing the ARRP concept based on the availability of water and reasonable unit cost, the question of the acceptability of the quality of the water leaving the natural treatment system remained. To address this question a pilot study was proposed, accepted by the FIPR, constructed and operated for three years. This document reports the construction of the pilot project using a wetland system and tailing sand filter basin, as well as the results of the chemical analyses of water samples and field data collected during the two years of actual operation. While the original plan called for a three-year project, operational problems extended the project by 1.5 years. Notwithstanding, the results of the project are quite promising. Of all the primary and secondary drinking water standards (PDWS/SDWS), including those for Unregulated Group I, II, and III contaminants, radionuclides, and microorganisms, the project documented only five parameters (in the SDWS list) that exceeded the recommended levels from time to time. The only other occasional exceedance was for total coliform with concentrations of 4.0 MPN/100 ml or greater. During the last year of operation, this concentration limit was exceeded less than thirty percent of the time. Schreuder, Inc. has identified the most probable mechanical/operational cause.

The other parameters that exceeded the SDWS standards were iron, manganese, fluoride (initially), color and odor. Schreuder, Inc asserts that with a careful selection of the tailing sand that is used in the construction of the filter basin, the iron, manganese and fluoride exceedances will be significantly reduced or eliminated. A better distribution of the water to be discharged to the surface of the filter basin and a more constant discharge of that water in combination with filter sand surface preparation will allow the build-up of a bacteriologically active layer in the "schmutzdecke" which will eliminate the exceedance of the total coliform standard. The exceedances of the color and odor standard may persist. While the filtration process clearly reduced the concentrations of both compounds in the water from the wetland system, it did not reduce them enough to meet the SDWS.

The investigators discussed and considered the issues related to endocrine disrupting chemicals (EDC), Pharmaceuticals, and Personal Care Products (PPCP). Several approaches were considered to incorporate possible research in this project. At the time this project was funded, however, the USGS and the USEPA were still in the process of establishing sampling and analytical protocols. This consideration along with the fact that the purpose of the study was to investigate if natural processes could produce water meeting the drinking water standards, which did not and still do not incorporate EDC / PPCP criteria, were the reasons not to incorporate any EDC / PPCP work into the Pilot Study.

The temperature of the warmer water from the cooling pond and effluent inflow into the wetland was reduced on an average by 5.4°C (9.7°F) while flowing through the wetland with a maximum difference of 8.5°C (15.3°F). The temperature increased slightly by an average of 1.3°C (2.3°F) during filtration through the tailing sand filter basin. The average net difference in temperature of the water flowing into the wetland and the treated and filtered water flowing from the filter basin is 3.9°C (7.0°F), with a maximum difference of 9.8°C (17.6°F).

During the wet season, the rainfall captured between the two dams on either side of the linear wetland would provide an additional source of water to the wetland. This action had a diluting effect on the water in the wetland and in the filter basin. This is reflected in the record on the chloride concentrations, particularly during the period when water from the cooling pond was being used as source water. The average chloride concentration flowing into the wetland was 105 mg/l. The average chloride concentration in the water pumped from the wetland was 89 mg/l, while the average concentration in the water pumped from the filter basin was 76 mg/l. Similarly, when the effluent was used as a source, the average concentrations were 94, 74, and 71 mg/l respectively in the effluent, wetland and filter basin water.

The concentrations of sulfate in the surface water were reduced to a larger extent than could be accounted for by dilution with rainfall. In addition, the pH of the cooling pond water was reduced by approximately 2 units during the flow through the wetland, indicating a reducing environment. This, in combination with the hydrogen sulfide odor coming from the wetland water being delivered to the surface of the filter basin, leads to a qualitative observation that sulfate in the water flowing into the wetland is most likely being reduced to sulfide by anaerobic bacteria in the wetland in the presence of organic matter. No field data were collected to determine the sulfide concentration in the water pumped from the wetland or in the water pumped from the basin. In addition to this observation, it is reasonable to infer a correlation between hydrogen sulfide smell and the odor measurements. If this correlation holds, then the odor data suggest that the water pumped from the basin may also be in a reducing state because the average odor concentration in the cooling pond water was 30 TON (Threshold Odor Number), in the wetland water 80 TON, and in the basin water 42 TON. Recharging water low or depleted in oxygen and in a reducing state will reduce the probability or prevent the dissolution of metals from the limestone matrix.

The present natural treatment system at the Hines Energy Complex site of Progress Energy of Florida can be easily adapted to use the water for different applications. The initial purpose of the natural treatment system was to investigate if the industrial wastewater from the cooling pond and the treated effluent from the City of Bartow could be treated to such an extent that this water could be recharged to the underlying Floridan Aquifer. This pilot study has documented that *all* primary drinking water standards were met all the time except for total coliform. Five secondary standards were exceeded from time to time. However, the Department of Environmental Regulation can and will allow exemptions for exceedances of secondary drinking water standards. The only remaining issue for the use of this water for recharge to the Floridan Aquifer is the compliance with the total coliform criterion. There is ample evidence from projects in this area that treatment of the water from the filter basin with ultraviolet light will bring this criterion into compliance. From the data that we have, we do not know of any limitations of this system except for the microorganism issue described above. As stated before this limitation can be easily overcome with the use of ultra-violet light treatment of the filtered water.

No range of costs to implement a natural treatment system was evaluated in this project. However, a previously published report by FIPR (Publication number 03-113-186), which is referenced above, provides several cost estimates for five proposed projects in the mining areas. According to that report, a total of 84 million gallons per day could be recharged to the Floridan Aquifer at an average unit cost of $1.10 per 1000 gallons. UV treatment was not considered in the conceptual engineering plans and cost estimates in the earlier study.

INTRODUCTION

This pilot project is part of a multi-stage research plan that involves the treatment of industrial wastewater from a cooling pond used by an electric power generating plant, as well as tertiary treated effluent and surface waters by treatment through natural processes on reclaimed lands previously mined by phosphate mining companies. The basic concept on which this project rests is the assumption that natural systems, in particular wetlands created on reclaimed waste clay settling areas (CSAs) followed by tailing sand filtration, will remove any organic, inorganic and microbiological contaminants in surface (storm) waters, industrial wastewaters, and domestic wastewaters. While a significant body of information exists on the capacity of wetlands to treat effluent to meet the NPDES standards, information on the capacity of wetlands on reclaimed CSAs followed by tailing sand filtration to remove these contaminants to such an extent that Primary and Secondary Drinking Water Standards (PDWS/SDWS) can be met is limited. The purpose of this pilot study was to fill this lack of information on the feasibility of the concept by using an existing wetland and by constructing a tailing sand filter basin (hereafter referred to as basin) at the Hines Energy Complex (hereafter referred to as Hines) in Polk County, which is owned and operated by Progress Energy Florida. In addition to the construction of the tailing sand filter basin, pumping stations and pipelines were built to transport treated effluent, storm water, and industrial wastewater to the site.

After the infra-structure was built, an intensive two year water quality sampling and assessment project was completed to evaluate if this natural treatment system can safely and effectively recondition different types of surface waters, industrial wastewaters, and domestic wastewaters to meet the Florida Department of Environmental Protection and State's drinking water standards. The Florida Institute of Phosphate Research (FIPR) and the Southwest Florida Water Management District (SWFWMD) funded the project in equal parts. The ultimate goal of the overall project was a complete assessment of the feasibility to use this natural treatment process in combination with recharging the treated water to the underlying Upper Floridan Aquifer to use the aquifer as a temporary surface water storage reservoir without incurring evaporative losses, while at the same time increasing the overall regional water availability by capturing flood and storm waters. This pilot project is the first part of a larger project, which also includes the construction of a recharge well at Hines and the subsequent testing of the concept by recharging the naturally treated water through this well during the one year testing of the Aquifer Recharge and Recovery Project (ARRP) well.

PURPOSE AND OBJECTIVES OF CURRENT INVESTIGATION

The purpose of the pilot test was to evaluate the feasibility of using natural processes under controlled conditions to purify surface and wastewater to meet drinking water standards. The original mandate for this project was to use three kinds of water to test this concept, namely water from the cooling pond (industrial waste water), tertiary treated effluent (domestic waste water) from the City of Bartow's wastewater treatment plant, and surface runoff (storm water) from the water cropping areas on the property.

Because of time constraints resulting from operational difficulties, it was decided to focus primarily on the cooling pond water and effluent. No surface water runoff (storm water) was used as a source.

Construction of the project started in March 2000. The water quality sampling phase of the pilot project started in May 2001. The system operated from May 2001 through December 2001 with water from the cooling pond as the initial water source. Significant changes and modifications were made to the system between January and July of 2002. One of the major actions during that time was the disinfection of the entire filter piping and standpipes using chlorine. This process was followed by redevelopment of the filter piping by high-pressure backwashing and pumping. The delay occurred in that additional funding was requested for this work, which had to be approved by the Governing Boards of FIPR and the SWFWMD. The system was restarted in August 2002.

The system ran more or less continuously from August 2002 through March 2003 with water from the cooling pond as the water source. The cooling pond water is a mixture of storm water and treated effluent subjected to heating and cooling as well as evaporative losses. From April 2003 through December 2003, the system ran continuously with tertiary treated effluent as the water source until its shutdown in January 2004. The tertiary treated effluent (from here on referred to as effluent) was transported to the site via an existing pipeline along the east side of Hines. The third type of water (storm water) was to be transported from the water cropping areas on the property. These water-cropping areas are essentially CSAs, where rainfall is captured and directed to the cooling pond to replace the evaporative losses. Although this section of the pilot test was not performed due to issues with operational system, equipment repairs, and excessive rainfall, conclusions can still be made regarding the effectiveness of the treatment system.

LOCATION OF PROJECT AREA

The project was located at Progress Energy Florida's (PEF's) Hines Energy Complex to the southwest of the City of Bartow in Polk County in Florida as seen in Figure 1. The Hines site was built on previously mined land in Polk County, southwest of Bartow, Florida, located on County Road 555, just south of State Road 640.

The project was a pilot test for much larger systems that can be implemented at several locations around the area. The ARRP concept was developed as a result of a previous FIPR Study (Publication No. 03-113-186) entitled "Feasibility of Natural Treatment and Recharge of Waste Water and Surface Waters using Mined Phosphate Lands, A Concept to Expand Regional Water Resource Availability." In this study a total of five project sites were identified where the ARRP concept could be implemented and the construction, operating, and maintenance costs were estimated for each project. The locations of the five project sites are shown in Figure 2. The pilot test provides the necessary design data to implement the concept at several locations within the Bone Valley phosphate-mining district.

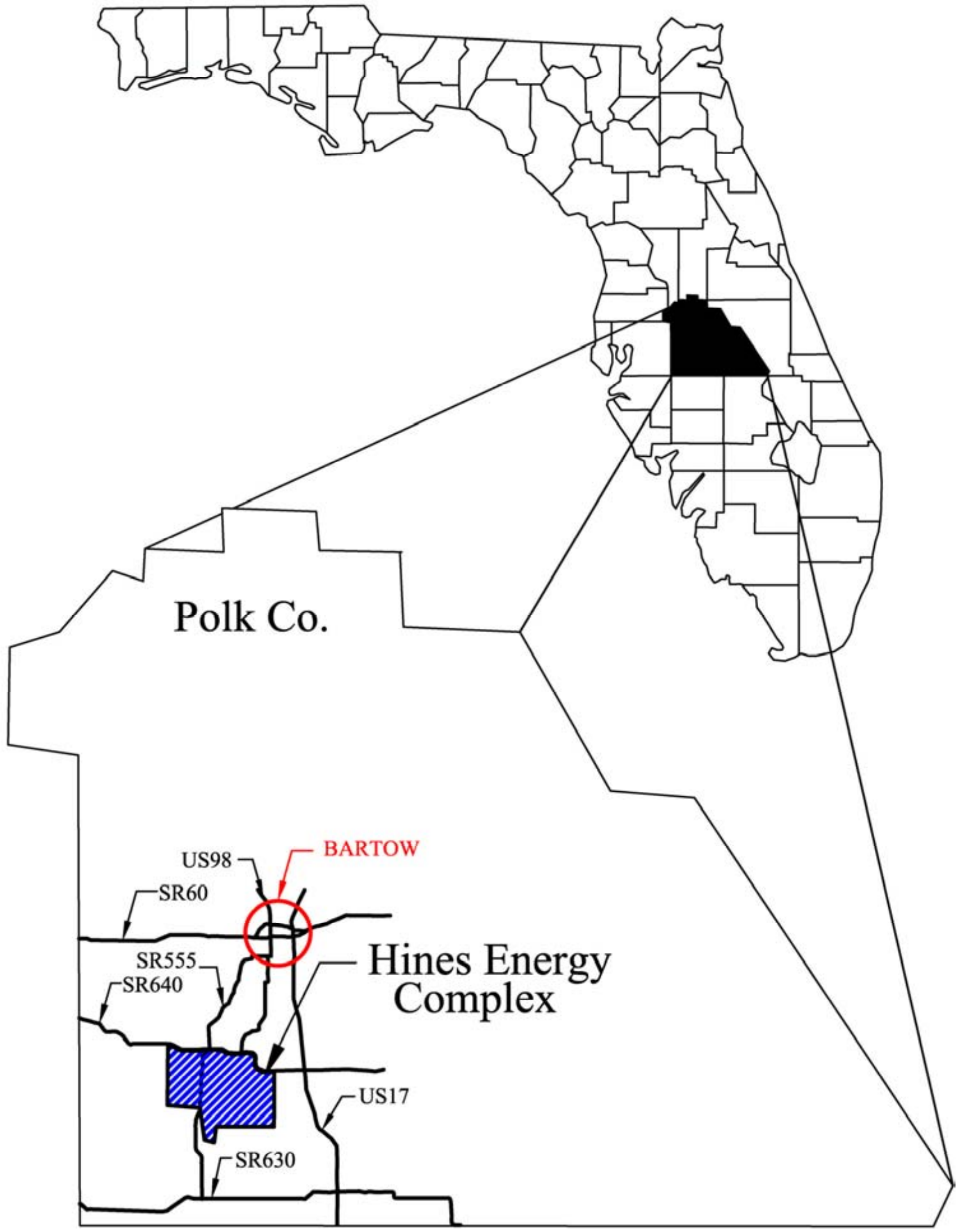


Figure 1. General Location of Progress Energy Florida's Hines Energy Complex with Surrounding Areas.

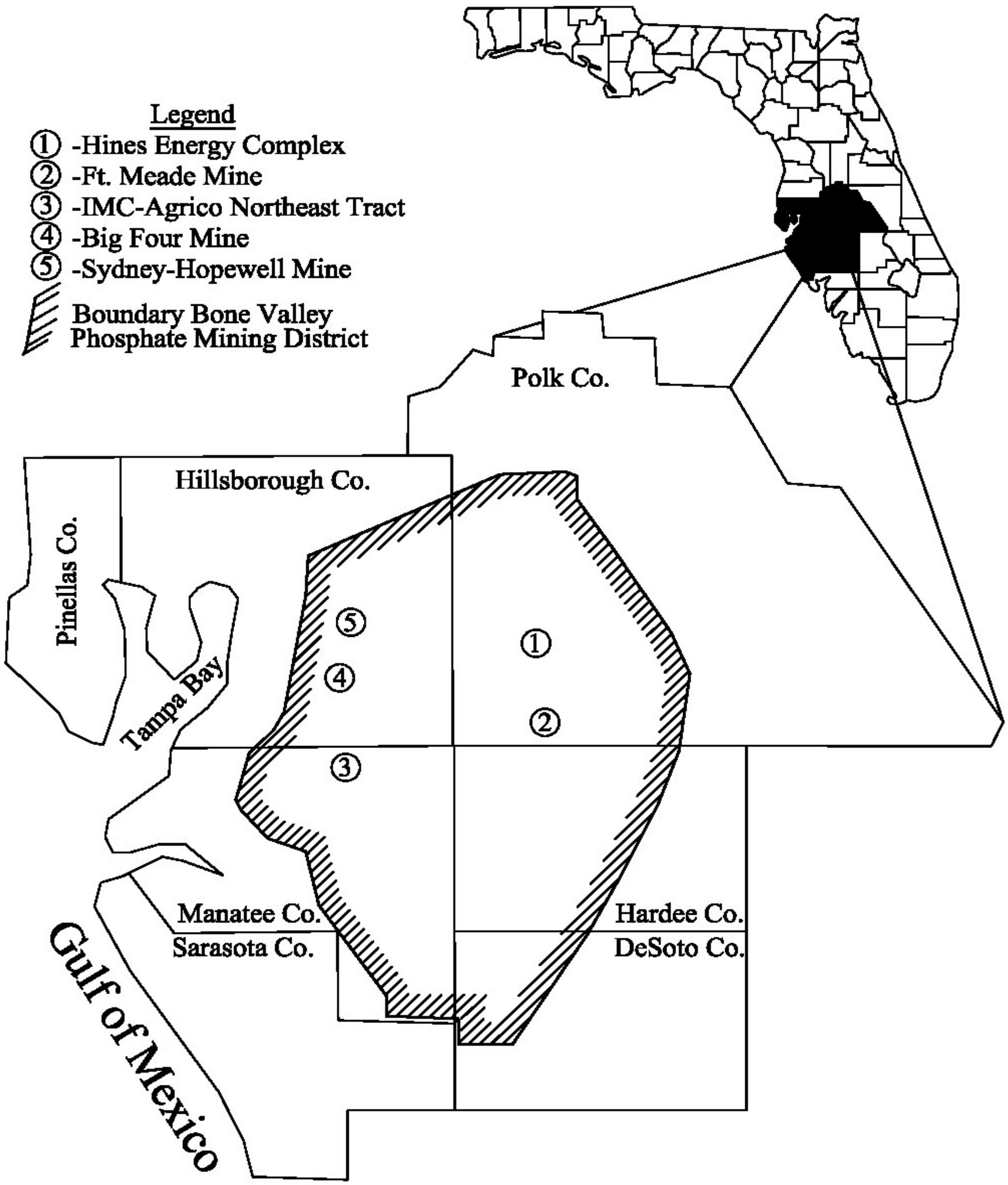


Figure 2. General Location of the Bone Valley Phosphate Mining District and the Project Sites.

SELECTION OF LOCATION OF THE PROJECT AREA

To select the location of the site for implementing the pilot study, Dr. Richardson and the Principal Investigator initially determined the criteria for the selection of a site. One of the key criteria for the selection of a site was the availability of three different types of water. The three types of water were storm water, treated or untreated effluent, and industrial wastewater. The second major criterion was the size of the system. While many clay-settling areas were possibly available, the size of the treatment area had to match the other testing constraints such as the size of the tailing sand filter basin to be constructed, the pumping rate, and the anticipated retention time within the wetland system.

After repeated field visits to several areas, a potential site was identified at Hines, which is owned and operated by PEF. This site came to the attention of the project team because PEF was interested in the ARRP concept as a means of creating additional long-term water storage for the capture of storm water from their water cropping areas (WCAs).

The Hines site occupies over 8,200 acres of previously mined phosphate land. This includes 900 acres of power generating and ancillary facilities, a 722-acre cooling reservoir, 2,000 acres that serve as buffer areas along the east and southeast portions of the site, and 520 acres along the west and southwest portions of the site that remain undeveloped and act as a wildlife preserve. A detailed map of the Hines site is presented in Figure 3.

The site selected for the pilot project at Hines consisted of two parallel ditches between two CSAs. One ditch (the larger one) was a return ditch for water from the N-15 CSA. The other (the smaller one) was initially constructed to collect toe drain seepage from the SA-8 CSA dam. To connect the two ditches hydraulically, a breach was dug in the berm separating the ditches. This connection is approximately 4000 feet to the west of the cooling pond. The location and layout of the ditches is presented in Figure 4. The ditches always contained surface water, and vegetation normally associated with wetland systems common to CSAs colonized both ditches (i.e., water hyacinths, water lettuce, baby's tears, cattails, dog fennel, and willows). The ditch system is considered a linear wetland system with a total length of approximately 8000 feet, an average width of approximately 25 feet and a depth of water ranging from 3 to 4 feet in the northern ditch and from 1.5 to 2.5 feet in the southern ditch. For the remainder of this report the two connected ditches will be identified as the "wetland."

The original concept of the pilot project set-up is shown in Figure 5. It was planned to excavate the eastern end of the ditch system to construct the tailing sand filter basin (hereafter referred to as the "basin"). After a detailed investigation, SI was informed that the N-15 dam was constructed with a sand drainage blanket. This sand drainage blanket drains towards the wetland, and therefore, the construction of a lined basin would have interfered with the draining function of the sand blanket. In addition, it was clear that constructing the basin could have also interfered with the toe of the dam containing the cooling pond. For these reasons it was decided to construct the filter basin at another location. This significantly increased the initially estimated cost of the project because of the additional pipe conveyance system that had to be built.

Two locations were considered for the construction of the basin. The first one was at the northwest corner of the SA-8 CSA. The second one was at the northeast corner of the N-11B CSA. The locations of both sites are shown in Figure 6. A soil-boring program was conducted at both sites. Based on the findings of this program, a decision was made to construct the basin at the northwest corner of SA-8. At both locations, the tailing sand was deposited on top of waste clays and mud waving had occurred resulting in an uncertainty where to find and mine clean (unmixed) sand tailings. At the SA-8 site, SI implemented a detailed soil exploration to map the depth and horizontal extent of the sand tailings deposits. The result of the soil boring survey was that SA-8 contained a sufficient quantity of clean unmixed sand tailing at the surface to construct the basin.

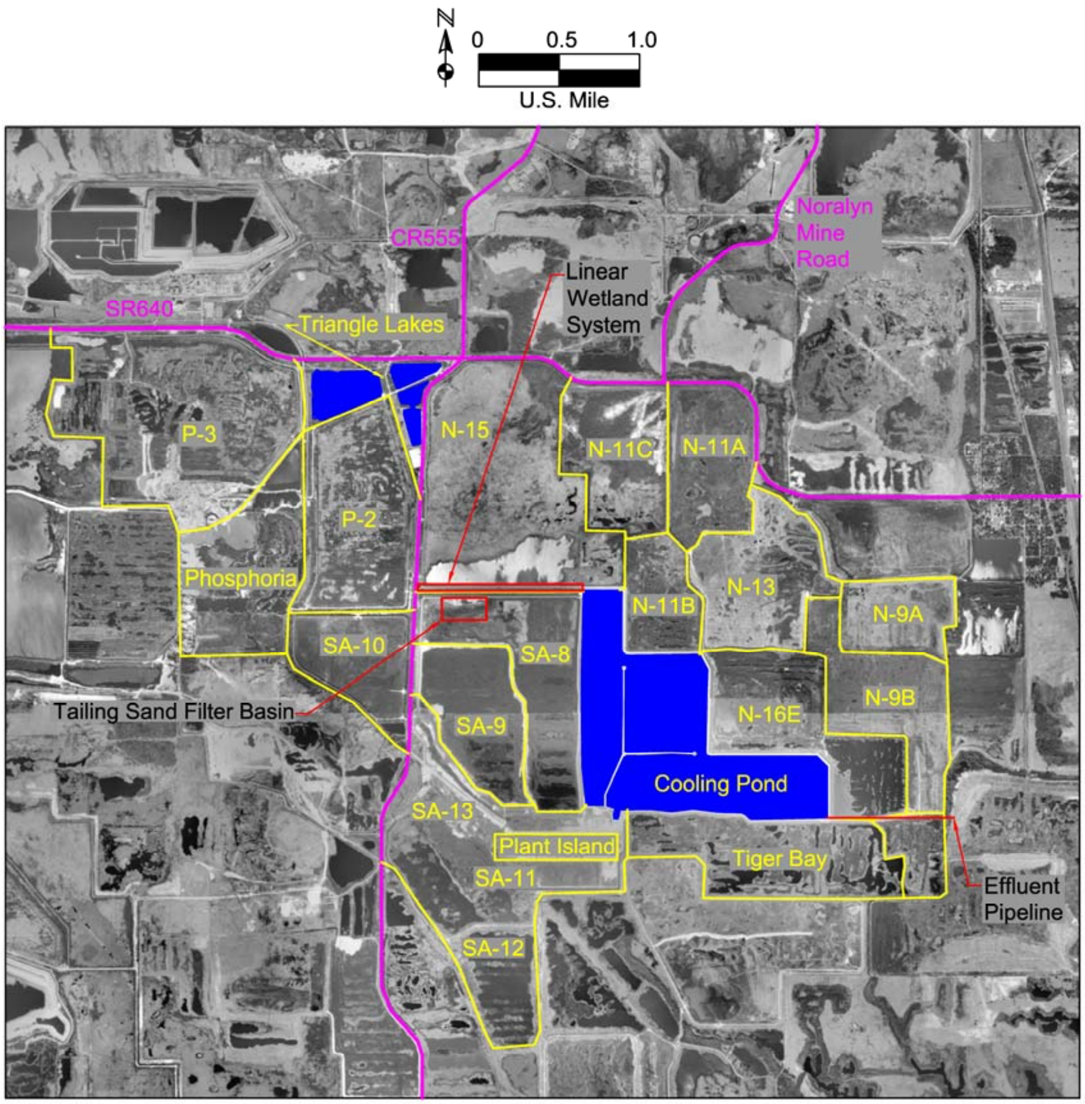


Figure 3. Detailed Map of the Hines Energy Complex.

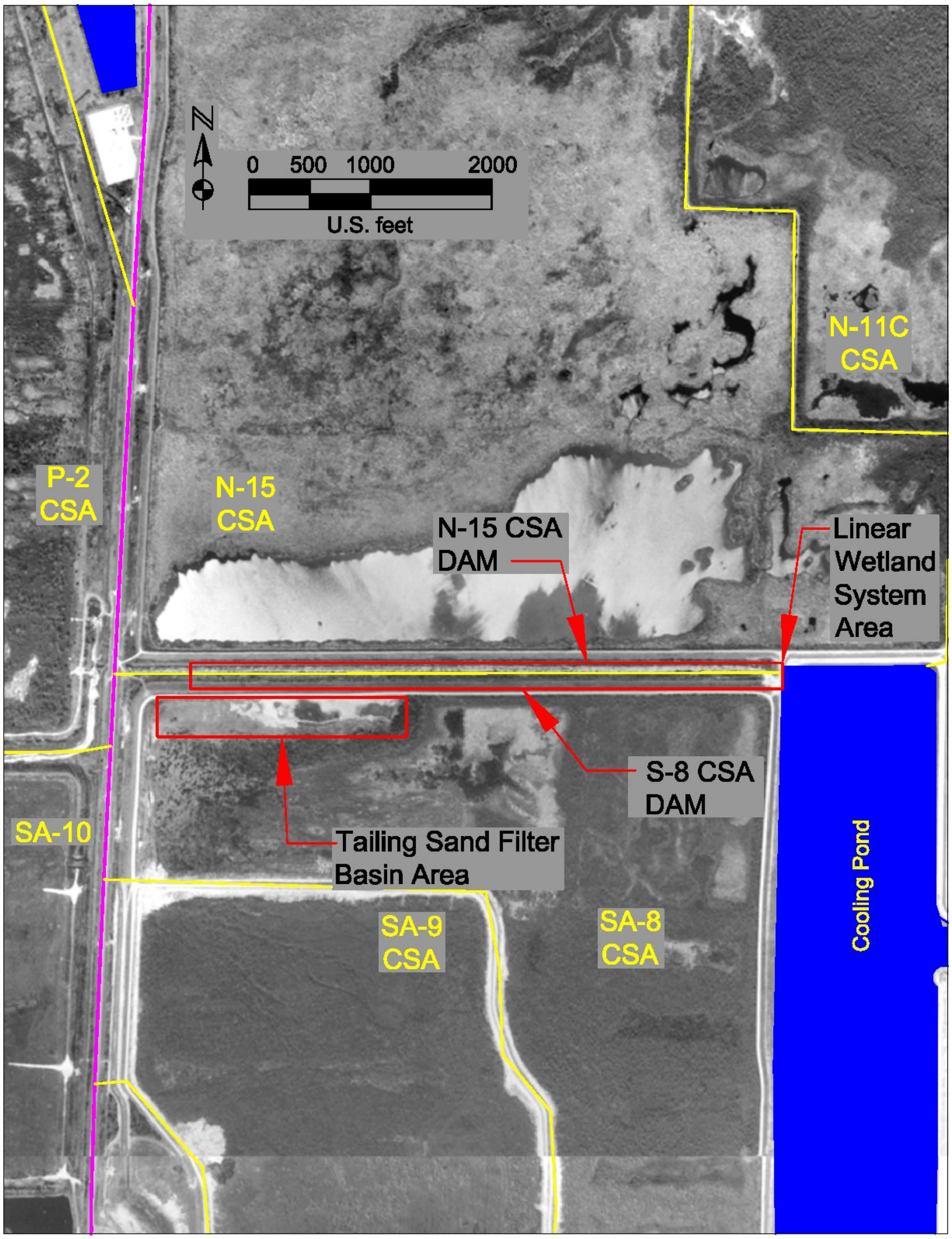


Figure 4. Detailed Map of Ditches.

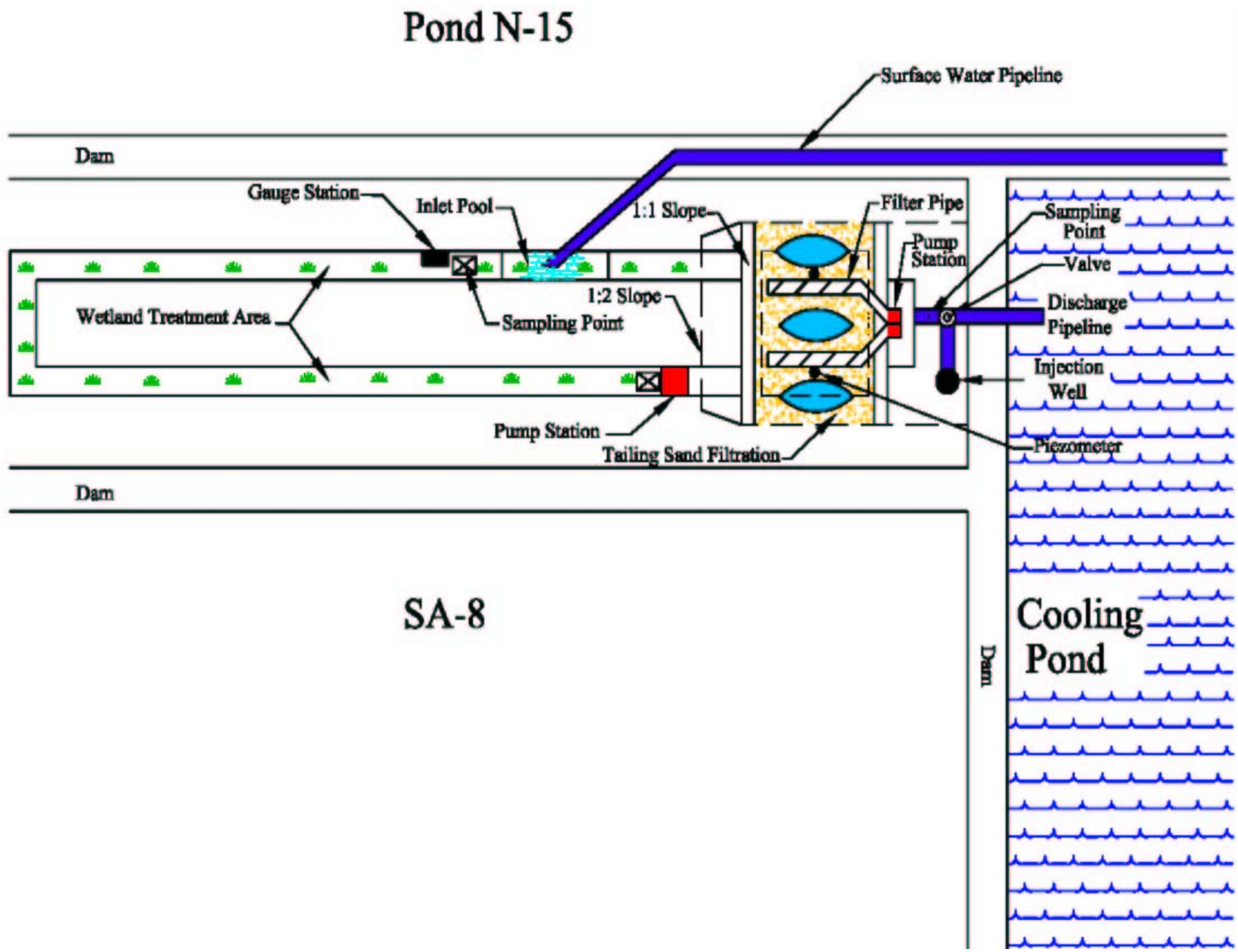


Figure 5. Original Concept of Pilot Project Set-Up.

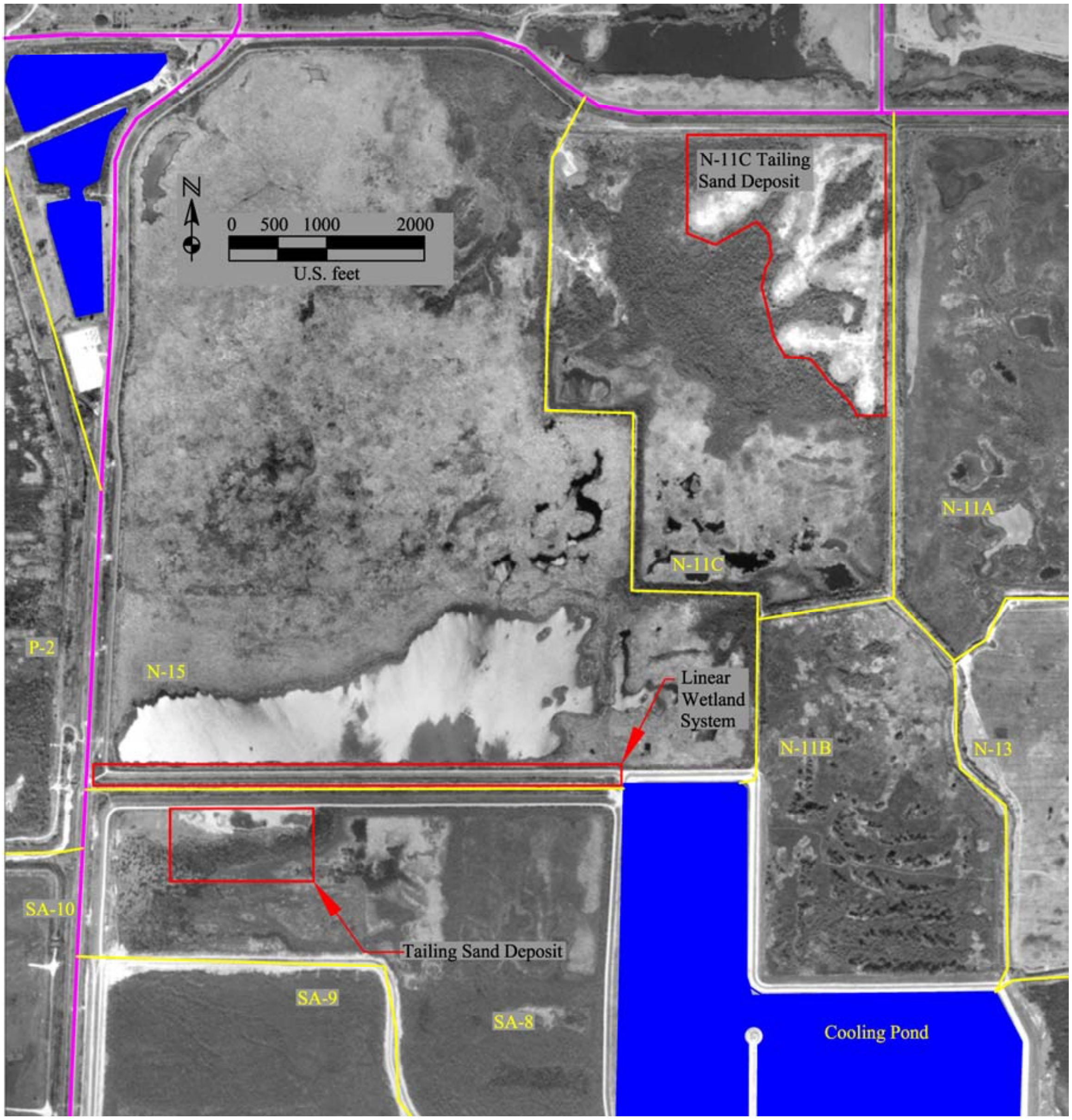


Figure 6. Map of the Two Tailing Sand Deposits at SA-8 and N-11B.

PROJECT HISTORY

A timeline of events beginning in 2000 and ending in 2004 is presented in Table 1. The initial meetings, planning, and testing occurred in the early part of the year 2000, followed by extensive construction to build the filter basin and pumping systems for the remainder of the 2000 and the beginning of 2001. The first testing phase of the wetland-filter basin treatment system began in May of 2001. In the summer of 2001, fish remains were found near the piping and it was conjectured that birds consuming fish while perched on the piping coming out of the two standpipes at the basin had contaminated the filter piping system with microorganisms in their fecal matter. To remedy this situation, SI requested and received additional funding to clean and disinfect the filter piping and standpipes. This phase was completed in June 2001. From that time, the system ran continuously through the end of the year. After an initial assessment of the project and data, there were several modifications made to the system, which were completed in the summer of 2002. The treatment system ran from August 2002 to March of 2003 with the cooling pond as the water source, and then from April 2003 to December 2003 with the effluent as the water source. During this time, a series of issues arose, such as equipment failures, climatic events, and operational problems. Problems with the equipment include faulty wiring and installations, defective equipment, and phase and power fluctuations. Lightning, excessive rain, and wildlife were uncontrollable events that were dealt with as best as possible. Operational problems consisted of differing water levels in the filter basin causing the water level float control system to work inconsistently, the major cause of the wetland filter basin treatment system shutting down.

A detailed time and event log of this project is presented in Appendix A.

Table 1. Timeline of 2000 through 2004.

Description	2000												2001												2002												2003												2004			
	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A
Meetings (On- and Off-Site)	X	X					X												X			X					X											X													X	
Soil Borings			X																																																	
Construction at Filter Basin							X		X			X	X	X	X	X																						X					X									
Construction at Wetland							X						X	X	X	X															X		X																			
Construction at Cooling Pond							X																																													
Construction at Effluent							X					X	X	X	X	X																																				
Construction at SA-8 & Plant Island							X						X	X																																						
HDPE Pipelines									X			X	X	X	X	X																													X	X						
Filling/Testing of Filter Basin															X	X	X																																			
Filling/Testing of System														X	X	X	X																																			
Balanced Operation of Wetland									X						X	X	X	X	X	X	X	X	X	X						X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X			
Power Loss/Pump Problems														X			X						X	X	X					X	X	X	X	X	X	X						X	X	X	X	X	X	X	X			
Pump Repairs at Filter Basin																												X	X									X														
Water Level Installation/Repairs																															X	X	X	X	X	X	X	X		X	X	X			X	X		X				
Pump Repairs at Wetland																									X		X	X	X	X								X	X				X	X			X	X	X			
Pump Repairs at Cooling Pond																											X	X	X	X																						
Pump Repairs at Effluent																																							X													
Electrical Repairs/Inspection														X	X	X	X						X	X	X					X	X	X	X	X	X	X						X	X	X		X		X	X			
Flow Meter Cleaning/Repairs																	X																		X	X										X	X	X				
Performance Samples																	X	X	X	X		X		X									X	X	X	X	X	X	X		X	X	X	X	X	X	X	X				
Primary/Secondary Samples																			X				X															X	X		X	X	X	X	X	X	X	X				
Full Suite Samples																	X				X																	X	X			X	X	X	X	X	X	X				
Cyptosporidium & *Giardia* Samples																	X																						X	X				X	X	X	X	X				
Airlift/Chlorination of Filter Basin																		X									X			X								X									X					
Progress Reports	X	X	X					X	X			X		X	X			X		X				X	X	X	X	X		X	X			X	X	X	X	X	X	X	X	X	X	X	X	X				X		
Data Analysis and Report Writing																																							X							X	X	X	X	X	X	X

Cooling Pond | Effluent

DESIGN AND CONSTRUCTION OF TREATMENT SYSTEM

PROJECT CONFIGURATION

The overall project configuration is shown in Figure 7. It consists of seven pumping stations: at the wetland, the basin, the cooling pond, the SA-8 CSA, the Plant Island drainage ditch, and at the effluent discharge pipe into the cooling pond. At each location, electrical power was provided by PEF to electrical panels, which were installed along with control systems. At the wetland, basin, cooling pond and effluent location, 7.5 HP electrically-driven centrifugal pumps, each with a 240-260 gallon per minute (gpm) capacity at 60-70 pounds per square inch (psi) total dynamic head were installed. In addition, continuously recording flow meters were installed. The water pumped from the cooling pond, SA-8, the Plant Island drainage ditch and Effluent Discharge pipe were all routed to discharge to the east side of the north ditch of the wetland through a 4-inch diameter HDPE pipe or larger. Similarly, the wetland pumping station was connected to the basin through a 4000 ft long 4-inch diameter HDPE pipeline. The water pumped from the basin was discharged to the cooling pond through a 4500 ft long 4-inch diameter HDPE pipeline.

DESIGN OF INDIVIDUAL PROJECT ELEMENTS

As previously described, the selection of the final project configuration depended on the selection of the final location of the tailing sand filter basin. After the project was authorized and field inspections were conducted in consultation with the PEF representatives, it was determined that the concept as originally envisioned for the filter basin could not be built; alternative ideas were therefore explored. One choice was to construct the filter basin at the nearest tailing sand deposits, which were at the northwest corner of the SA-8 CSA. SI conducted a test boring program to evaluate the feasibility of using this tailing sand deposit as an in-situ filter bed. This was not found to be feasible due to the interlayer of clays with the sand. A similar exploration program was conducted at the tailing sand deposits at N-11C CSA. The results were that this site also could not be used as a tailing sand filter in the “as is” condition. After much deliberation, it was decided that since neither site was viable “as is,” SI would design and construct a tailing sand filter basin at the SA-8 CSA site using the tailing sand that was on-site.

There was never a problem for the use of the two ditches as the linear wetland. There was however, a discussion followed by a field visit to assess the need for the improvement of the wetland by removing invasive species and replacing these with native wetland vegetation. After much debate, a consensus was reached that the vegetation as it appeared in the linear wetland is representative of the vegetation that can be expected to occur in clay settling areas after they are no longer in operation and have been drained. Therefore, the vegetation remained unmodified.

A detailed description of the design steps and selection of the equipment is presented in Appendix B.

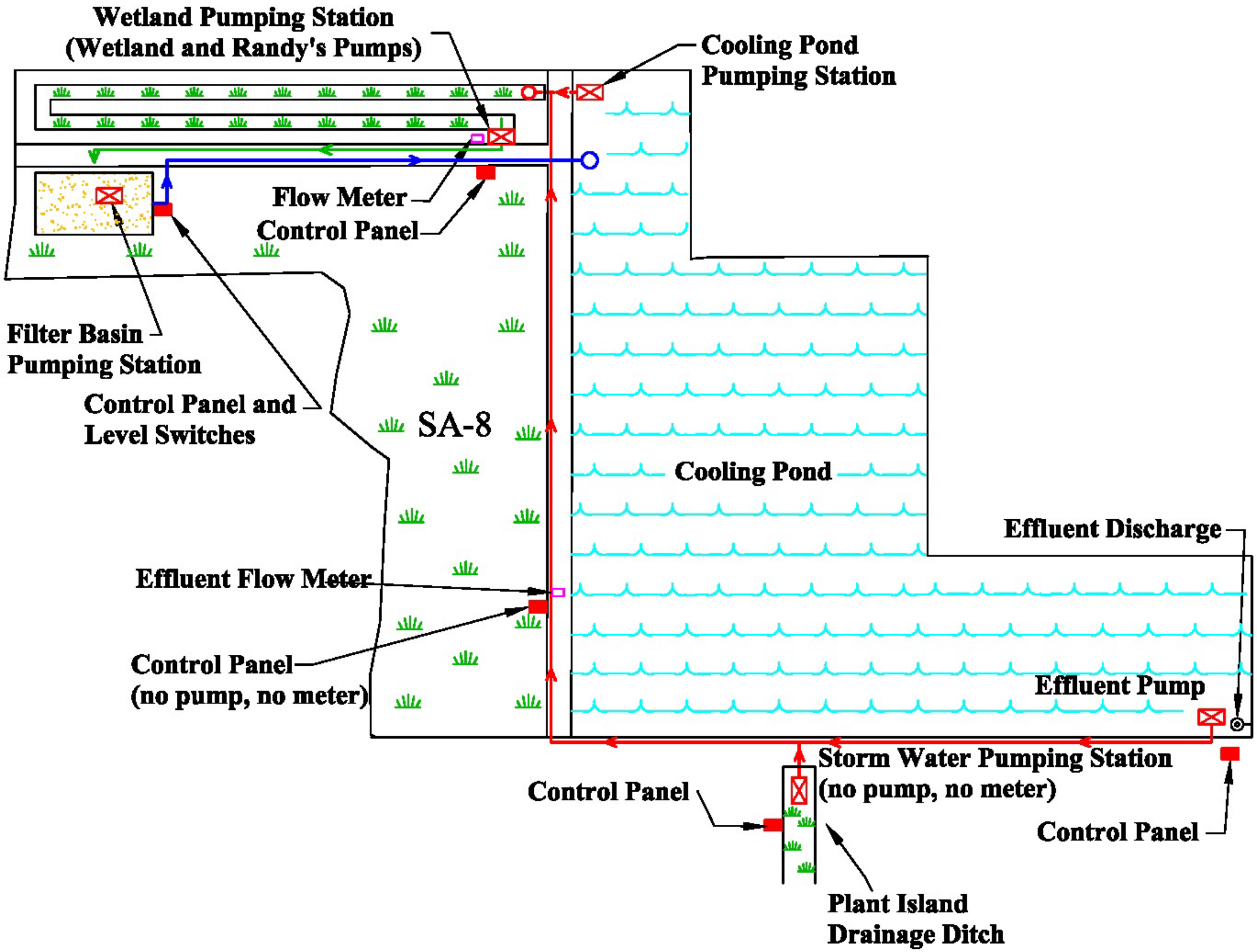


Figure 7. Final Systems Map.

CONSTRUCTION OF INDIVIDUAL PROJECT ELEMENTS

There were three major construction elements to the project: (1) the construction of the tailing sand filter basin; (2) the construction of the wetland filter and pumping intake structure; and (3) the installation of approximately 22,000 linear feet of 4-inch diameter HDPE pipeline and 5 pumping stations with the associated electric power supplies, flow meters and valving. A detailed description of the construction elements is provided in Appendix C.

RESULTS AND DISCUSSION

OVERVIEW

As described in the previous chapter, a large number of samples were collected and analyzed. These samples were divided in the four groupings: Performance, PDWS/SDWS, Full Suite, and Microorganisms. In some of the groupings, chemical analyses were duplicated. For example, the analysis for the presence and concentration of iron is included in the Performance; PDWS/SDWS and Full Suite groupings. To present the results of all these analyses, SI decided to list each chemical parameter per grouping and as an individual chemical. Because of the sheer number of results, they are presented in the Appendices. The results of the Performance sampling are presented in Appendix E. They are separated into the results obtained when the cooling pond water was used as source water (Table E-1) and when the effluent was used as source water (Table E-2). This distinction holds in all the data appendices.

The results of the sampling program for the PDWS and SDWS are presented in Appendix F. The results of the analyses for the Full Suite are presented in Appendix G. The results of the analyses for the presence and concentrations of Microorganisms are presented in Appendix H. All the values measured in the field are presented in Appendix I.

It is important to emphasize: 1) that the source water changed from the cooling pond to effluent in March 2003; and 2) that the location of the water samples collected at the basin changed in May 2003. Until that time, water samples were collected while the surface centrifugal pump was drawing water from both the south standpipe (SS) and from the north standpipe (NS). The reason for the change was the fact that on three occasions the hydrologic technician observed that the water level in the SS was becoming progressively higher than in the NS. This was caused by iron biofilm being deposited in the SS by iron-reducing bacteria (IRB), obstructing the free flow of water into the suction pipe going to the centrifugal pump. A simple technique was developed to remove the biofilm without having to remove the suction pipe. The formation of biofilm was attributed to inward seepage of groundwater from the tailing sand outside the filter basin into the filter basin.

After May 2003, SI implemented a different sampling schedule at the basin by collecting three samples from the basin pump. The first sample was of water pumped from both standpipes. The second sample was from water pumped only from the SS and the third sample was from water pumped only from the NS. Prior to collecting the samples from the SS and NS, the pumping rate was reduced by half to make sure that the flow velocity in the filter pipes remained the same.

As mentioned previously the presence and concentration of 140 chemical compounds were measured. In addition, samples were collected to determine the presence/absence and concentration of four kinds of microorganisms. Information was collected and recorded on the readings of flow and electric meters, water levels, pH, specific electrical conductance and temperature.

RESULTS

In this part of this chapter, summaries of the results are presented. How well the natural treatment system performed in improving the quality of the incoming source water is discussed in the "Discussion" part of the chapter. To keep the discussion focused on the important findings, SI concentrated on the parameters that explain the chemical findings and on those chemical compounds of which concentrations in the water exceeded the recommended drinking water standards. As an overview, all the chemical compounds and microorganisms that were sampled and analyzed are shown, the number of samples and the number of samples in which the concentrations exceeded the recommended standards.

Table 2 presents the total number of water samples in each Group that were collected from each water source, for the wetland and for the basin are shown. A total of 725 samples were collected. When the cooling pond was the source water 343 samples were collected, of these 107 were from the cooling pond, 115 were from the wetland and 121 were from the filter basin. Similarly, 382 samples were collected and analyzed when the effluent was the source water; 131 samples were from the effluent source, 120 were from the wetland and 131 were from the filter basin. It should be emphasized that each sample was analyzed for the presence and concentrations of several chemicals listed for that Group. For example there are 18 chemicals listed in the PDWS, thus the total number of chemical analyses performed for that Group is 972. As a result, several thousand analyses were performed.

Table 2. Number of Samples Collected.

Water Source	Sample Location	Performance Standards	PDWS	SDWS	Volatile Organic Contami-nants	Synthetic Organic Contami-nants	Group I Unreg-ulated	Group II Unreg-ulated	Group III Unreg-ulated	Radio-nuclide Contami-nants	Micro-organisms	TOTAL
Cooling Pond	Cooling Pond	22	6	6	4	4	4	4	4	22	31	107
	Wetland	22	6	6	4	4	4	4	4	22	39	115
	Basin	22	7	10	4	4	4	4	4	22	40	121
Effluent	Effluent	7	12	12	12	12	12	12	12	12	28	131
	Wetland	7	11	11	11	11	11	11	11	12	24	120
	Basin	7	12	12	12	12	12	12	12	12	28	131
Total # of Samples*		87	54	57	47	47	47	47	47	102	190	725

* Does not include measurements of the physical parameters.

The results are summarized and presented in Tables 3 through 11. These tables list all the parameters in the PDWS (Table 3); in the SDWS (Table 4); in the Volatile Organic Compounds (Table 5); in the Synthetic Organic Compounds (Table 6); in the Group I Unregulated Compounds (Table 7); in Group II Unregulated Compounds (Table 8); in the Group III Unregulated Compounds (Table 9); the Microorganisms (Table 10); and the Radionuclides (Table 11). The name of each chemical compound is shown, along with the number of samples that were collected and the number of samples that exceeded the recommended drinking water standards. In the data appendices, the drinking water standard value for each compound (where applicable) has been listed along with the detection limit.

The tables illustrate there were no exceedances of the PDWS for any of the chemical compounds listed. There were no exceedances for the Volatile Organic Compounds, the Synthetic Organic Compounds, the Group I, II or III Unregulated Compounds and none for the radionuclides. There were, however, exceedances of the recommended SDWS as shown in Table 4. Of the 14 listed parameters, 6 exceeded the recommended SDWS. They were for Aluminum (1/18); Fluoride (22/44); Iron (36/44); Manganese (20/44); Color (18/18); and Odor (16/18). Other exceedances were for concentrations of Microorganisms (Table 10), with Fecal Coliform (4/30) and Total Coliform (34/65).

The measurements of the physical parameters (such as the specific electrical conductance, pH and temperature), turbidity, flow and electric meter readings are presented in Appendix I (Table I-1, Table I-2, Table I-3 and Table I-4). The physical parameters show several interruptions in the data collection caused by inaccessibility either of the instruments and/or by malfunction. The turbidity of the water pumped from the cooling pond, the effluent, the wetland and the basin was measured regularly. The results are presented in Table I-3. The first instrument used for turbidity measurements was not sensitive enough, so on February 21, 2003, SI purchased a new instrument. This is the reason the information in Table I-3 appears different after February 2003.

In February 2003, SI expanded the data collection system for the basin. The hypothesis was that groundwater from outside the basin was entering the basin, most likely along its southern periphery. This seepage groundwater was assumed to contain higher iron concentrations because it was intercepted primarily by the filter pipe in the southern part of the basin, which is connected to the SS, and the SS water had much higher iron concentrations. To assess this hypothesis, SI implemented a more elaborate measurement and sampling program by collecting samples from the NS and SS separately. The collected data are summarized in Table I-6.

During the data analysis phase of the project after December 2003, SI realized that it would be helpful to obtain additional information regarding the infrequent exceedances of the concentrations of Total Coliform bacteria. The literature indicates that the formation of a layer of mostly organic matter on the surface of the sand will aid in the reduction of the concentration of total coliform bacteria. This is called the "schmutzdecke" or dirt layer. Because of the periodic operation of the wetland pump, the formation of an effective schmutzdecke on the surface of the filter basin was not optimized. To gather quantitative bench test data about the possible relationship between the formation of a schmutzdecke, the reduction of the total coliform bacteria count, and the reduction of the effective vertical hydraulic conductivity, SI created a field testing operation at its field office.

A description of the test set-up, photographs and results of the field-testing are presented in Appendix J.

Table 3. Samples and Exceedances for Primary Drinking Water Standards.

Primary Drinking Water Standards			
Parameter	PDWS	Number of Samples	Number of Exceedances
Antimony	0.006 mg/L	15	0
Arsenic	0.05 mg/L	15	0
Asbestos	7 million fibers/L	6	0
Barium	2 mg/L	15	0
Beryllium	0.004 mg/L	15	0
Cadmium	0.005 mg/L	15	0
Chromium	0.1 mg/L	15	0
Cyanide	0.2 mg/L	13	0
Fluoride	4.0 mg/L	44	0
Lead	0.015 mg/L	15	0
Mercury	0.002 mg/L	15	0
Nickel	0.1 mg/L	15	0
Nitrate	10 mg/L as Nitrogen	14	0
Nitrite	1 mg/L as Nitrogen	14	0
Total Nitrate and Nitrite	10 mg/L as Nitrogen	14	0
Selenium	0.05 mg/L	15	0
Sodium	160 mg/L	15	0
Thallium	0.002 mg/L	15	0

Table 4. Samples and Exceedances for Secondary Drinking Water Standards.

Secondary Drinking Water Standards			
Parameter	SDWS	Number of Samples	Number of Exceedances
Aluminum	0.2 mg/L	18	1
Chloride	250 mg/L	18	0
Copper	1.0 mg/L	18	0
Fluoride	2.0 mg/L	44	22
Iron	0.3 mg/L	44	36
Manganese	0.05 mg/L	44	20
Silver	0.1 mg/L	18	0
Sulfate	250 mg/L	44	0
Zinc	5.0 mg/L	18	0
Color	15 CU	18	18
Odor	3 TON	18	16
pH	6.5-8.5	44	0
Total Dissolved Solids	500 mg/L	18	0
Foaming Agents	0.5 mg/L	18	0

Table 5. Samples and Exceedances for Volatile Organic Compounds.

Volatile Organic Compounds			
Parameter	MCL	Number of Samples	Number of Exceedances
1,1-Dichloroethylene	0.007 mg/L	12	0
1,1,1-Trichlororethane	0.2 mg/L	12	0
1,1,2-Trichloroethane	0.005 mg/L	12	0
1,2-Dichloroethane	0.003 mg/L	12	0
1,2-Dichloropropane	0.005 mg/L	12	0
1,2,4-Trichlorobenzene	0.07 mg/L	12	0
Benzene	0.001 mg/L	12	0
Carbon tetrachloride	0.003 mg/L	12	0
cis-1,2-Dichloroethylene	0.07 mg/L	12	0
Dichloromethane	0.005 mg/L	12	0
Ethylbenzene	0.7 mg/L	12	0
Monochlorobenzene	0.1 mg/L	12	0
O-Dichlorobenzene	0.6 mg/L	12	0
para-Dichlorobenzene	0.075 mg/L	12	0
Styrene	0.1 mg/L	12	0
Tetrachloroethylene	0.003 mg/L	12	0
Toluene	1 mg/L	12	0
trans-1,2-Dichloroethylene	0.1 mg/L	12	0
Trichloroethylene	0.003 mg/L	12	0
Vinyl chloride	0.001 mg/L	12	0
Xylenes (total)	10 mg/L	12	0
m/p-xylenes	0.5 µg/L (DL)	12	0
o-xylene	0.5 µg/L (DL)	12	0

Table 6. Samples and Exceedances for Synthetic Organic Compounds.

Synthetic Organic Compounds			
Parameter	MCL	Number of Samples	Number of Exceedances
2,3,7,8-TCDD (Dioxin)	$3 * 10^{-8}$ mg/L	12	0
2,4-D	0.07 mg/L	12	0
2,4,5-TP (Silvex)	0.05 mg/L	12	0
Alachlor	0.002 mg/L	12	0
Atrazine	0.003 mg/L	12	0
Benzo(a)pyrene	0.0002 mg/L	12	0
Carbofuran	0.04 m g/L	12	0
Chlorodane	0.002 mg/L	12	0
Dalapon	0.2 mg/L	12	0
Di(2-ethylhexyl)adipate	0.4 mg/L	12	0
Di(2-ethylhexyl)phthalate	0.006 mg/L	12	0
Dibromochloropropane (DBCP)	0.0002 mg/L	12	0
Dinoseb	0.007 mg/L	12	0
Diquat	0.02 mg/L	12	0
Endothall	0.1 mg/L	12	0
Endrin	0.002 mg/L	12	0
Ethylene dibromide (EDB)	0.00002 mg/L	12	0
Glyphosate	0.7 mg/L	12	0
Heptachlor	0.0004 mg/L	12	0
Heptachlor epoxide	0.0002 mg/L	12	0
Heptachlorobenzene	0.001 mg/L	12	0
Hexachlorocyclpentadiene	0.05 mg/L	12	0
Lindane	0.0002 mg/L	12	0
Methoxychlor	0.04 mg/L	12	0
Oxamyl (vydate)	0.2 mg/L	12	0
Pentachlorophenol	0.001 mg/L	12	0
Picloram	0.5 mg/L	12	0
Polychlorinated biphenyl (PCB)	0.0005 mg/L	12	0
Simazine	0.004 mg/L	12	0
Toxaphene	0.003 mg/L	12	0

Table 7. Samples and Exceedances for Group I Unregulated Compounds.

Group I Unregulated Compounds			
Parameter	DL	Number of Samples	Number of Exceedances
3-Hydroxycarbofuran	0.5 µg/L	12	0
Aldicarb	0.5 µg/L	12	0
Aldicarb sulfone	0.5 µg/L	12	0
Aldicarb sulfoxide	0.5 µg/L	12	0
Aldrin	0.08 µg/L	12	0
Butachlor	0.06 µg/L	12	0
Carbaryl	0.5 µg/L	12	0
Dicamba	0.25 µg/L	12	0
Dieldrin	0.06 µg/L	12	0
Methomyl	0.5 µg/L	12	0
Metalachlor	0.05 µg/L	12	0
Metribuzin	0.1 µg/L	12	0
Propachlor	0.07 µg/L	12	0

Table 8. Samples and Exceedances for Group II Unregulated Compounds.

Group II Unregulated Compounds			
Parameter	DL	Number of Samples	Number of Exceedances
1,1,1,2-Tetrachloroethane	0.3 μg/L	12	0
1,1,2,2-Tetrachloroethane	0.3 μg/L	12	0
1,1-Dichloroethane	0.3 μg/L	12	0
1,1-Dichloropropene	0.3 μg/L	12	0
1,2,3-Trichloropropane	0.3 μg/L	12	0
1,3-Dichloropropane	0.3 μg/L	12	0
1,3-Dichloropropane, Total	0.3 μg/L	12	0
2,2-Dichloropropane	0.3 μg/L	12	0
Bromobenzene	0.5 μg/L	12	0
Bromodichloromethane	0.3 μg/L	12	0
Bromoform	0.5 μg/L	12	0
Chloroethane	0.5 μg/L	12	0
Chloroform	0.2 μg/L	12	1
Chloromethane	0.5 μg/L	12	0
Dibromochloromethane	0.5 μg/L	12	0
Dibromomethane	0.5 μg/L	12	0
Dichlorodifluoromethane	0.5 μg/L	12	0
m-Dichlorobenzene	0.5 μg/L	12	0
Methyl-tert-butyl-ether	0.5 μg/L	12	0
o-Chlorotoluene	0.5 μg/L	12	0
p-Chlorotoluene	0.5 μg/L	12	0
Trichlorofluoromethane	0.5 μg/L	12	0

Table 9. Samples and Exceedances for Group III Unregulated Compounds.

Group III Unregulated Compounds			
Parameter	DL	Number of Samples	Number of Exceedances
2,4,6-Trichlorophenal	0.8 μg/L	12	0
2,4-Dinitrotoluene	3 μg/L	12	0
2-Chlorophenol	1 μg/L	12	0
4,6-Dinitro-o-cresol	1 μg/L	12	0
Butylbenzylphthalate	2 μg/L	12	0
Diethylphthalate	1 μg/L	12	0
Dimethylphthalate	1 μg/L	12	0
Di-n-butylphthalate	2 μg/L	12	0
Di-n-octylphthalate	2 μg/L	12	0
Isophorone	2 μg/L	12	0
Phenol	0.8 μg/L	12	0

Table 10. Samples and Exceedances for Microorganisms.

Microorganisms			
Parameter	DWS	Number of Samples	Number of Exceedances
Fecal Coliform	0 MPN/100mL	30	4
Total Coliform	4 MPN/100mL	65	34
Cryptosporidium	0 detected/100mL	6	0
Giardia	0 detected/100mL	6	0

Table 11. Samples and Exceedances for Radionuclide Contaminants.

Radionuclide Contaminants			
Parameter	DWS	Number of Samples	Number of Exceedances
Gross Alpha	15 pCi/L	42	0
Radium 226	5pC/L	42	0
Radium 228	5 pCi/L	42	0

DISCUSSION

In this part of the report, the focus is on the operational aspects of the system and how it relates to the performance of the treatment system in improving the quality of the influent source water.

Performance Assessment

The purpose of the pilot study was to evaluate the use and effectiveness of the treatment capacity of a wetland on mined phosphate land followed by filtration through tailing sand. The success or failure of such a system can be determined in two ways: 1) by looking at the chemical analytical results of the filtered water and comparing these to the published standards and 2) the changes in concentrations of chemical compounds in the source water while flowing through the wetland and filter basin.

The first assessment of the overall performance has been discussed previously. The outcome is that of the 140 physical and chemical parameters tested for, exceedances of only six regulatory standards (SDWS) occurred. This section discusses the changes that were observed in the water during the flow through the treatment system. The capacity of the system is further evaluated by comparing its performance for treating industrial wastewater from the cooling pond to its performance for treating effluent from the City of Bartow wastewater treatment plant.

Physical Parameters

The physical parameters of interest are the total volume of water treated, rainfall, pH, specific electrical conductance, temperature, turbidity, color, odor and total dissolved solids.

Volume Pumped

There is uncertainty about the volume of water that was pumped during the life of the project from each source into the wetland and from the wetland to the filter basin and from the filter basin to the cooling pond. To save costs, an existing pump installed by PEF for a previous test was used to move the water from the cooling pond to the wetland. Similarly, an existing pump (Randy's pump) was used to pump water from the wetland back to the cooling pond. Neither flow meters nor electric meters were installed on these pumps. Based on operational logs the pumpage record from the basin, wetland and effluent pumps show many interruptions by either a partial blockage in the flow meter or an electrical interruption caused by lightning or by a power surge or phase change.

According to the flow meter records presented in Appendix I, Table I-4, a total of approximately 151 million gallons (MG) were pumped from the basin and returned to the cooling pond. A total of approximately 77 MG were pumped from the wetland to the filter basin. There is no record of the total pumpage from the cooling pond to the wetland. There is a record of the total pumpage from the effluent to the wetland (35 MG). An assessment of the most complete record during the time when the effluent was used as a source, estimates that a total of 35 MG of effluent was discharged to the wetland. During that same time interval, 20 MG were pumped to the basin from the wetland, and approximately 46 MG were pumped from the basin to the cooling pond. The numbers vary quite significantly because the meters sometimes malfunctioned and did not always accurately register the flow.

A slightly better indication of the total water moved from the effluent to the wetland and from the wetland to the basin and from the basin to the cooling pond is the electric meter record in kw/hr. The total amount for the effluent was 18,813 kw/hr. For the wetland it was 13,735 kw/hr and for the basin 20,391 kw/hr. While these numbers appear to be closer, care needs to be exercised in their interpretation. For example, the basin pump has to lift the water from a depth that ranged from 2 to 13 feet below pump intake, and averaged approximately 8 feet. The deeper the groundwater level below the pump intake the lesser the volume of water the surface centrifugal pump will displace. The result is that more energy is needed to displace the same volume of water from a greater depth.

If the meters were most accurate at the beginning of the operation, the volume of water pumped per kw/hr used was calculated. They were 2,517, 1062 and 1679 g/kw/hr respectively. Using these values and the difference between the electric meter reading when the effluent operation began, SI estimates that 47.4 MG of effluent were pumped to the wetland, 14.6 MG of water from the wetland were pumped to the basin and 34.2 MG were pumped from the basin to the cooling pond. While using this approach provides a reasonable comparison between the volumes of effluent and basin water pumped, it does not explain the small volume of water pumped from the wetland to the filter basin. Based on the visual record of the operation, SI does not believe the recorded wetland pumpage to be realistic.

The rainfall capture area for the linear wetland system extended from the edge of the SA-8 dam to the edge of the N-15 dam, a distance of approximately 330 ft. The length of the linear wetland is 4000 ft, thus the total capture area is 30.3 acres. A one-inch rainfall event could produce as much as 2.53 acre-feet of water (823,000 gallons). Because the TDS concentration in rainfall is low, the total mass input will be relatively low, but volume will be high. This will dilute the TDS mass in the wetland water. Utilizing a second pump (Randy's pump) pumping at 150 gpm (210,000 gallons per day) continuously will reduce the volume of captured rainfall, thereby reducing the dilution potential following rainfall events. Randy's pump was, in addition, used to help keep the wetland water level reasonably constant. This pump was operated continuously to move the water from the wetland directly to the cooling pond. This discharge was not measured.

While the actual pumping rate from the basin may be somewhat uncertain ranging from 151 MG (based on the totalizing flow meter reading) to the estimated 117 MG using the kw/hr and conversion factor of 1,678 g/kw/hr, the average pumping rate during the operation of the filter basin ranges from 145 to 112 gallons per minute (gpm). To illustrate the pumping regime for the filter basin, Figure 8 is presented. This figure was prepared using the flow meter record.

Rainfall and pH

As before, a distinction is made between the periods when the waters were from the cooling pond and then the effluent as sources. The median pH of the cooling pond water was 8.52. After the cooling pond water flowed through the wetland, the median pH was lowered to 6.97, indicating a reducing environment. The median pH of the water leaving the basin was 6.88.

The median pH of the effluent entering the wetland was 7.45. The median pH leaving the wetland was 6.97 and leaving the basin 6.77.

Clearly, the wetland-basin system appears to have a good treatment/buffering capacity as shown by the data. The median pH of the water leaving the basin for either source of water varies in a very narrow range from 6.88 to 6.77. It is interesting to note that the median pH of the water declined by 1.78 during its flow through the wetland indicating a reducing environment.

The median pH was 6.88 in the basin, 6.85 in the NS of the basin and 6.88 in the SS of the basin. The median pH of the wetland water percolating through the filter basin declined slightly from 7.14 to 6.88, indicating a continuation of the reducing conditions observed in the wetland. This effect was most pronounced when cooling pond water was the source.

Figure 9 shows the rainfall measured at the basin against time, along with the pH measurements at the wetland and the basin. It is interesting that the reduction of the pH does not seem to be greatly influenced by the rainfall, which totaled approximately 158 inches for the entire study period. This amounts to an input of 4.9 MG onto the total surface area of the filter basin.

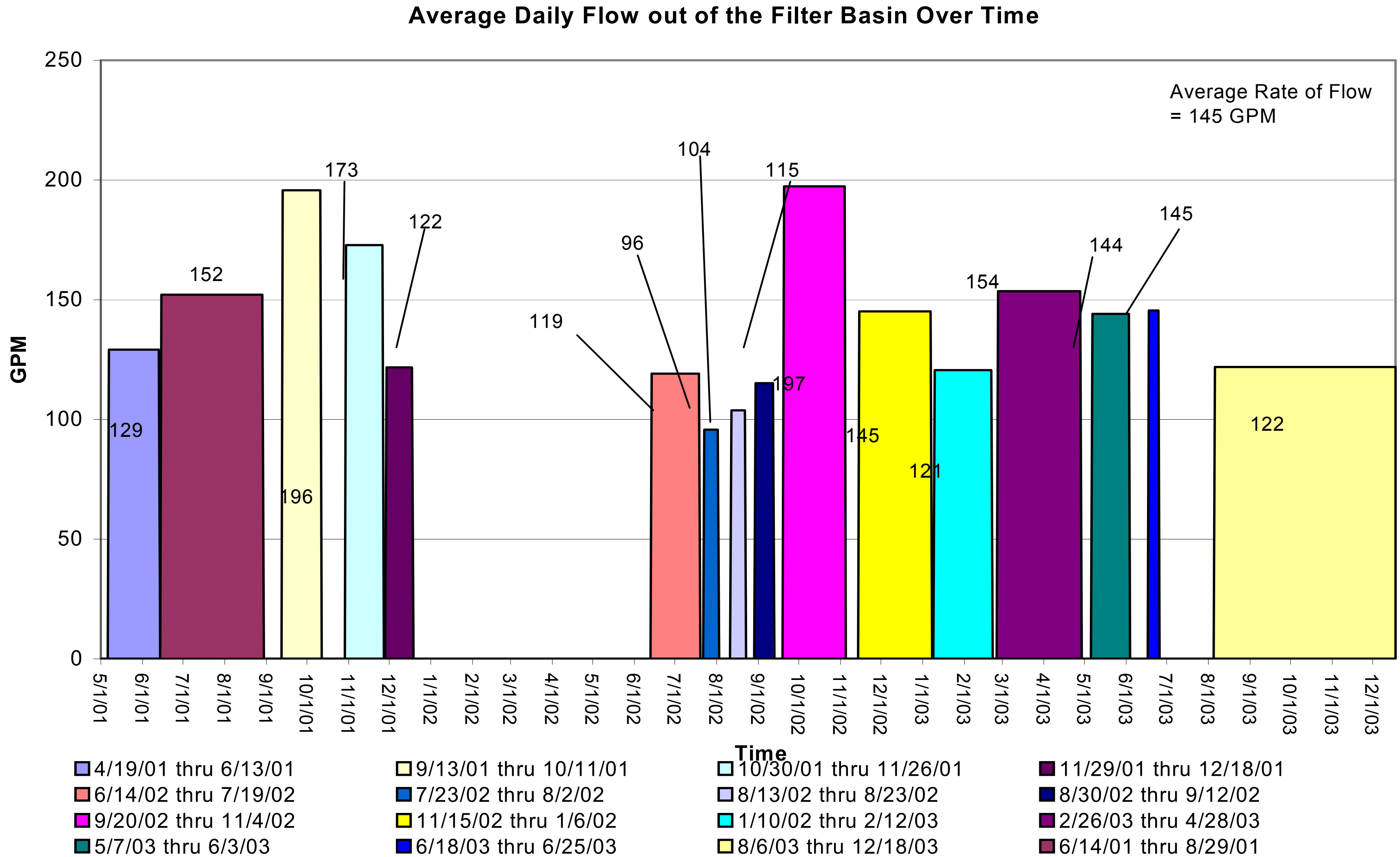


Figure 8. Average Daily Pumping Rate from the Filter Basin.

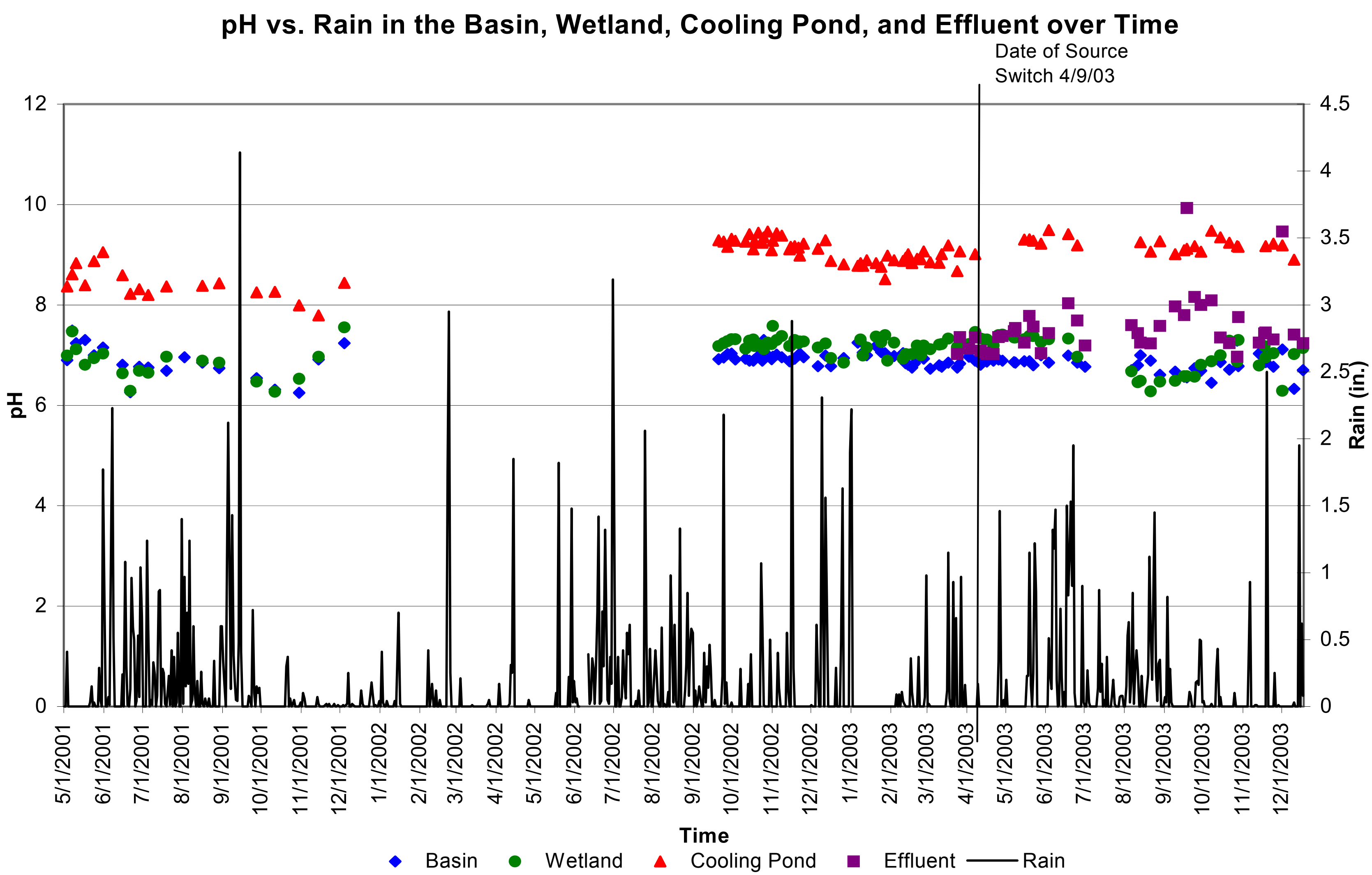


Figure 9. pH and Rainfall Over Time.

Specific Electrical Conductance

This parameter was used as a tracer of source water through the system. During the study, the median specific electrical conductance (SEC) of the cooling pond water was 886 μS. While flowing through the wetland, the median SEC was reduced to 657 μS. Percolating through the filter basin reduced the median SEC to 608 μS. The median SEC of the effluent was 582 μS. The median SEC of the water from the wetland during the time that the effluent was used as the source was 551 μS and in the water from the basin 530 μS.

As shown in Figure 10, it is well documented that as the cooling pond source water traveled through the system, the specific electrical conductance would rise from normal conductance levels in the wetland and filter basin to levels similar to or close to those of its water source. Rain influenced the specific electrical conductance in the wetland and filter basin. Due to the location (between two CSAs) and shape of the wetland area, it acts as a collection basin, adding significant volumes of rainwater to the wetland during rainstorms. This dilution influences the specific electrical conductance. No measurements were taken of specific electrical in the rainwater.

Apparently, dilution of rainfall and groundwater seepage inflow reduced the SEC in the wetland. Other processes such as the reduction of concentration of chemicals by microorganisms may have reduced the concentrations of selected chemicals resulting in a reduction of the SEC. It is interesting to note that the SEC value in the water percolating through the wetland-filter basin system was reduced consistently by 31% when cooling pond water was the source and by 9% when the effluent was used. The median SEC of the cooling pond was, however, 1.5 times higher than the median SEC of the effluent.

Temperature

During the study, the median temperature of the water pumped from the basin was 22.6°C and ranged from 12.8 to 29.5°C. The median temperature of the water pumped from the NS in the basin was 20.9°C and ranged from 15.9 to 28.3°C. The median temperature of the water pumped from the SS in the basin was 21.1°C and ranged from 15.2 to 27.7°C. The median temperature of the water in the wetland was 21°C and ranged from 9.9 to 27.9°C. The median temperature of the water in the cooling pond was 26.5°C and ranged from 16.2 to 35.6°C. The median temperature of the water discharging from the effluent pipeline was 29.2°C and ranged from 22.4 to 36.1°C.

The recorded temperatures in the cooling pond, wetland basin and effluent station are presented graphically in Figure 11. The changes in season were reflected by the changes in the temperatures as seen in the same figure. The greatest seasonal change in temperature occurred in the water in the cooling pond declining from a high of 32.5°C on September 20, 2002 to a low of 16.2°C on January 27, 2003, a seasonal change of more than 16°C.

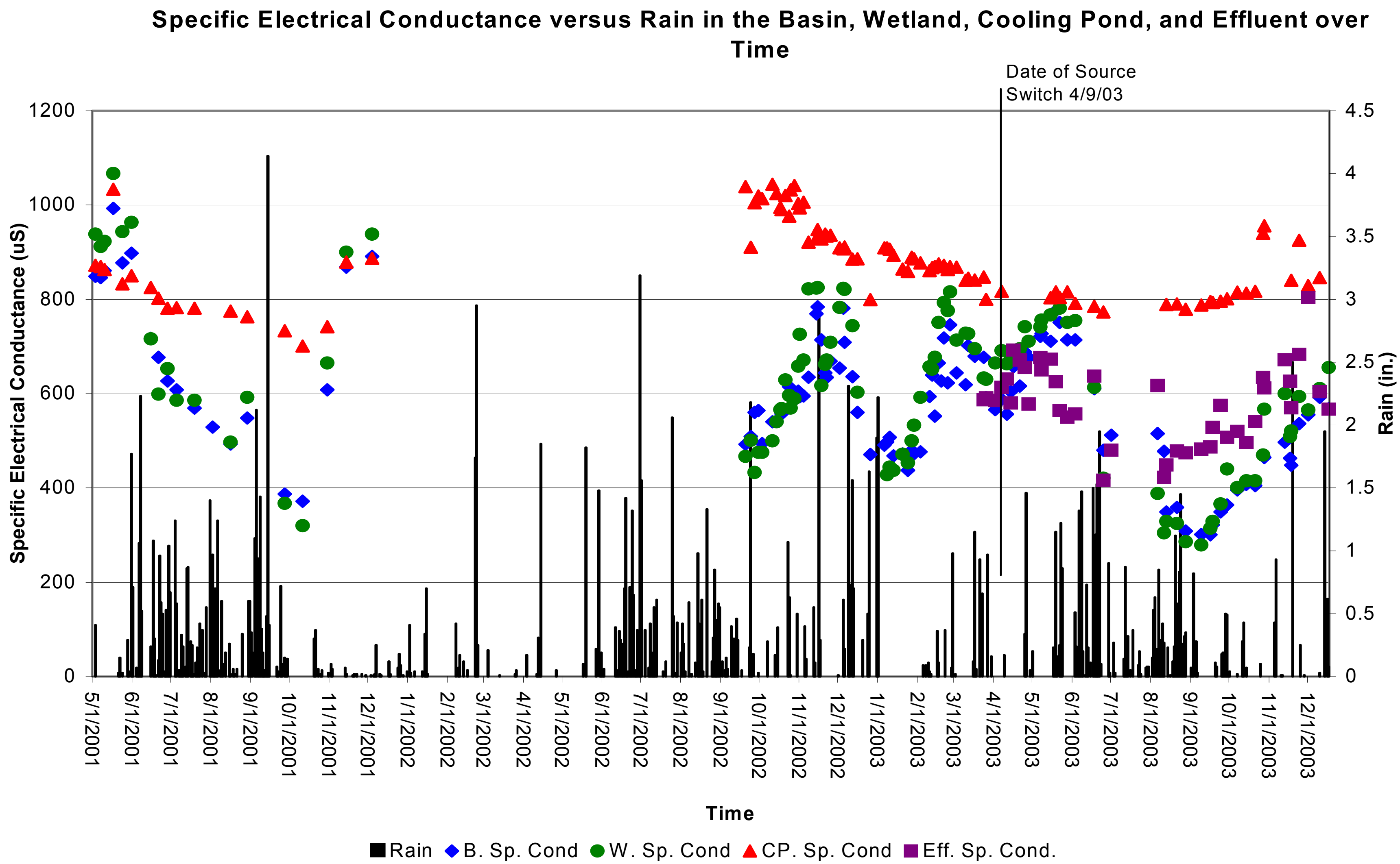


Figure 10. Specific Electrical Conductance and Rain Over Time.

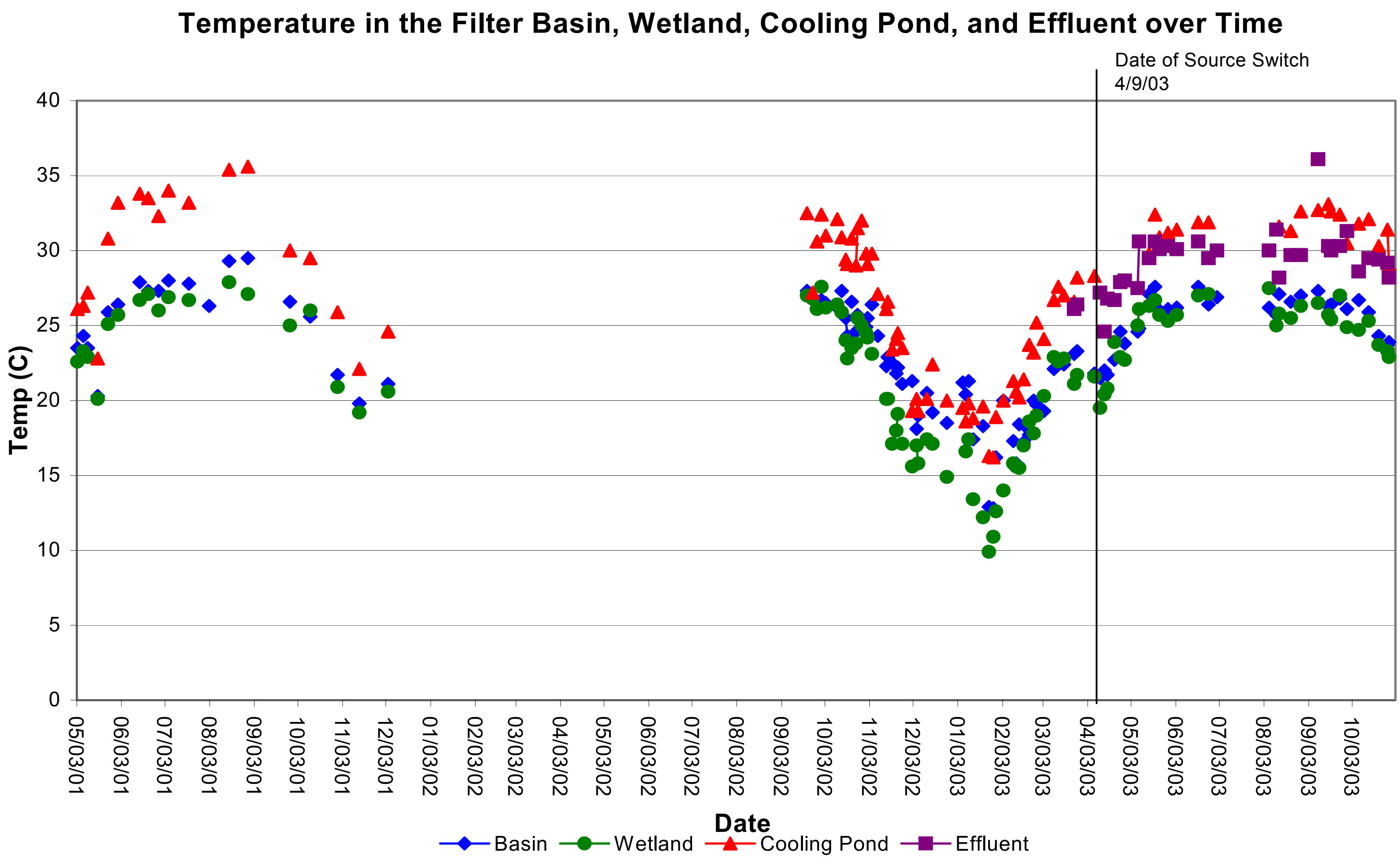


Figure 11. Temperature Over Time.

In addition, there is a reduction in temperature of the source water flowing through the wetland. The decrease in temperature of the surface water in the wetland is attributed to the shade provided by the vegetation preventing solar heating of the surface water in the wetland. The difference between the temperature of the surface water being discharged from the cooling pond or the effluent to the wetland and the temperature of the water being pumped from the basin ranged form a high of 9.6°C to a low of -2°C. The median difference is 3.9°C. The greatest seasonal change of 17.7°C in the wetland occurred between September 30, 2002 and January 24, 2003.

The treatment system reduced the median temperature by approximately 15%. When the effluent was used as a source the drop in median temperature was 3.8ºC (6.8º F) or 13%.

Comparing these median values leads to the conclusion that the treatment system reduces surface water temperatures significantly. Although no solar radiation measurements were taken as part of this project, the data clearly suggest that the largest temperature drop occurred in the wetland. This leads to the observation that the vegetative cover in the wetland system prevented direct solar radiation of the water surface, thereby preventing heat build-up in the surface water. This observation leads to the question if clay-settling areas with large vegetated surfaces would be useful or even practical alternatives to the open water cooling ponds. Not calculated as part of this project is the total reduction in heat load for an average pumping rate of 150 gpm and a median drop in temperature of 3.9ºC (6.8ºF).

Turbidity

The measurement of turbidity provides an indicator of the effectiveness of the filter media. The turbidity data are presented in Table I-3. As mentioned previously, a more sensitive turbidity meter was purchased in February 2003. This is reflected in the data in Table I-5. The information presented in this section applies to the data that were collected and recorded since February 2003.

The median values of turbidity for the water from the cooling pond was 7.5 Nephelometric Turbidity Units (NTU), for the effluent it was 1.7, for the wetland 2.0 NTUs and for the basin 1.65 NTUs. For the same waters the ranges from minimum to maximum were 0.0 to 25.3 NTUs (cooling pond); 0.4 to 10.3 NTUs (effluent); 0.1 to 15.0 NTUs (wetland) and 0 to 413 NTUs (filter basin). The high value at the filter basin is most likely because a change in the pumping regime may have caused IRB biofilm sludge in the filter pipe to be loosened and to be pumped out.

In general, the turbidity in all three water sources is low. This has been apparent in the operation of the filter basin. During its operational life, it was anticipated in the surface distribution design that high turbidity from suspended solids in the water pumped from the wetland would cause significant reductions in the surface hydraulic conductivity. This assumption was because the wetland could be producing algal growth and the algae could be deposited in the sand surface thereby reducing the hydraulic conductivity. From field observations and actual periodic measurements of wetted areas, it became clear that this anticipated phenomenon did not occur. The explanation lies in the fact that 1) a complete cover of the water surface by floating vegetation at the wetland intake structure prevented sunlight to enter the water thereby suppressing the growth of algae, and 2) the gravel envelope surrounding the intake filter pipe was effective in retaining suspended solids.

Color

The SDWS for color is 15 platinum-cobalt units (PCU). Color concentrations were detected in all samples from the cooling pond, wetland, and filter basin. The SDWS was only exceeded in the water samples from the wetland and basin. The median concentration in the cooling pond was 10 PCU, while the median concentrations in the wetland and basin ranged from 20 to 60 PCU.

Color concentrations exceeded the SDWS in the effluent discharge, wetland, and basin. The median color concentrations were 15, 100 and 45 CPU in the effluent, wetland and basin discharges. In the effluent, the color concentrations exceeded the SDWS in 10 out of the 15 samples. In the wetland the drinking water standard was exceeded in all 15 samples. The SDWS for color was exceeded in all samples from the basin.

In the wetland, color seems to be introduced into the system, which is to be expected. It is important to note that the median color concentrations were reduced by passage through the filter basin by 67%, from 60 to 20 PCU during the time that cooling pond water was used as a source and by 55%, from 100 to 45 PCU when effluent water was used as a source.

Odor

The SDWS for odor is 3 threshold odor number (TON). Odor exceeded the SDWS in all samples from the cooling pond, wetland, and basin. The concentrations in the cooling pond ranged from 6 to 120 TON, with a median value of 23.5 TON. The concentrations in the wetland ranged from 12 to 200 TON, with a median value of 100; in the basin, odor ranged from 12 to 70 TON, averaging 50 TON.

Odor was detected and exceeded the SDWS in all samples from the effluent discharge, wetland, and for all except two samples in the basin. The concentrations in the effluent discharge ranged from 8 to 200 TON, with a median value of 50 TON. The concentrations in the wetland ranged from 17 to 140 TON, with a median value of 35 TON. In the basin, concentrations ranged from 2 to 100 TON, with a median value of 5.85 TON.

Of note is the fact that the median odor concentration in the effluent discharge is more than twice as high as in the cooling pond. The reducing environment in the wetland increases the median odor concentration more than fourfold when the cooling pond water is used as a source. The median odor concentration in the wetland actually declines from 50 TON to 35 TON when the effluent is used as a source. Based on field observations by SI personnel, the wetland water discharging to the surface of the tailing sand filter basin produced an unmistakable and strong hydrogen sulfide odor. The median sulfate concentration in the cooling pond water is 110 mg/l, whereas the median concentration in the effluent is 50 mg/l. SI hypothesizes that the reduction of sulfate ions by microorganisms results in the hydrogen sulfide odor. With a lesser supply of sulfate in the wetland when effluent is used, the capacity to generate odor is diminished.

Total Dissolved Solids

The SDWS for total dissolved solids (TDS) is 500 mg/l. In the cooling pond, the SDWS was exceeded in every sample. The median value was 520 mg/l and ranged from 510 to 530 mg/l. When the cooling pond water was used as a source, the TDS in the wetland was in exceedance of SDWS in two of the nine samples. The median TDS value was 430 and ranged from 260 to 570 mg/l. The TDS concentrations in the water from the basin never exceeded the SDWS. The median value was 360 and the concentrations ranged from 250 to 500 mg/l.

The TDS SDWS was not exceeded in samples from the effluent discharge, wetland, or basin. In the effluent discharge, the median TDS concentration was 295 mg/l ranged from 270 to 440 mg/l. In the wetland, the median TDS concentration was 280 mg/l and ranged from 180 to 490 mg/l. In the filter basin, the median TDS was 255 mg/l and ranged from 180 to 440 mg/l.

The decline in the median TDS concentrations between the cooling pond water as a source and the water discharging from the basin was 31%. This same percentage reduction was observed in the measurements of the SEC. The decline in the median TDS concentration when the effluent was used as a source, between the effluent and the water discharging from the basin was 14%. This number is somewhat higher than that for the SEC under the same circumstances (14 versus 9), but could still be interpreted as a similar occurrence.

Inorganic Chemicals

The inorganic chemicals of interest are iron, manganese, fluoride, sodium, sulfate and chloride. While there were no exceedances reported for sodium, chloride and sulfate, a comparison of the change in concentrations of these chemicals is an indication of an important function of the system while the water is moving through the treatment system.

Iron and Manganese

There were two sets of data collected. The first set were field measurements using a field test kit, the second set were the concentrations determined by a laboratory. In the following paragraphs, SI used the information obtained from the laboratory analyses only. The SDWS for iron is 0.3 mg/l and for manganese 0.05 mg/l. It is important to note that the sampling location in the basin changed from collecting ground water from both NS and SS combined to only from NS. This change in sampling protocol occurred on May 22, 2003.

During the period when the cooling pond was the source water, iron concentrations in the cooling pond were present in 23 of the 25 samples and ranged from 0.02 to 0.12 mg/l, with a median value of 0.04 mg/l, which does not exceed the SDWS. Manganese was present in all but three of the 25 samples dates with concentrations ranging from 0.01 to 0.02 mg/l, with a median value of 0.01 mg/l, well below the SDWS. In the wetland, iron was detected in all 25 samples, ranging from 0.05 to 0.26 mg/l, with a median value of 0.14 mg/l, which does not exceed the SDWS. Manganese was present in all 25 samples ranging from 0.01 to 0.07 mg/l, with a median value of 0.03, which is below SDWS.

In the basin, iron was detected in all 26 samples and ranged from 0.48 to 4.7 mg/l, with a median value of 1.15 mg/l. The iron concentrations in the basin samples exceeded SDWS for all 26 samples. Manganese was detected in all 26, with 20 samples exceeding standards. The concentrations ranged from 0.02 to 0.11 mg/l, with a median value of 0.07 mg/l.

When the effluent was used as the source, iron was detected in all 24 effluent discharges, wetland, and basin samples. In the effluent discharge, iron concentrations ranged from 0.042 to 0.49 mg/l, exceeding SDWS in only one sample. The median concentration was 0.08 mg/l. Manganese was present in 20 of 25 samples with concentrations ranging from 0.01 to 0.08 mg/l with two samples exceeding the SDWS. The median concentration was 0.03 mg/l.

In the wetland, iron concentrations ranged from 0.06 to 0.37 mg/l with two exceedances on 8/13/03 and 8/28/03. The median concentration was 0.11 mg/l. Manganese was present in 22 of the 24 samples with concentrations ranging from 0.01 to 0.03 mg/l. None of the samples exceeded SDWS. The median concentration was 0.02 mg/l.

In the basin, iron concentrations ranged from 0.04 to 6.00 mg/l, with eight samples exceeding the SDWS. The median value was 0.0.23 mg/l. Manganese was detected in 19 of the 24 samples with concentrations ranging from 0.012 to 0.060 mg/l with only one sample above SDWS. The median concentration was 0.03 mg/l.

When the cooling pond was used as a source of water, the import of iron and manganese were quite low with median values of 0.04 and 0.01 mg/l, respectively. The median concentrations of iron and manganese increased by 3.5 and 3.0 times while the water flowed through the wetland. The median concentration of the iron increased more than 8 times while percolating through the filter basin leading to the supposition that iron was leached from the tailing sand or was present in groundwater seeping from outside of the filter basin into the filter basin. Field observations of IRB biofilm formation in the SS support this supposition. As a further proof, the data collected from the NS and the SS clearly indicated that the iron concentration varied considerably with the water from the NS being significantly lower. This led to the conclusion that the SS acted as an interceptor drain to "catch" influent seepage, while the NS received percolating wetland water from the surface recharge system. This is further supported by the fact that the median iron concentrations in the basin water when the effluent was used were 0.23 mg/l, which is below the SDWS. This happened because the change in sample location to the NS occurred at approximately the same time as the switch to using effluent as a source. Based on this information, it is realistic that the large iron concentrations in the basin water could be primarily due to high iron concentrations in the groundwater seeping into the filter basin and intercepted by the south filter pipe. This hypothesis is further supported by the fact that the median manganese concentrations in the basin water declined from 0.07 to 0.03 mg/l, a 57% reduction after the source and sampling point switch. No actual samples of the groundwater outside the filter basin were collected and analyzed.

Fluoride

It is interesting to note that there are different standards for the same chemical compound in the drinking water standards. In the PDWS, the standard for fluoride is 4.00 mg/l, while in the SDWS it is 2.00 mg/l. The lower SDWS level is an advisory level for families with children below the age of 9 years. Fluoride concentrations between 2.00 and 4.00 may affect the development of teeth in children. Fluoride was present in all the samples from the cooling pond, wetland, and filter basin. In the cooling pond, fluoride concentrations exceeded the SDWS in all samples with the concentrations ranging from 2.30 to 2.80 mg/l, and a median value of 2.50 mg/l. The fluoride concentrations in the wetland when the cooling pond was used as a source were above the SDWS for 11 of 25 samples and ranged from 1.10 to 2.70 mg/l, with a median value of 2.00 mg/l. In the basin, fluoride concentrations exceeded the SDWS in 13 of the 26 samples and ranged from 1.40 to 2.50 mg/l, with a median value of 1.95 mg/l.

Fluoride was present in the effluent discharge, wetland, and basin in all samples. In the effluent discharge, fluoride concentrations ranged from 0.11 to 0.38 mg/l, with a median value of 0.27 mg/l. The fluoride concentrations in the wetland using the effluent as a source ranged from 0.7 to 2.2 mg/l, with a median value of 0.93 mg/l, and exceeded SDWS in three samples out of 23. In the basin, fluoride concentrations exceeded the SDWS in 8 out of the 23 samples, ranging from 1.1 to 3.3 mg/l. The median concentration was 1.70 mg/l.

It is interesting to note that when the cooling pond was used as a source, the median fluoride values in the samples from the filter basin declined by 22% in comparison to the cooling pond water. When the effluent was used as a source the median concentrations in the samples from the filter basin increased more than six times in comparison to the effluent. In both cases, the median values still met the SDWS and at no time did any sample (from any location) ever exceed PDWS.

Sodium, Chloride and Sulfate

The PDWS for sodium is 160 mg/l, and SDWS is 250 mg/l for chloride and sulfate. In this section, the sodium and chloride concentrations are used as conservative markers and their fate in the treatment system is compared to that of sulfate. Sodium concentrations ranged from 76 to 85 mg/l (with a median of 77.5 mg/l) in the cooling pond, 34 to 80 mg/l (median 69.5 mg/l) in the wetland, and 35 to 79 mg/l (median 61.0 mg/l) in the basin.

When the effluent was used as a source, the sodium concentration ranged from 37 to 85 mg/l (median 58.5 mg/l) in the effluent, 31 to 86 mg/l (median 43.0 mg/l) in the wetland, and 32 to 75 mg/l (median 44.0 mg/l) in the basin.

Comparing the median sodium concentrations in the wetland to those in the cooling pond, they declined by approximately 10%. Similarly, comparing the sodium concentrations in the basin water to those in the cooling pond, they declined by approximately 21%. Comparing the median sodium concentrations in the wetland to those in the effluent, they declined by approximately 26%. Similarly, comparing the sodium concentrations in the basin water to those in the effluent, they declined by approximately 25%.

In the cooling pond, chloride concentrations ranged from 93 to 120 mg/l, with a median of 100 mg/l. Samples from the wetland contained concentrations from 38 to 110 mg/l, with a median 97 mg/l. Samples from the basin contained concentrations ranging from 37 to 100 mg/l and a median of 79 mg/l.

In the effluent, the concentrations ranged from 61 to 140 mg/l, with a median 89 mg/l. In the wetland, concentrations ranged from 41 to 110 mg/l, with a median of 65 mg/l. In the basin, concentrations varied from 40 to 140 mg/l, with a median of 64 mg/l.

When the cooling pond water was used as a source, the median chloride concentrations in the wetland declined by approximately 3% compared to those in the cooling pond. Similarly, comparing the median chloride concentrations in the basin water to those in the cooling pond, they declined by approximately 21%. Comparing the median chloride concentrations in the wetland to those in the effluent, they declined by approximately 26%. The chloride concentrations in the basin water declined by approximately 25% compared to those in the effluent.

Sulfate was present in all samples in the cooling pond, wetland, and basin. In the cooling pond, the sulfate concentrations ranged from 95 to 120 mg/l with a median concentration of 110 mg/l. In the wetland, the concentrations ranged from 9.4 to 100 mg/l, with a median of 60 mg/l. The concentrations in the basin ranged from 22 to 100 mg/l with an average of 58.5mg/l.

Sulfate was present in all samples in the effluent discharge, wetland, and basin. In the effluent discharge, the sulfate concentrations ranged from 46 to 62 mg/ with a median of 50 mg/l. In the wetland, the concentrations ranged from 6.5 to 66 mg/l with a median of 20.0 mg/l. The concentrations in the basin ranged from 10 to 70 mg/l with a median of 22.0 mg/l.

When the cooling pond water was used as a source, the median sulfate concentrations in the wetland declined by approximately 46% compared to those in the cooling pond. Similarly, comparing the median sulfate concentrations in the basin water to those in the cooling pond, they declined by approximately 47%. Comparing the median sulfate concentrations in the wetland to those in the effluent, they declined by approximately 60%. The sulfate concentrations in the basin water declined by approximately 56% compared to those in the effluent.

The reduction in median concentration in the sodium, chloride and sulfate is presented in the following Table 12.

Table 12. Reductions in Median Concentrations of Sodium, Chloride and Sulfate in the Treatment System.

	Source: Cooling Pond % Reduction in Median Concentration			Source: Effluent % Reduction in Median Concentration		
	Na^+	Cl^-	$SO_4^=$	Na^+	Cl^-	$SO_4^=$
Wetland/Cooling Pond	10	3	46			
Basin/Cooling Pond	21	21	47			
Wetland/Effluent				26	27	60
Basin/Effluent				25	28	56

It is clear from the summary of the percentages of the reductions in median concentrations, that the sulfate concentrations were reduced by nearly twice the reductions in concentrations of the conservative chemical compounds sodium and chloride. The reductions in concentrations of these compounds were due to rainfall dilution. A rationalization is that the reductions in sulfate were due to rainfall dilution and desulphurization by anaerobic bacteria, according to the following processes:

$$SO_4^= + organic\_matter \xrightarrow{anaerobic\_bacteria} S^= + H_2O + CO_2$$ Equation (1)

$$S^{=} + 2H^{+} \leftrightarrow H_2S \qquad \text{Equation (2)}$$

According to Sawyer and McCarty (1967), under anaerobic conditions "the sulfate ion is reduced to the sulfide ion, which established an equilibrium with hydrogen to form hydrogen sulfide in accordance with its primary ionization constant ($K_1 = 9.1 \times 10^{-8}$). At levels of pH of less than 8, the equilibrium shifts rapidly toward the formation of un-ionized H_2S and is about 80% complete at pH 7. Under such conditions the partial pressure of hydrogen sulfide becomes great enough to cause serious odor problems whenever sulfate reduction yields a significant amount of sulfide ion."

This process is clearly at work in the wetland. While no samples were collected to test the concentrations of hydrogen sulfide, field observations at the basin established strong to very strong hydrogen sulfide odors. The median odor value in the water leaving the wetland was 425% higher than in the cooling pond when the cooling pond water was used as a source. This source water had a median sulfate concentration of 110 mg/l. When effluent was used as a source water with a median sulfate concentration of 50 mg/l, the median odor concentration in the water leaving the wetland was 30% less than in the effluent. The point in these analyses is to emphasize that the availability of the sulfate in the source water also plays an important role in the production of hydrogen sulfide.

Nutrients

Water samples were analyzed for the presence and concentrations of un-ionized ammonia, nitrite and nitrate. Not many analyses were performed for the ammonia and concentrations were found to be at or near detection limits (0.002 mg/l). There were many analyses performed for nitrite, but these were also at or near detection limits (0.005 mg/l). During the time that the cooling pond was used as the source, the median concentration of nitrate nitrogen entering the wetland from the cooling pond was 0.002 mg/l. During that same time, the median concentration of nitrate nitrogen in the water leaving the wetland was 0.002 mg/l and in the water leaving the basin, 0.08 mg/l. The median nitrate nitrogen concentration increased slightly during the flow through the basin, although the concentrations are well below the 10 mg/l of nitrate nitrogen given as a PDWS.

After changing the source water to effluent, there is a change in the median concentration of nitrate nitrogen flowing into the wetland to 2.7 mg/l. The median concentration of nitrate nitrogen in the water from the wetland declines rather significantly to 0.01 mg/l, indicating the effectiveness of the wetland treatment at reducing the concentrations of nitrate nutrients. As before, the median concentration of the nitrate increases slightly in the water leaving the basin (0.19 mg/l). There is no immediately apparent explanation for this slight increase.

Another important nutrient parameter is total phosphorus with a method detection limit of 0.03 mg/l. Because the HEC is constructed on mined phosphate lands, there is interest in testing the waters to see if this fact may influence the quality of the water.

This study has not found this to be the case. During the time that the cooling pond water was the source water, the median concentration of total phosphorus in the surface water in the 722 acres cooling pond was 0.54 mg/l. The median concentration in the water leaving the wetland during that time was 1.1 mg/l and the median concentration in the water leaving the basin was 0.58 mg/l.

When the effluent was used as the source water, the median concentration of phosphorus in the effluent flowing into the wetland was 2.2 mg/l. The median concentration in the water pumped from the wetland during that time was 1.5 mg/l and the median concentration in the water pumped from the basin was 0.97 mg/l. From the data collected during the operation with effluent as the source water, it showed that the wetland-basin treatment reduced the total phosphorus concentration from a median value of 2.2 mg/l to 0.97 mg/l.

Organic Chemical Compounds

The results of all of the analyses that were performed to compare the organic chemical compounds to the Maximum Contaminant Level (MCL) are presented in Appendix G. This section focuses on only those very few organic chemical compounds with concentrations that were above the detection limits. It should be noted that no organic chemical compounds were detected in any sample from the cooling pond, the wetland or basin when the cooling pond was used as the source water. The only detection of organic chemical compounds occurred after the system was switched to effluent as the source water in May 2003.

Volatile Organic Compounds

In samples collected between August and November 2003 from the wetland pump, toluene was detected at a concentration barely above detection limits (0.5µg/l) and still below MCL of 1mg/l. No toluene was found in the effluent or basin water. The occurrence of these low level toluene concentrations are attributed to be the result of engineering work that was done on the intakes of the wetland pump, where solvents were used to loosen the bolts connecting the intake piping to the pump.

In one sample from the effluent collected in August 2003, para-dichlorobenzene was detected in a concentration (0.58 µg/l) barely above the detection limit of 0.5 µg/l, well below the MCL of 0.075 mg/l. In another sample collected in November 2003, xylene was detected (limit of 0.5 µg/l) at a concentration of 2.0 µg/l, well below the MCL of 10 mg/l. Neither of these chemicals were detected in the wetland or basin.

Trihalomethanes

No trihalomethanes were detected in any of the samples from the cooling pond, wetland, or filter basin from March 2001 to April 2003, when the cooling pond was used as the source water.

Trihalomethanes are known to be associated with the treatment processes of drinking water and wastewater. They are formed during the disinfection stage by combining residual organic compounds with chlorine. It is therefore not surprising that trihalomethanes were found in the treatment system when the effluent was used as the source from May 2003 through December 2003. There were only a few trihalomethanes detected. They were: bromodichloromethane (DL: 0.3 µg/l), bromoform (DL: 0.5 µg/l), bromomethane (DL: 0.5 µg/l), chloroform (DL: 0.2 µg/l), dibromochloromethane (DL: 0.5 µg/l), and total trihalomethanes (DL: 0.002 mg/l). Detailed information is provided in Tables G-1 and G-2 in Appendix G.

Bromodichloromethane was detected in the effluent discharge in all 16 samples with a concentration ranging from 2.0 to 16 µg/l, with a median of 6.45 µg/l. It was not detected in any samples from the wetland or basin indicating that they are apparently removed in the wetland.

Bromoform was only detected once in the effluent discharge on 11/18/03 with a concentration of 1.1 µg/l., therefore it is considered an aberration. It was not detected in any samples from the wetland or basin.

Chloroform was detected in the effluent discharge in all samples with concentrations ranging from 1.0 µg/l to 44 µg/l and a median of 14.0 µg/l. It was also detected once in the wetland on 6/25/03 with a concentration of 5.5 µg/l. In the filter basin, it was detected twice on 7/1/03 and 11/24/03 with a concentration of 0.83 and 0.52 µg/l respectively.

Dibromochloromethane was detected in the effluent discharge in 13 out of 16 samples with a concentration ranging from 0.13 to 12 µg/l and a median 1.6 µg/l. It was not detected in any of the samples from the wetland or basin.

Total trihalomethanes (TTHM) are the sum of bromodichloromethane, bromoform, bromomethane, chloroform, and dibromochloromethane. These were detected in the effluent discharge in all samples with concentrations ranging from 11 µg/l to 64 µg/l, with a median 33 µg/l.. These were also detected once in the wetland on 6/25/03 with a concentration of 6 µg/l. In the filter basin, they were detected twice on 7/1/03 and 11/24/03 with a concentration of 0.83 and 0.52 µg/l respectively. The MCL for TTHM is 80 µg/l, therefore the detected amounts never exceeded the limit in any part of the system In spite of the findings of the TTHM in the water leaving the wetland and the filter basin, the treatment system does remove and in most cases eliminates the trihalomethanes concentration.

Microorganisms

The measurement of microorganisms provided an indicator of the effectiveness of the filter media in reducing total and fecal coliform bacteria, and *cryptosporidium* and *Giardia*. Although *cryptosporidium* and *Giardia* were found in the water before they entered the filter basin, none were detected in the water leaving the filter basin, indicating its effectiveness in reducing the concentrations of these microorganisms.

The capacity of the tailing sand filter basin to remove coliform bacteria to the regulatory MCL has not been entirely reliable during the project period. One of the factors appears to be the depth to the water table in the filter basin. Because of climatic and operational difficulties, the desired operational depth between 6 and 8 feet bls initially was not always maintained. Every time water levels fluctuated significantly, there were "breakthroughs" of higher total coliform bacteria counts as illustrated in Figure 12.

The previously used descriptive statistics are not appropriate for the interpretation of coliform results. The coliform information is presented in tables in Table H-1 and H-2 in Appendix H. As previously noted, there were two sources of water, the cooling pond and the effluent. The information contained in Table H-1 and H-2 was separated based on the source water, the type of analysis (total coliform and fecal coliform) and MPN (most probable number) interval. The intervals were selected to reflect a modified logarithmic division of concentration reductions. The first interval is less than (<) 2 MPN for the fecal coliform and <4 MPN for the total coliform. These two intervals represent levels at which regulatory standards would be met. The summary of the data from Tables H-1 and H-2 are presented in Table 13. The information in Table 13 is presented in graphical form in Figures 13 and 14 to emphasize the capacity of the tailing sand filter basin to remove the total and fecal coliform bacteria.

In Figure 13, the total coliform count in each one of the five intervals (<4, 4-10, 11-100, 101-1000, >1000) is plotted when the cooling pond or the effluent was used as a source. In Figure 14 the fecal coliform count in each one of the five intervals (<4, 4-10, 11-100, 101-1000, >1000) is plotted when the cooling pond or the effluent was used as a source.

The residual counts in the samples from the basin did not always meet the regulatory standard. When the cooling pond was used as a source, the regulatory standard for total coliform was met in 20 out of 38 samples. When the effluent was used, the regulatory standard for total coliform was met 18 out of 29 samples. Fecal coliform standards were met in 31 out of 39 samples when cooling pond water was the source and in 25 out of 29 samples when the effluent was used as a source.

Although the success rate of not exceeding regulatory standards was not 100 percent, the treatment system significantly reduced the concentrations of fecal and total coliform. In only a very few samples (4 out of 67) did the total coliform count in samples from the basin fall into the 101-1000 interval. No samples were found in which the total coliform count exceeded 1000.

While not part of this study, SI determined that the total coliform counts and the quality of the water lends itself well to the removal of total coliform by the use of ultra-violet radiation.

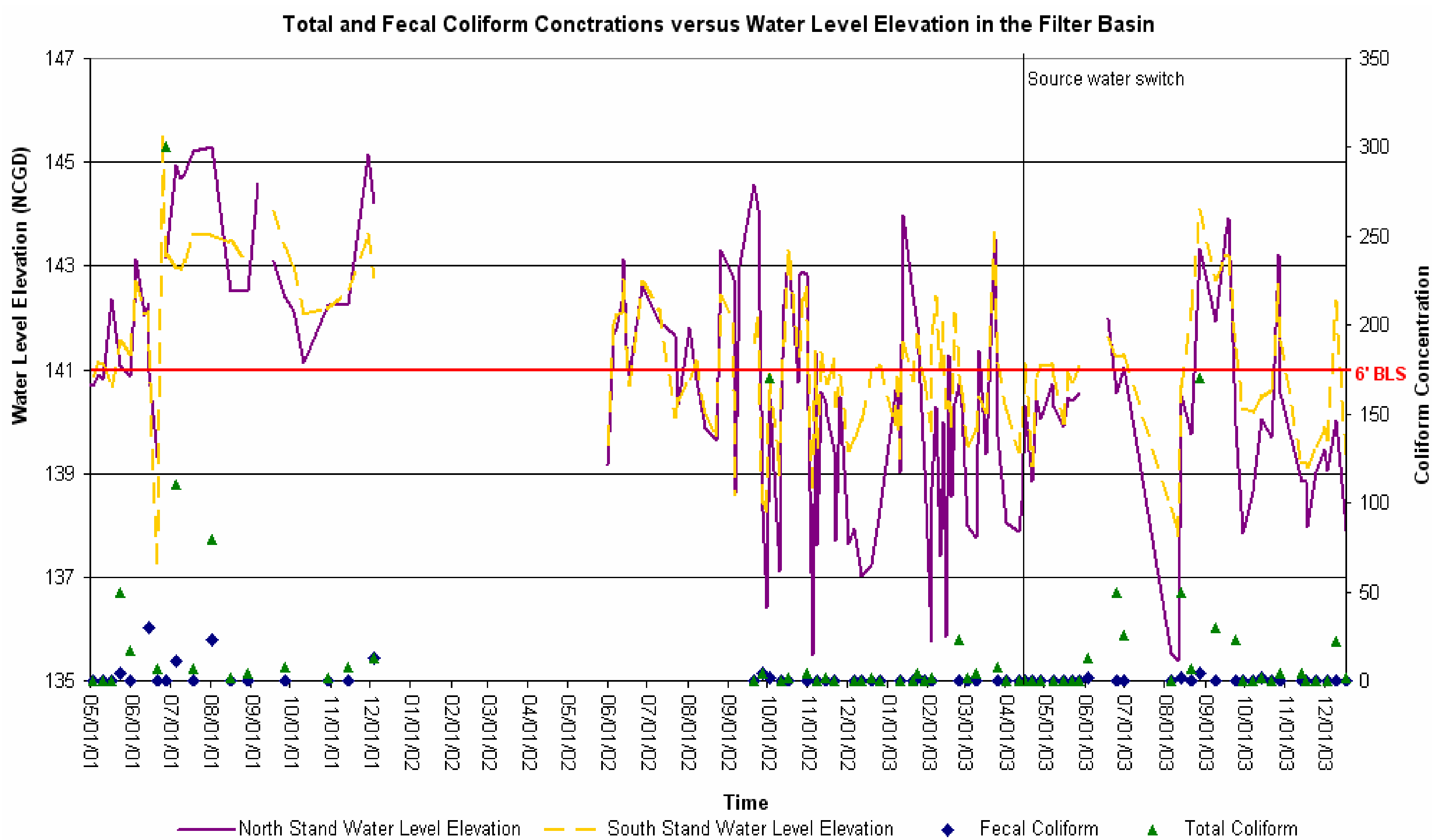


Figure 12. Water Levels in North and South Stand Pipes with Fecal and Total Coliform Concentrations.

Table 13. Comparison of Frequency Distribution of Total and Fecal Coliform Concentrations in Wetland and Basin for Both Water Sources.

	Source Water: Cooling Pond				Source Water: Effluent			
	Wetland		Basin		Wetland		Basin	
MPN	TC	FC	TC	FC	TC	FC	TC	FC
<2		4		31		2		25
<4	0		20		0		18	
2-10		4		4		4		4
4-10	0		10		0		3	
11-100	3	16	5	4	5	10	7	0
101-1000	17	10	3	0	12	6	1	0
>1000	16	3	0	0	10	4	0	0
Total	36	37	38	39	27	26	29	29

Note: MPN refers to Most Probable Number of coliform colonies, TC is Total Coliform and FC is Fecal Coliform. The regulatory requirement for Fecal Coliform is <2 MPN and for Total Coliform is <4 MPN.

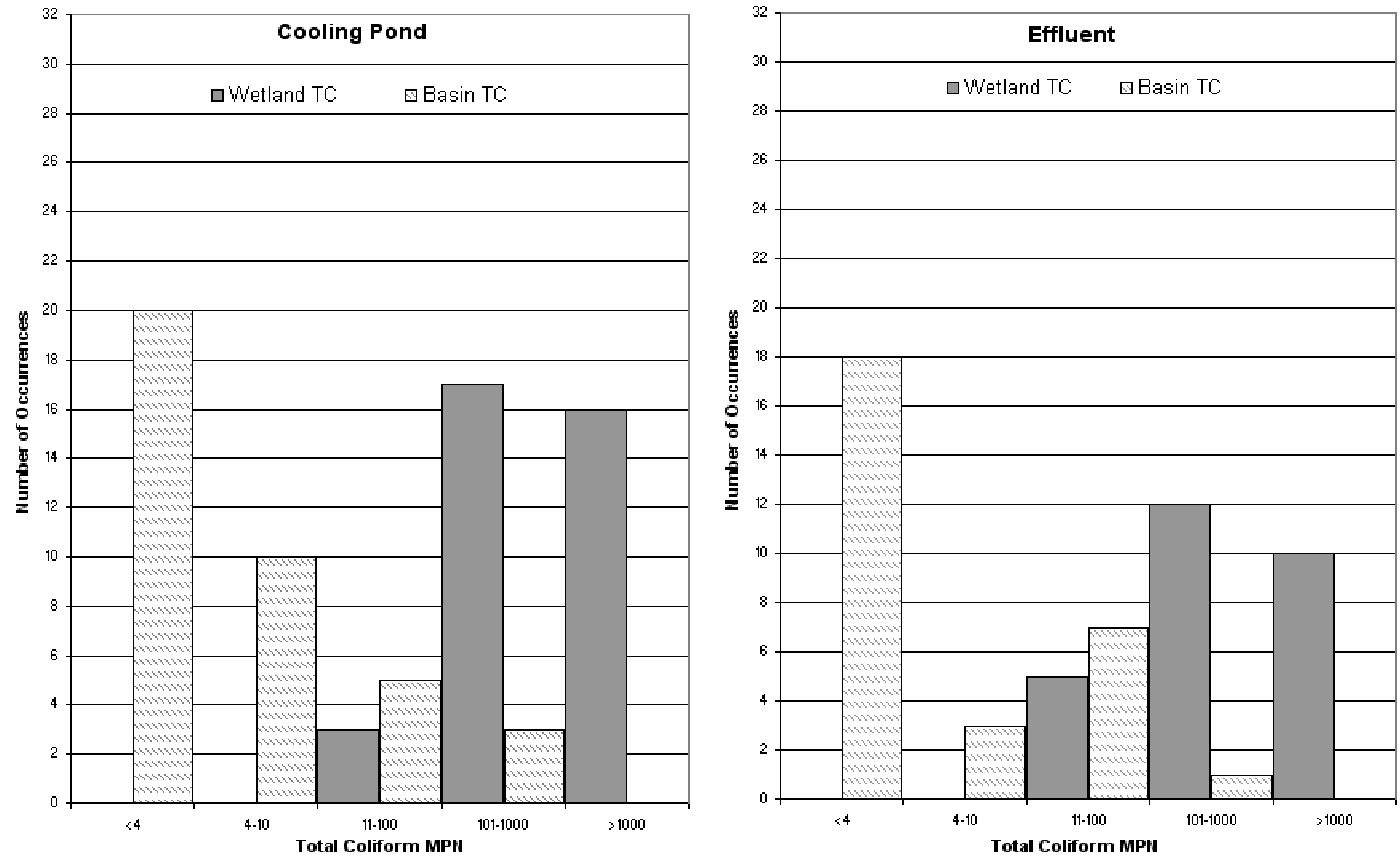


Figure 13. Total Coliform Frequency Distribution at Wetland and Filter Basin.

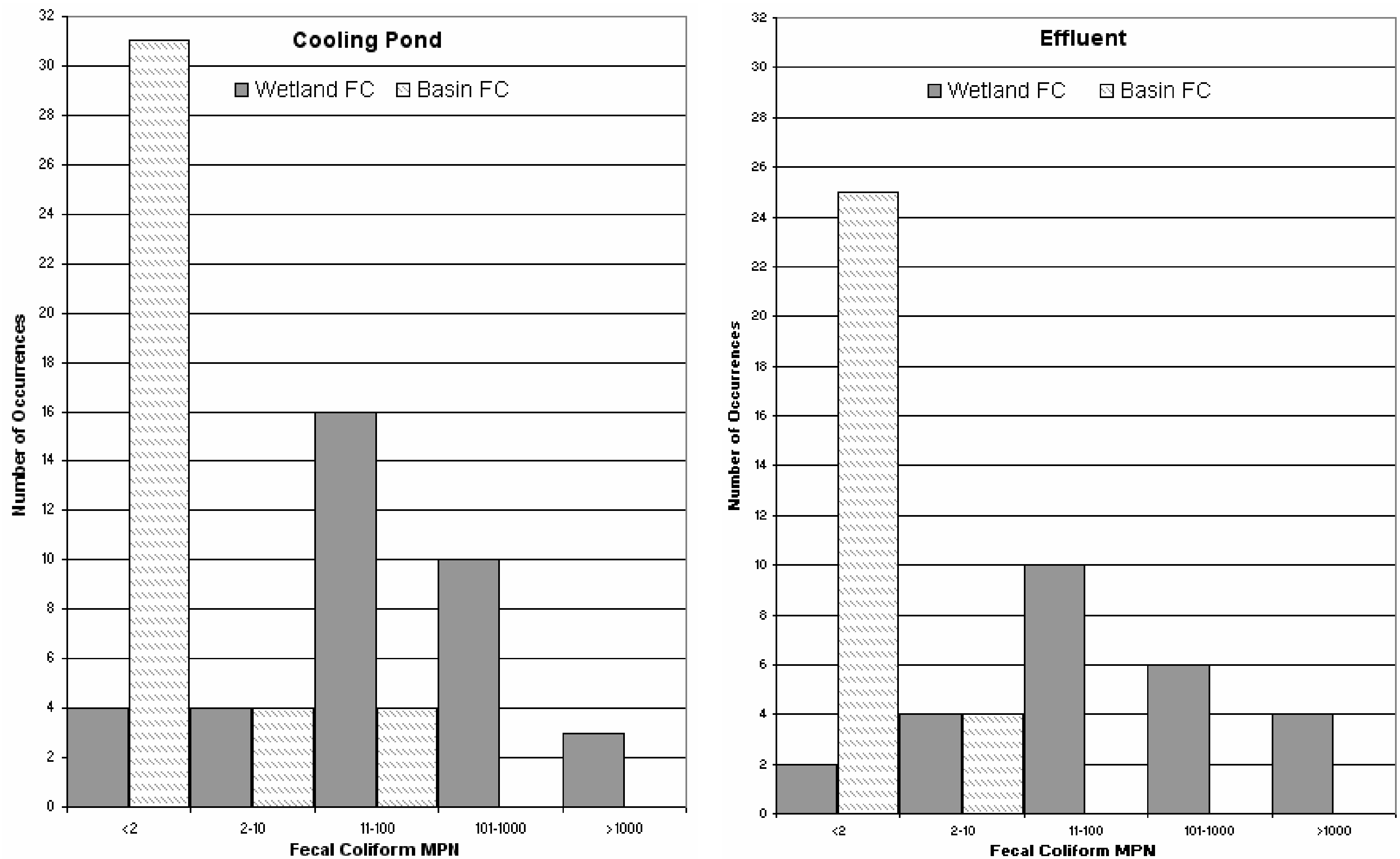


Figure 14. Fecal Coliform Frequency Distribution at Wetland and Filter Basin.

Treatment Assessment

To assess the treatment performance of the system, it was decided to use the median values of the data that were collected. Treatment for the purpose of this report is defined as the reduction in concentration of a specific chemical. If the concentration remained the same or increased, no treatment was provided. There are three elements to this assessment. In the first one, the treatment in the wetland of the cooling pond and effluent water is evaluated. In the second element, the treatment of the water in the filter basin is evaluated. In the third element, the treatment of the water from the cooling pond or effluent flowing through the entire system (wetland and filter basin) is addressed.
A summary of the median values of selected chemical compounds that were found in the water samples from the cooling pond, effluent, wetland and filter basin is provided in Tables 14 through 17. In the Tables, a distinction is made between the chemical compounds that were found to be present but never exceeded the standards and those that were present but exceeded the standards one or more times. Another distinction is made based on the source of the water (cooling pond versus effluent).

In Table 14 the median values of chemical compounds are listed that was detected but never exceeded the PDWS or SDWS when the cooling pond was used. In Table 15 the median values of the chemical compounds and physical parameters are listed that was detected and exceeded at least once the PDWS and SDWS, when the cooling pond was used as a source.

Table 14. Median Values of Chemical Compounds That Never Exceeded PDWS/SDWS with Cooling Pond Water as the Source.

Water Quality Parameter	Units	Cooling Pond Median	Wetland Median	Basin Median
Sulfate	mg/l	110	60	58.8
Nitrate	mg/l	0.002	0.002	0.08
Nitrite	mg/l	0.005	0.005	0.005
Arsenic	mg/l	0.0019	0	0.001
Sodium	mg/l	78	70	61
Aluminum	mg/l	0.17	0	0
Chloride	mg/l	100	97	79
Copper	mg/l	0	0	0.01
Silver	mg/l	0.01	0	0
Zinc	mg/l	0.01	0	0
Foaming Agents	mg/l	0.05	0	0

Table 15. Median Values of Chemical Compounds and Physical Parameters That Exceeded PDWS/SDWS with Cooling Pond Water as the Source.

Water Quality Parameter	Units	Cooling Pond Median	Wetland Median	Basin Median
Iron	mg/l	0.04	0.14	1.15
Manganese	mg/l	0.01	0.03	0.06
Fluoride	mg/l	2.5	2	1.95
Color	PCU	10	60	20
Odor	TON	24	100	50
Total Dissolved Solids	mg/l	520	420	360

In Table 16, the median values of chemical compounds are listed that were detected but never exceeded the PDWS or SDWS when the effluent was used. In Table 17 the median values of the chemical compounds and physical parameters are listed that were detected and exceeded at least once the PDWS and SDWS, when the effluent was used as a source.

Table 16. Median Values of Chemical Compounds That Never Exceeded PDWS/SDWS with Effluent as the Source.

Water Quality Parameter	Units	Effluent Median	Wetland Median	Basin Median
Manganese	mg/l	0.03	0.02	0.02
Sulfate	mg/l	50	20	22
Nitrate	mg/l	2.7	0.01	0.19
Nitrite	mg/l	0.018	0	0
Arsenic	mg/l	0.0017	0	0.0009
Sodium	mg/l	59	43	44
Chloride	mg/l	89	65	64
Copper	mg/l	0	0	0.0057
Zinc	mg/l	0.046	0	0
Total Dissolved Solids	mg/l	295	280	255
Foaming Agents	mg/l	0	0.06	0

Table 17. Median Values of Chemical Compounds and Physical Parameters That Exceeded PDWS/SDWS with Effluent as the Source.

Water Quality Parameter	Units	Effluent Median	Wetland Median	Basin Median
Iron	mg/l	0.08	0.11	0.23
Fluoride	mg/l	0.27	0.93	1.7
Color	PCU	15	100	45
Odor	TON	50	35	6
Bromodichloromethane	μg/l	6.45	0	0
Chloroform	μg/l	14	0	0
Bromoform	μg/l	1.1*	0	0
Dibromochloromethane	μg/l	1.15	0	0
Total Trihalomethanes	mg/l	0.028	0	0

*Only one reading was above detection limit.

Treatment Capacity

A total of approximately 150 million gallons were pumped through the treatment system from the cooling pond at the Hines Energy Complex and from the effluent discharge from the wastewater treatment plant of the City of Bartow. The cooling pond is an industrial wastewater source and the effluent a domestic wastewater source. The operation of the system was hampered somewhat by its location. The tailing sand filter basin was constructed at a relatively (topographically) high elevation. The power supply lines were therefore elevated exposing them more than normal to climatic conditions in particular lightning strikes. Much time was spent in repairing lightning damage to the equipment and replacing sensitive water level monitoring and operational control equipment.

A comprehensive analysis of all the available data suggest that some groundwater from outside the filter basin was induced to seep into the filter basin affecting the concentrations of in particular iron and possibly manganese and fluoride. The impacts are believed to be small.

Another important finding was that the combination of a gravel filter bed around the intake pipes at the wetland pumping station in combination with a cover of floating plants on the surface of the water in the wetland at the pumping station provide water with a relatively low turbidity concentration. This low concentration did not significantly affect the percolation capacity of the tailing sand surface. The average percolation rate during the life of the project is approximately 3 ft per day.

During the project turbidity measurements were made in the field and are useful for comparisons and not for absolute value interpretations. Nevertheless, the current EPA drinking water standards lists a value of 5 NTU. Active water treatment plants need to meet less than 1 NTU. During the project, the first meter was inaccurate so a new meter was purchased and used from February 2003 through the end of the project. From April 2003 until the end of the project, turbidity values were measured in the cooling pond, effluent, wetland and filter basin. There was only one exceedances in 37 measurements of the 5 NTU limit in the water from the filter basin. It is believed that this is an artifact measurement. The limit was exceeded five times out of 36 measurements in the water from the wetlands, two times in 37 measurements in the water from the effluent discharge pipe, and 23 times out of 25 measurements in the water from the cooling pond. The median values are as follows: Cooling Pond 7.5 NTU; Effluent 1.7 NTU; Wetland 2.0 NTU; Basin 1.6 NTU.

Debris in the effluent discharge from the City of Bartow's wastewater treatment plant was a problem for the flow meters. Similarly, from time to time iron hydroxide particles suspended in the water from the south standpipe in the filter basin would impede the proper operation of the flow meter.

During operation of the treatment system, the pumpage rate averaged approximately 150 gallons per minute, which is a good rate for a pilot study providing confidence for the design of much larger systems.

Wetland Detention

Detailed cross sections of the wetted areas in the linear wetland were not available and were estimated. Based on these estimated cross-sections and the measured length of the linear wetland, the total water volume was estimated to be 4.8 million gallons. At an average inflow rate of 150 gallons per minute the detention time was approximately 22 days.

Wetland Performance

Because two different sources of water were used, it is expected that the treatment system will react differently. It was decided to illustrate the performance of the wetland by graphically presenting the declines or increases in the median value of the concentrations of the chemical compounds. In Figure 15 and Figure 16, the increases or decreases in the median values of the concentrations of the chemical compounds with the use of the cooling pond or effluent water as a source to the wetland are presented. The red color (vertical hatch lines) indicates an increase in the median concentration of that specific chemical compound or physical parameter in the water flowing through the wetland. The green color (horizontal hatch lines) indicates a decrease in the median value of the concentration of that specific chemical compound or physical parameter in the water flowing through the wetland. Where no color or hatch patterns are shown, the value of the median concentration did not change.

While the cooling pond water was flowing through the wetland, the value of the median concentrations of 10 chemical compounds declined, while the median value of the concentrations of 2 chemical compounds and 2 physical parameter increased. The median value of 2 chemical compounds remained the same.

While the effluent water was flowing through the wetland, the value of the median concentrations of 14 chemical compounds and 4 physical parameters declined, while the median value of the concentrations of 2 chemical compounds and 2 physical parameter increased.

Water Quality Parameter	Wetland Treatment (CP as Source)
Iron	increased
Manganese	increased
Fluoride	decreased
Sulfate	decreased
Nitrate	
Nitrite	
Arsenic	decreased
Sodium	decreased
Aluminum	decreased
Chloride	decreased
Silver	decreased
Zinc	decreased
Color	increased
Odor	increased
Total Dissolved Solids	decreased
Foaming Agents	decreased

LEGEND

(blank)	= stayed the same
(red vertical lines)	= increased
(green horizontal lines)	= decreased

Water Quality Parameter	Wetland Treatment (Effluent as Source)
Iron	increased
Manganese	decreased
Fluoride	increased
Sulfate	decreased
Nitrate	decreased
Nitrite	decreased
Arsenic	decreased
Sodium	decreased
Chloride	decreased
Zinc	decreased
Color	increased
Odor	decreased
Total Dissolved Solids	decreased
Foaming Agents	increased
Bromodichloromethane	decreased
Bromoform	decreased
Chloroform	decreased
Dibromochloromethane	decreased
Total Trihalomethanes	decreased
pH	decreased
Specific Electrical Cond.	decreased
Total Suspended Solids	decreased

Figures 15 (left) and 16 (right). Changes in Water Quality in the Water Flowing through the Wetland Using Cooling Pond Water or Effluent as Source Water.

On balance, the data indicate that the wetland had a positive effect in reducing the concentrations of certain chemical compounds and physical parameters. Because the number of chemical compounds that were reduced in their concentrations is greater in the water coming from the effluent source, one could conclude that its treatment capacity of the wetland for the effluent is more effective. One ought, however to be cautious in this conclusion in that the quality of the cooling pond water was quite good. The best function of the wetland for the cooling pond water was the significant reduction in the sulfate concentrations and the reduction in the pH and the significant reduction in the temperature of the surface water.

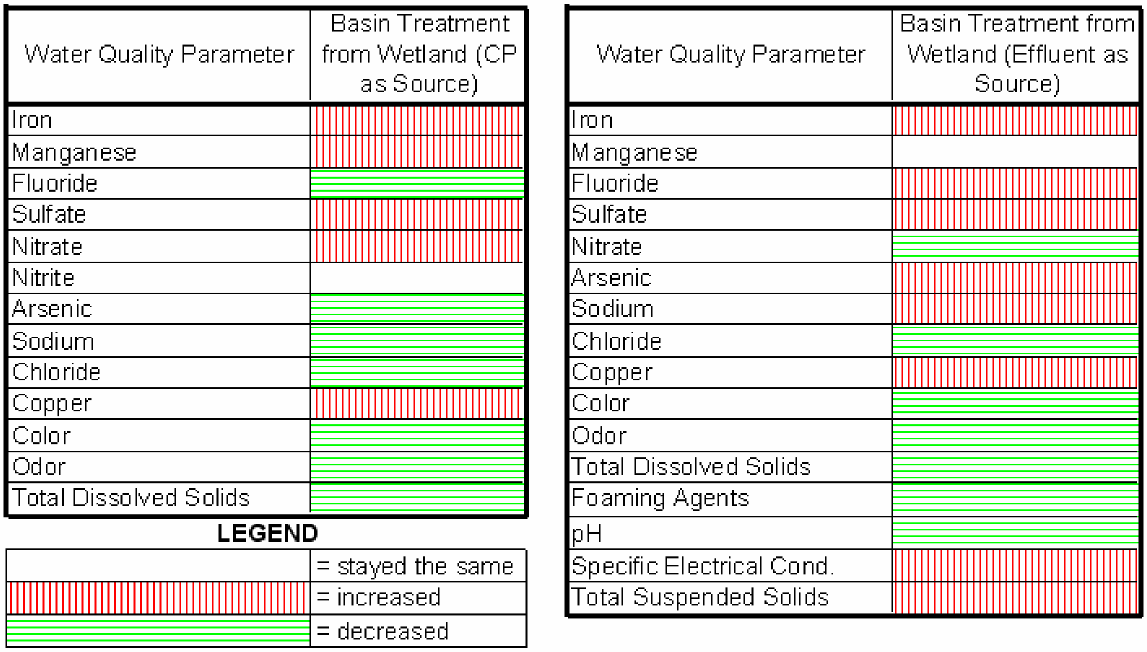
Filter Basin Treatment

Because two different sources of water were used, it is expected that the treatment system will react differently. It was decided to illustrate the performance of the basin by graphically presenting the declines or increases in the median value of the concentrations of the chemical compounds. In Figure 17 and Figure 18, the increases or decreases in the median values of the concentrations of the chemical compounds with the use of the cooling pond or effluent water as a source to the wetland and subsequently the basin are presented. The red color (vertical hatch lines) indicates an increase in the median concentration of that specific chemical compound or physical parameter in the water flowing through the wetland. The green color (horizontal hatch lines) indicates a decrease in the median value of the concentration of that specific chemical compound or physical parameter in the water flowing through the wetland. Where no color or hatch patterns are shown, the value of the median concentration did not change.

While the cooling pond water was flowing through the wetland and then through the basin, the value of the median concentrations in the water flowing from the basin of 4 chemical compounds and 3 physical parameters declined, while the median value of the concentrations of 5 chemical compounds increased. The median value of 1 chemical compounds remained the same.

While the effluent water was flowing through the wetland and then through the basin, the value of the median concentrations of 3 chemical compounds and 4 physical parameters declined, while the median value of the concentrations of 7 chemical compounds and 1 physical parameter increased. The median value of 1 chemical compounds remained the same.

On balance, the data indicate that the basin had a positive effect in reducing the turbidity in the water flowing from the basin. The concentrations of certain chemical compounds and physical parameters increased slightly while others declined.



Figures 17 (left) and 18 (right). Changes in Water Quality in the Water Flowing through the Filter Basin Using Cooling Pond Water or Effluent as Source Water.

Entire System Treatment

Because two different sources of water were used, it is expected that the treatment system will react differently. It was decided to illustrate the performance of the entire system by graphically presenting the declines or increases in the median value of the concentrations of the chemical compounds. In Figure 19 and Figure 20, the increases or decreases in the median values of the concentrations of the chemical compounds with the use of the cooling pond or effluent water as a source to the wetland are presented. The red color (vertical hatch lines) indicates an increase in the median concentration of that specific chemical compound or physical parameter in the water flowing through the wetland. The green color (horizontal hatch lines) indicates a decrease in the median value of the concentration of that specific chemical compound or physical parameter in the water flowing through the wetland. Where no color or hatch patterns are shown, the value of the median concentration did not change.

While the cooling pond water was flowing through the wetland, the value of the median concentrations of 10 chemical compounds declined, while the median value of the concentrations of 2 chemical compounds and 2 physical parameter increased. The median value of 2 chemical compounds remained the same.

While the effluent water was flowing through the wetland, the value of the median concentrations of 14 chemical compounds and 4 physical parameters declined, while the median value of the concentrations of 2 chemical compounds and 2 physical parameter increased.

The concentrations of iron, copper, color and suspended solids increased regardless of the sources of the water. In the case of the effluent as a source the concentration of fluoride increased. This did not happen when cooling pond water was used as a source. The only other chemical compound which concentration increased was nitrate when the cooling pond water was used. With all these comments, the reader is cautioned that while median concentrations of certain parameters might increase in concentration, this does not mean that the concentrations are or will be in exceedance of the PDWS and SDWS.

Water Quality Parameter	System Treatment (CP as Source)
Iron	increased
Manganese	increased
Fluoride	decreased
Sulfate	decreased
Nitrate	increased
Nitrite	
Arsenic	decreased
Sodium	decreased
Aluminum	decreased
Chloride	decreased
Copper	increased
Silver	decreased
Zinc	decreased
Color	increased
Odor	increased
Total Dissolved Solids	decreased
Foaming Agents	decreased
pH	decreased
Specific Electrical Cond.	increased
Total Suspended Solids	decreased

(blank)	= stayed the same
(red vertical hatching)	= increased
(green horizontal hatching)	= decreased

Water Quality Parameter	System Treatment (Effluent as Source)
Iron	increased
Manganese	decreased
Fluoride	increased
Sulfate	decreased
Nitrate	decreased
Nitrite	decreased
Arsenic	decreased
Sodium	decreased
Chloride	decreased
Copper	increased
Zinc	decreased
Color	increased
Odor	decreased
Total Dissolved Solids	decreased
Foaming Agents	
Bromodichloromethane	decreased
Bromoform	decreased
Chloroform	decreased
Dibromochloromethane	decreased
Total Trihalomethanes	decreased
pH	decreased
Specific Electrical Cond.	decreased
Total Suspended Solids	increased

Figures 19 (left) and 20 (right). Changes in Water Quality in the Water Flowing through the System Using Cooling Pond Water or Effluent as Source Water.

System Performance for Recharge

To use the filtered water for recharge to the Floridan Aquifer, the FDEP requires the water to meet all drinking water standards. Exceptions can be obtained for exceedances of the SDWS. Another criterion that can be applied by the FDEP is that the quality of the injected water is equal to or better than the quality of the receiving ground water. It may therefore be useful to compare the median values of the SDWS results to those from the analyses of a water sample of the Floridan Aquifer obtained from a pumping test after the recharge well at the site was completed. The results are shown in Table 18.

Table 18. Exploratory Well TW-1 Versus Treatment System Results.

Water Quality Parameter	Units	Basin CP as Source Median	Basin E as Source Median	Exploratory Well TW-1 Sample 1-13-04
Iron	mg/l	1.15	0.23	0.23
Manganese	mg/l	0.06	0.02	0.0063
Fluoride	mg/l	1.95	1.7	0.45
Color	PCU	20	45	ND
Odor	TON	50	6	ND

Because the treatment by the wetland adds color to the water, the reduction of the color concentration below the standard may not be achieved even after redesigning the filter basin. While the data show that major reductions in total coliform bacteria counts were achieved for water from the basin, the injection standard of 4 MPN was not always met and this provides a risk of uncertainty that may not be acceptable or permittable. It is strongly believed that a modification of the operation of the basin and a modification and/or redesign of the wetland water delivery system to the surface of the basin will significantly reduce the risk of coliform exceedances. To achieve risk-free delivery of basin water for ARRP recharge, it has been concluded that the installation of a post-filtration non-chemical disinfection system would reduce the exceedance risk to zero. A Ultra-Violet (UV) system could provide such a non-chemical disinfection system.

CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS

The initial goal and purpose of the project was to investigate the possibility of using mined phosphate lands to improve surface water quality. The results of this project were generally positive, but also revealed certain operational challenges.

The standards to meet in this project were quite high. Meeting all drinking water standards set by the State of Florida was a big task because it involved a total of 140 chemical and physical parameters and three criteria for microorganisms. The result is that the final product of the project (the water pumped from the basin) consistently met the standards for 134 of the 140 chemicals on the State's drinking water standards list.

Six chemical and physical parameters on the State's list of SDWS were occasionally exceeded. They were iron, manganese, color, odor, fluoride and total coliform. However, this project provided information that will facilitate redesigning and modifying certain aspects of the project to eliminate exceedances of the standards for iron, manganese, odor, fluoride and total coliform.

The data show a significant reduction in the concentration of sulfate by the wetland/filter basin system. This process creates water in a reducing state. Stuyfzand (1998) studied the quality changes upon injection of treated surface water into aquifers. He found that if the injected water is oxic the recharge water would result in the oxidation of pyrite in the aquifer matrix. Although specific parameters (such as dissolved oxygen or sulfide) in the basin water were not tested, there are strong indications that the water discharging from the filter basin may be anoxic and therefore will likely not cause the dissolution of pyrite minerals in the limestone and dolomite formations of the Floridan Aquifer.

RECOMMENDATIONS

Project Specific

It is recommended that the project be continued and modified to include different pumping and water level control equipment. It is advised that the sampling program be modified to focus on the quality of the water discharging from the filter basin, in particular those aspects of the water quality as they relate to the use of the water for recharging operations, more specifically those quality aspects as they relate to the potential for pyrite oxidation in the limestone aquifers. A specific suggestion is the modification of the surface areas of the filter basin to better promote the establishment of a bacteriologically active layer between the water surface and the sand surface. This layer is called the "dirtlayer" or schmutzdecke.

It is recommended to change the operation of the system in two significant steps. As the first step, it is recommended to install submersible pumps in each one of the standpipes. The operation of the submersible pumps will be controlled with a water level controller in each standpipe. The purpose of this revised system is to maintain the water level in each standpipe within a narrow range, being the same in each standpipe. At the same time, it is recommended to pump the water from the wetland continuously. As a second step, it is recommended to install flow-diffusing equipment on the surface of the filter basin to more evenly distribute the flow from the wetland in a much less turbulent (softer) manner.

The installation of additional piezometers outside the filter basin is further suggested, to aid in the evaluation of the impact of the pumpage from the filter basin on the inward seepage of ground water, possibly containing high concentrations of dissolved iron.

SI recommends continuing and expanding the sampling program to include the collection and chemical analyses of rainfall on site.

General

Critical to the success of an ARRP project is the construction of the tailing sand filter basin and the selection of the filter medium. It is recommended that leaching tests be conducted on the tailing sand to determine the leachable quantities of iron, manganese and fluoride. The second most critical factor is maintaining a sufficient unsaturated zone above the water table in the filter basin. The third critical factor is preventing or minimizing groundwater seepage from the sediments surrounding the filter basin. With regards to the wetland construction, it is critical to have the water flow from the deeper end of the clay settling area to the shallower end. It is recommended that the outfall structure will filter the water before being pumped.

BIBLIOGRAPHY

Davis SN, DeWiest, RJM. 1966. Hydrogeology. New York: John Wiley & Sons, 463 p.

Kadlec RH, Knight RL. 1995. Treatment wetlands. New York: Lewis Publishers, 893 p.

Kruse EG, Burdick CR, Yousef YA (editors). 1982. Environmentally sound water and soil management. New York: American Society of Engineers, 524 p.

Peters and others (editors). 1998. Artificial recharge of groundwater. Rotterdam, A. A. Balkema, 474 p.

Schreuder, Inc. 2001a. Potential use of phosphate mining tailing sand for water filtration: leaching tests. Bartow (FL): Florida Institute of Phosphate Research. Publication nr 03-113-154. 88 p.

Schreuder, Inc. 2001b. An investigation of the capacity of tailing sand to remove microorganisms from surficial waters. Bartow (FL): Florida Institute of Phosphate Research. Publication nr 03-124-153. 40 p.

Schreuder, Inc. 2002a. Feasibility of natural treatment and recharge of wastewater and surface waters using mined phosphate lands. Bartow (FL): Florida Institute of Phosphate Research. Publication nr 03-113-186. 53 p.

Schreuder, Inc. 2002b. Water quality investigation of in-situ tailing sand deposits under natural environmental conditions. Bartow (FL): Florida Institute of Phosphate Research. Publication nr 03-129-185. 40 p.

Sawyer CN, McCarty PL. 1967. Chemistry for sanitary engineers. 2nd ed. New York: McGraw-Hill Company, 518 p.

Stuyfzand PJ. 1998. Quality changes upon injection into anoxic aquifers in the Netherlands: evaluation of 11 experiments. In: Peters JH and others (editors), Artificial Recharge of Groundwater: Proceedings of the 3rd International Symposium on Artificial Recharge of Groundwater (TISAR 1998); 21-25 Sep 1998; Amsterdam, Netherlands. Rotterdam: A.A. Balkema. p. 283-291.

Appendix A

DETAILED DESCRIPTION OF PROJECT TIMELINE EVENTS

DETAILED DESCRIPTION OF PROJECT TIMELINE EVENTS

Table A-1. Timeline of 2000.

Date			Description
2000	J	01/01/00	Kick off Meeting
	F	02/01/00	3rd Progress Meeting
	M	03/01/00	Exploratory Drilling Program at N-11C
			Installation of Test Well for Hydraulic Conductivity at SA-8
	A	04/01/00	
	M	05/01/00	
	J	06/01/00	
	J	07/01/00	Meeting
			Filter Basin Construction Completed
			Wetland Sump Completed
			Cluster Wells Completed
	A	08/01/00	
	S	09/01/00	HDPE Pipeline from Wetland to Filter Basin Complete
			Testing of Wetland Pumping Station
			Outfall of Filter Basin
	O	10/01/00	
	N	11/01/00	
	D	12/01/00	HDPE Pipeline from Cooling Pond to Wetland
			Pumping Station at Filter Basin
			Pumping Station and HDPE Pipeline at Effluent
			Electrical Service at SA-8

Table A-2. Timeline of 2001.

Date			Description
2001	J	01/11/01	Background Water Samples
	F	02/01/01	Elbow Installation at Effluent
			Effluent Pipeline Across Cooling Pond Intake Structure
			Connection of Effluent HDPE Pipeline to SA-8 HDPE Pipeline
			Pumping Station at SA-8
			Modifications to Wetland Sump
			Pumping Station at Plant Island
			Filling of the Wetland System to Operational Level Using Effluent and Cooling Pond Water
			Landscape Maintenance of Filter Basin
		02/13/01	Start of Balanced Pumping At Wetland
		02/14/01	Phase Loss Power Outage
		02/16/01	Modifications to Plant Island
	M	03/28/01	Electrical Site Inspection
	A	04/11/01	Electrical Corrections at Pumping Stations
		04/14/01	Cooling Pond to Wetland
		04/15/01	Filter Basin Pump Check
		04/19/01	Testing Phase of Filter Basin Pumping Station
			Beginning of Operational Testing Phase
		04/20/01	Filter Basin Pump Check
		04/23/01	Filter Basin Pump Check
		04/27/01	Filter Basin Pump Check
		04/28/01	Refinements to Pumping Stations
	M	05/01/01	Full Suite Samples
			Cleaning of Wetland Flow Meter--Shavings from HDPE Piping
		05/07/01	*Cryptosporidium* and *Giardia* Samples
		05/10/01	Performance Analysis Samples
		05/16/01	Power Loss by Lightning--Test of Electrical Phase Protection System
		05/17/01	Performance Analysis Samples
			Cleaning of Filter Basin Flow Meter--Fish Remains
		05/24/01	Performance Analysis Samples
		05/31/01	Performance Analysis Samples
	J	06/05/01	Chlorination of Filter Basin--Birds Perching on Stand Pipes of Filter Basin
		06/15/01	Performance Analysis Samples
		06/21/01	Performance Analysis Samples
		06/28/01	Performance Analysis Samples

Table A-2 (Cont.). Timeline of 2001.

2001	J	07/05/01	Primary and Secondary Samples
		07/19/01	Performance Analysis Samples
		07/20/01	Meeting with Dr. Stark about Coliform Contamination
	A	08/02/01	Performance Analysis Samples
		08/16/01	Performance Analysis Samples
		08/29/01	Performance Analysis Samples
	S	09/27/01	Full Suite Samples
	O	10/01/01	Performance Analysis Samples
		10/26/01	Meeting for Water Level Control System and Disinfections of Filter Basin
		10/30/01	Performance Analysis Samples
	N	11/14/01	Primary and Secondary Samples
		11/27/01	Power Loss to System
	D	12/04/01	Performance Analysis Samples
		12/18/01	Power Loss to System

Table A-3. Timeline of 2002.

Date			Description
2002	J	01/03/02	Power Loss to System
		01/10/02	Power Loss to System
		01/14/02	Pump Problems
	F	02/01/02	
	M	03/01/02	Meeting with Pump Representatives On-site
	A	04/01/02	Meeting for Water Level Controls and Disinfections of Filter Basin
		04/14/02	Site Visit with Pump Representatives
			Preparation for Disinfections of Filter Basin
			Blown Fuses in the Wetland and Cooling Pond Pumping Stations
		04/17/02	Removal of Pumps at Filter Basin, Wetland, and Cooling Pond Pumping Stations
	M	05/28/02	Reinstallation of Pumps at Filter Basin, Wetland, and Cooling Pond Pumping Station
	J	06/03/02	Disinfections of Filter Basin
		06/07/02	Power Loss to System
		06/17/02	System Operational
	J	07/03/02	Installation of Warning Light at Wetland Pumping Station
		07/24/02	Water Level Control System Complete
		07/30/02	Power Loss to System-Lightning
	A	08/07/02	Equipment Defect-System Off
		08/13/02	Equipment Repairs
		08/26/02	Power Loss to System-Lightning
	S	09/06/02	Replacement Intake Pipe on Randy's Pump in Wetland Pumping Station
		09/12/02	Power Loss to System
		09/20/02	Performance Analysis Samples
		09/30/02	Water Level Control System Malfunction
	O	10/01/02	Water Level Control System Repaired
		10/10/02	Power Loss to System-Power line fuses pulled
		10/14/02	Cooling Pond Pumping Station Off - High Water Levels in Wetland
		10/18/02	Performance Analysis Samples
			Water Level Differences in Filter Basin
		10/28/02	Cooling Pond Pumping Station-On
	N	11/01/02	Performance Analysis Samples
		11/04/02	Power Loss to System
			Water Levels Differences in Filter Basin
		11/07/02	Replaced Flow Meter at Wetland
		11/08/02	Calibration of Water Level Control System
		11/14/02	Power Loss to System
		11/15/02	Performance Analysis Samples
			Water Level Control System Malfunction due to increasing Specific Electrical Conductance-Calibration of Water Level Control System
		11/20/02	Differences in Water Levels in the Filter Basin
	D	12/02/02	Water Levels Differences in Filter Basin
		12/06/02	Performance Analysis Samples
		12/19/02	Performance Analysis Samples

Table A-4. Timeline of 2003.

Date			Description
2003	J	01/13/03	Differences in Water Levels in the Filter Basin
		01/20/03	Differences in Water Levels in the Filter Basin
		01/29/03	Differences in Water Levels in the Filter Basin
	F	02/03/03	Secondary Samples in Filter Basin
			Differences in Water Levels in the Filter Basin
		02/14/03	On-site with Pump Representatives to Remove Obstruction from South Stand Pipe in Filter Basin
		02/19/03	Air-lift Cleaning of Sumps in Filter Basin
		02/24/03	Secondary Samples in Filter Basin
			False Triggering of Water Level Control System
		02/26/03	Full Suite Samples
	M	03/03/03	Secondary Samples in Filter Basin
		03/12/03	Effluent Pump Station Check
		03/17/03	Cooling Pond Pumping Station-Off
		03/26/03	Full Suite Samples
			Cooling Pond Pumping Station-On
	A	04/02/03	Randy's Pump in Wetland Pumping Station-Off
		04/07/03	*Cryptosporidium* and *Giardia* Samples
			Randy's Pump in Wetland Pumping Station-Repaired and Rocks removed from Motor
		04/09/03	Switch Source Water from Cooling Pond to Effluent
		04/11/03	Water Level Control System Malfunction-Loss of Water Level Sensor
		04/24/03	Water Level Control System Calibration
	M	05/07/03	Water Level Control System Malfunction-South Stand Pipe
		05/08/03	Performance Analysis Samples
		05/15/03	Primary and Secondary Samples
		05/22/03	Performance Analysis Samples
	J	06/03/03	Performance Analysis Samples
		06/09/03	Power Loss to System-Lightning
		06/11/03	Water Level Control System Malfunction-North Stand Pipe
		06/25/03	Full Suite Samples

Table A-4 (Cont.). Timeline of 2003.

2003	J	07/01/03	Full Suite Samples
			Power Loss to System-Wetland Pumping Station Submerged
		07/15/03	Concrete Blocks Complete at Wetland Pumping Station
	A	08/06/03	Performance Analysis Samples
		08/11/03	*Cryptosporidium* and *Giardia* Samples
			Wetland Motor Replaced at Wetland Pumping Station
		08/13/03	Primary and Secondary Samples
			Randy's Motor Replaced at Wetland Pumping Station
		08/20/03	Full Suite Samples
			Connection Between Wetland and Randy's Pump at Wetland Pumping Station Complete
		08/28/03	Performance Analysis Samples
	S	09/09/03	Primary and Secondary Samples
		09/10/03	Repair of HDPE Connection to Wetland Pumping Station
		09/16/03	Performance Analysis Samples
		09/24/03	Performance Analysis Samples
		09/27/03	Replacement Water Level Sensor in North Stand Pipe Installed
		09/29/03	Full Suite Samples
			Cryptosporidium and *Giardia* Samples
	O	10/01/03	Calibration of Water Level Control System
		10/03/03	System Down-Damage on Pipeline to Filter Basin
		10/07/03	Performance Analysis Samples
		10/10/03	Calibration of Water Level Control System-7 to 9 ft. BLS
		10/21/03	Performance Analysis Samples
		10/14/03	Full Suite Samples
		10/27/03	*Cryptosporidium* and *Giardia* Samples
		10/28/03	Primary and Secondary Samples
	N	11/04/03	Repairs to Wetland Pumping System-Randy's Pump Needs to be Replaced
		11/11/03	Air-lift Cleaning of Sumps in Filter Basin
		11/13/03	Performance Analysis Samples
		11/18/03	*Cryptosporidium* and *Giardia* Samples
		11/19/03	Full Suite Samples
		11/24/03	Performance Analysis Samples
	D	12/01/03	*Cryptosporidium* and *Giardia* Samples
		12/03/03	Performance Analysis Samples
		12/10/03	Performance Analysis Samples
		12/17/03	Full Suite Samples
		12/18/03	Wetland Pumping Station-Manual Switching of Pumps by Drillers
		12/30/03	Wetland Pumping Station-Key Switch Installation

Appendix B

PROJECT DESIGN INFORMATION

PROJECT DESIGN INFORMATION

TESTING OF FILTER BASIN MATERIALS

One of the ideas tested was to use the SA-8 tailing sand deposit as a filter basin in the condition it was at the beginning of the study. To test this hypothesis, SI installed one test well and two monitor wells and conducted a short-term aquifer test. The tailing sand material was tested to determine the vertical hydraulic conductivity using a constant head and falling head test method. The results ranged from 2.3 feet per day (ft/d) to 3.0 ft/d with an average of 2.6 ft/day. In February 2000, Driggers Engineering conducted grainsize analysis and permeability tests on the tailing sands used in the filter basin. The results were: permeability (k) 1.2 x 10^{-3}, grainsize analysis reported 92% sand, 7% silt and clay, and 1 % gravel.

A cluster of three wells was installed in July of 2000 located southwest of the basin. The north cluster well was completed at a shallow (10-20 feet) depth; the south cluster well is deeper at 30 to 40 feet. The north and south monitor wells were to test the physical characteristic composition between the upper and lower potions of the sand. A 6" well was installed as a production test well to a depth of 46.5 feet below grade with 20' of screen. A pump test was conducted on the 6" cluster well, and the well stabilized at 23' BLS with a pumping rate of approximately 45 gpm.

Based on the results of these testing programs, it was decided to construct a filter basin at the tailing sand deposit at the northwest corner of the SA-8 CSA.

DESIGN OF THE TAILING SAND FILTER BASIN

In the original design concept, it was assumed that the surface water pumped from the wetland would contain significant amounts of suspended solids, in particular algae. These suspended solids would, as assumed, continually reduce the surface permeability of the sand. To test several surface maintenance options, it was decided to divide the total surface area of the basin into four quadrants. In each quadrant, a different percolation pattern was installed as shown in Figure B-1. As the pumping rate of the system, a capacity of 150 gallons per minute (gpm) was selected. Using this pumping rate and the average vertical hydraulic conductivity value of 2.6 ft/day, a total surface area of approximately 11,105 square feet (ft^2) was calculated. To include the non-percolating areas in each quadrant, the surface area was arbitrarily increased to 12,500 $ft.^2$. Based on this calculation, the total surface area of the basin was set at 50,000 $ft.^2$

The surface dimensions of the basin are shown in Figure B-1. The points were the water from the wetland can be discharged to the surface of the basin are shown in Figure B-2. The mechanical and electrical control systems are shown in Figure B-3. The length of the basin is 300 ft. from east to west and 210 ft. from north to south. The east-west cross-section is shown in Figure B-4. The north-south cross-section is shown in Figure B-4. The total depth of the filter basin is 13 ft. Two 6-inch diameter Schedule 40

PVC 0.02-inch slotted wire wrapped well screens each 150 feet long were installed in the bottom of the excavation at a depth of 13 feet below grade. The filter pipes were covered with well-rounded silica gravel, and an 11 ft. thick layer of clean tailing sand was deposited on top of the gravel bed. The horizontal filter pipes were connected on the east side of the basin to 8-inch diameter, vertical PVC standpipes with a 5 ft. sump. As shown in Figure B-4, the west sides of the horizontal filter pipes are connected to a clean out, which allows for the redevelopment of the well screens. During the filling of the basin, four sets of piezometers with horizontal screen were placed in the northwest, northeast, southwest and southeast areas of the filter basin (see Figure B-5) at three different depths, 13, 9, and 5 feet below grade. The monitoring and data collection points are shown in Figure 12.

Due to FDEP permitting restrictions, treated industrial wastewater from the basin could not be discharged to the SA-8 CSA when that water originates from either the cooling pond or the City of Bartow's effluent. For this reason SI included in its design a 4500 ft 4 inch diameter HDPE pipeline to return the water pumped from the filter basin to the cooling pond.

DESIGN OF THE LINEAR WETLAND SYSTEM

Two parallel ditches exist at the test site, situated between two CSAs, as shown in Figure 13, and were connected approximately 4,000 ft. to the west of the cooling pond by a channel dug by PEF, making a U-shape that doubles back between the N-15 and SA-8 CSA (see Figure 13). It is filled with aquatic vegetation, such as cattails, willow, water lettuce, water hyacinth, Brazilian pepper, dog fennel, pennywort, and baby's tears. It was designed to allow the water to flow west from the northeast corner of the wetland, south and then back east to the southeast corner of the wetland in approximately 14 days.

The final design of the wetland focused on the design of the filter system and the pumping station, which was located at the east end of the smaller and shallower (south) ditch. The design of the filter system called for the installation of a 36-inch diameter perforated high-density polyethylene (HDPE) pipe. The pipe was 20 feet long surrounded by an envelop of washed number 57-limestone gravel 1 to 2 feet thick. A 24-inch diameter HDPE standpipe was heat welded to the drainpipe to provide access for the intake pipes of the pumping system. The standpipe is covered with a solid lid in which two 4.5 inch diameter round openings provide for access of the suction intake pipes to the two surface centrifugal pumps. The purpose of the gravel filter system was to reduce or eliminate any suspended solids resulting from algae and other fine-grained materials.

DESIGN OF THE PUMPING STATIONS

Cooling Pond

The cooling pond is a 722-acre cooling reservoir of the Hines power plant, which contains storm water run-off and treated effluent from the city of Bartow. SI selected a

7.5 hp electrically driven surface centrifugal pump producing 300 gpm at 75 psi. A 4-inch HDPE pipeline was selected to transfer water from the cooling pond to the northeast side of the linear wetland. The cooling pond water was used as the first water source for treatment through the wetland and basin. The pump was to be set on the soil cement surface of the interior of the cooling pond dam.

Effluent Line

In the southeast corner of the cooling pond, a 24-inch diameter cast iron pipeline discharges treated effluent (domestic wastewater) directly into the cooling pond. A 90-degree flanged elbow was fitted to the existing effluent line to discharge the effluent vertically upward, providing a standing head of water in the effluent line when effluent delivery is interrupted or reduced. SI calculated that the residual effluent storage in the 24-inch diameter pipeline was sufficient to allow continuous operation of the 300 gpm surface centrifugal pump, even during the longest time that the City of Bartow was not discharging effluent. A 4-inch HDPE pipeline, flow meter and shut-off valve were installed along the south side of the cooling pond on the upper lip of the soil cement liner. At regular intervals stainless steel ½ inch diameter pins were driven into the soil cement to support the HDPE pipeline. The 4-inch diameter HDPE pipeline connects the effluent source to the existing 12-inch HDPE pipeline that was previously installed by PEF to connect their S-8 surface water pumping station to the linear wetland system.

PEF provided electrical power to the location of the effluent pumping system. SI electrical subcontractor provided the panels and all necessary electric wiring, breakers, interruptors and other equipment necessary to operate the pumping system.

Plant Island

At the Plant Island site, the design called for installing the pump and intake on a floating platform that was already used by the PEF surface water pumping system to pump storm water from their 900 acre plant island drainage system into the cooling pond. The 4-inch diameter HDPE discharge pipeline was connected to the 4-inch diameter HDPE pipeline coming from the effluent pumping system. A flow meter and shut-off valve were to be installed in the discharge line.

SA-8

At the SA-8 site, the design called for installing the pump and intake on a floating platform that was already used by the PEF surface water pumping system to pump storm water from the SA-8 CSA surface water storage reservoir into the cooling pond. The 4-inch diameter HDPE discharge pipeline was connected to the 12-inch diameter HDPE pipeline from the SA-8 pumping system. A flow meter and shut-off valve were to be installed in the discharge line.

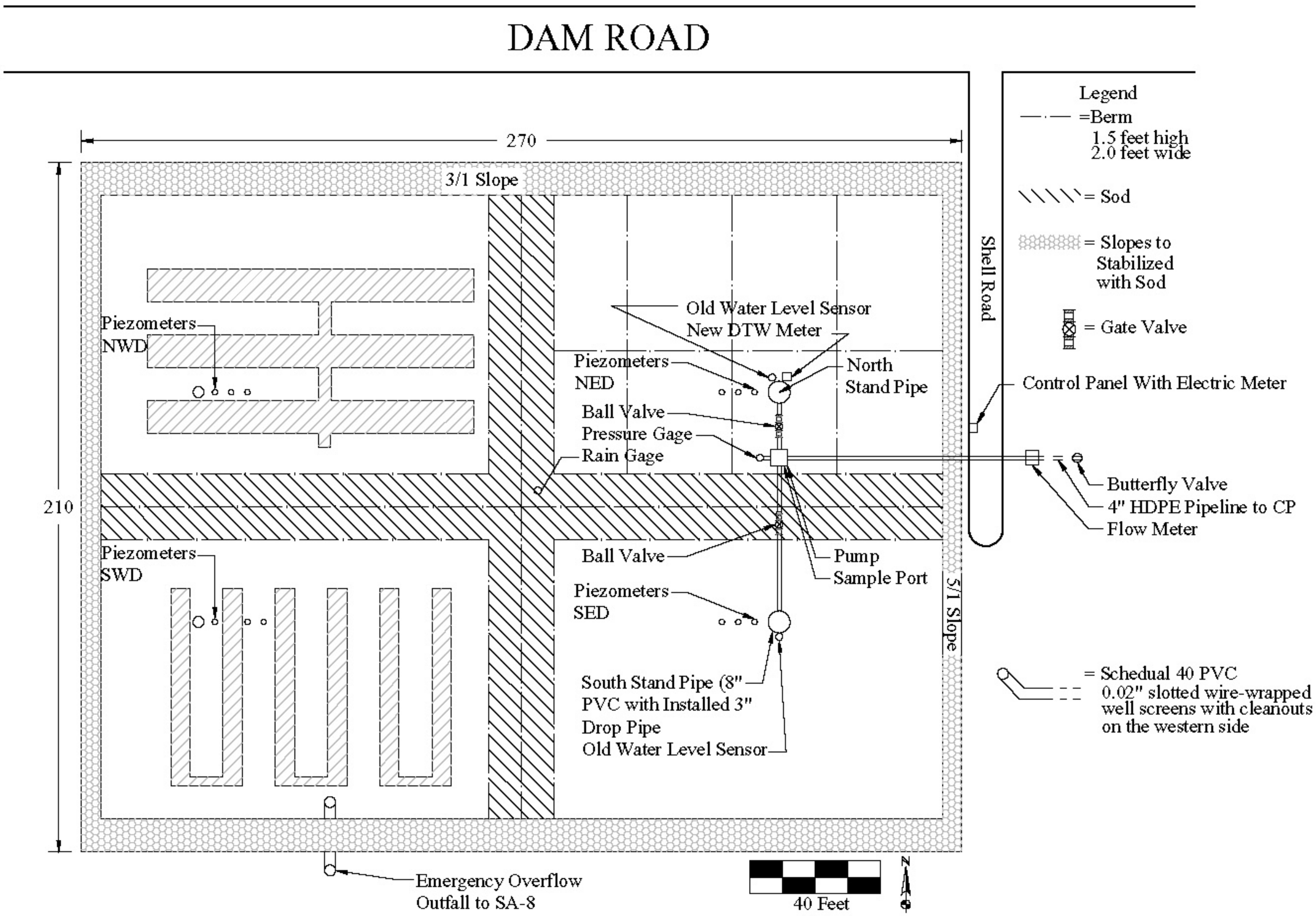


Figure B-1. Surface Dimensions of Tailing Sand Filter Basin and Constructed Surface Depressions for Different Percolation Patterns.

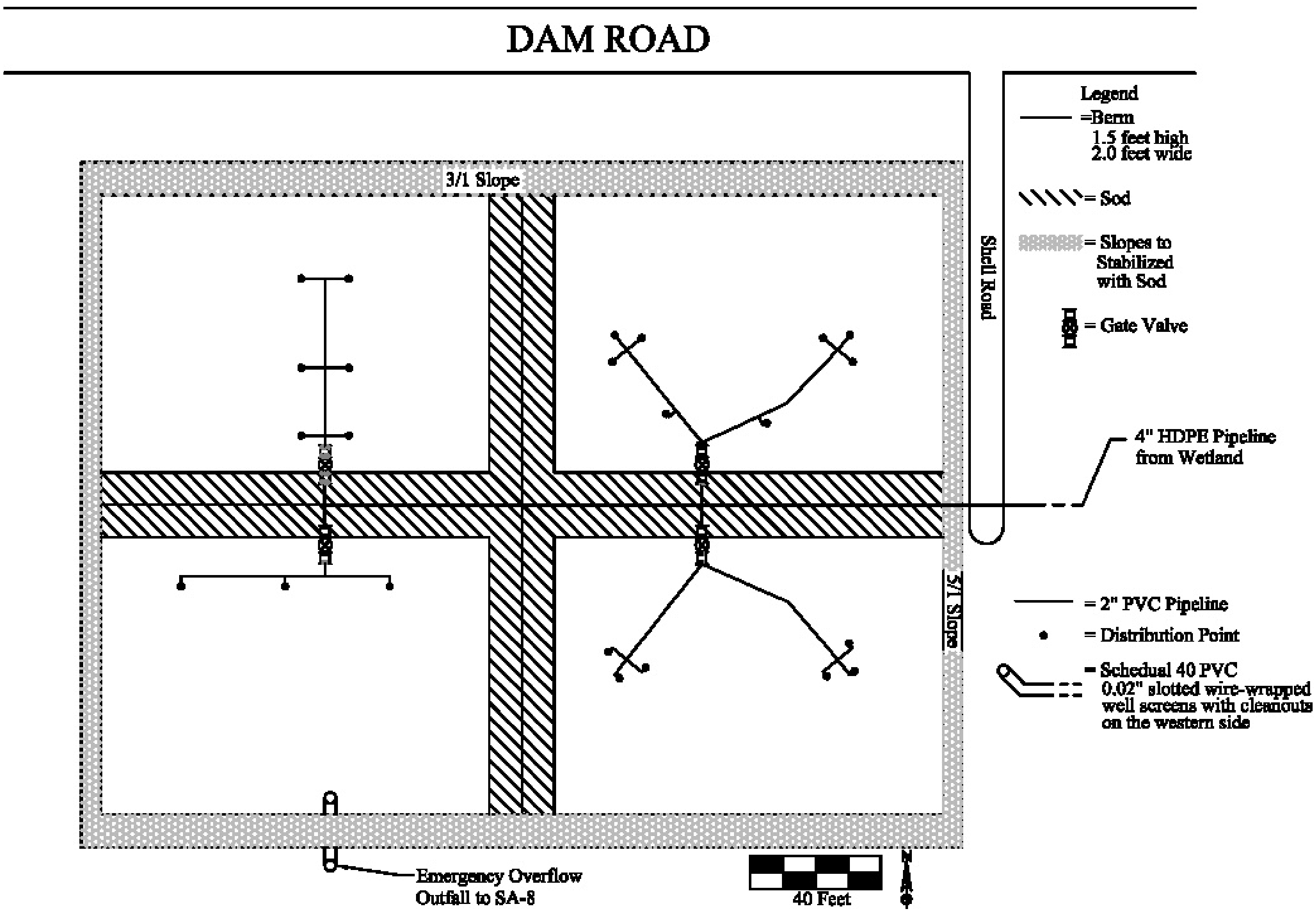


Figure B-2. Plan View of Distribution Points from the Wetland on the Filter Basin.

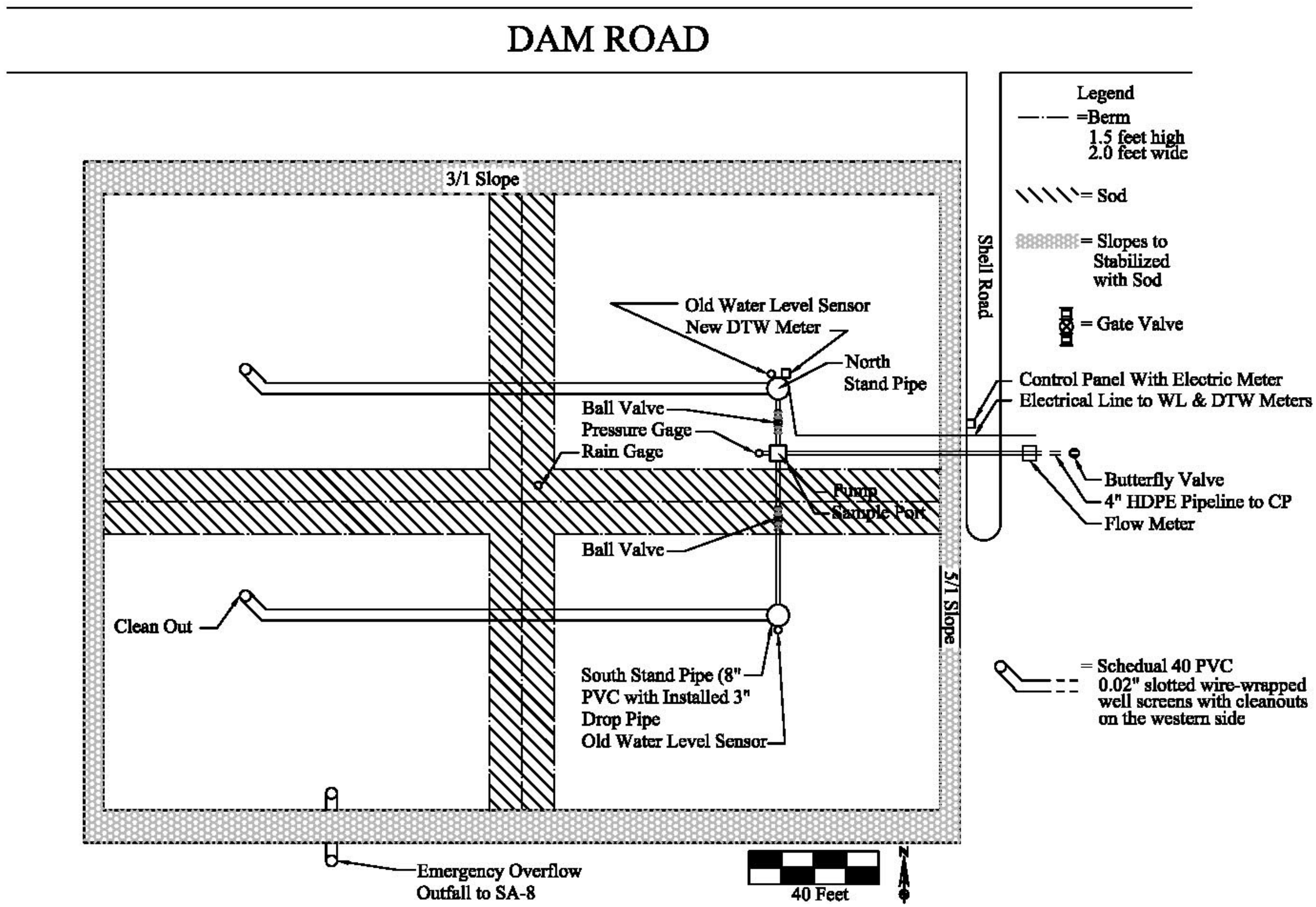


Figure B-3. Mechanical and Electrical Control System for the Filter Basin.

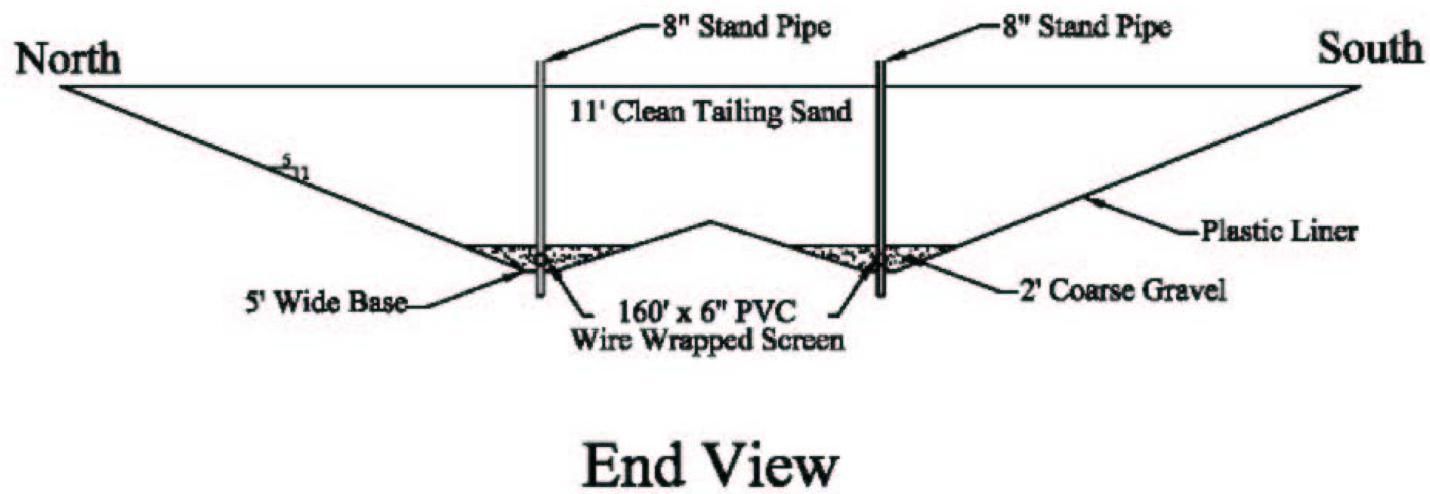


Figure B-4A. North/South View of the Filter Basin in Cross-Section.

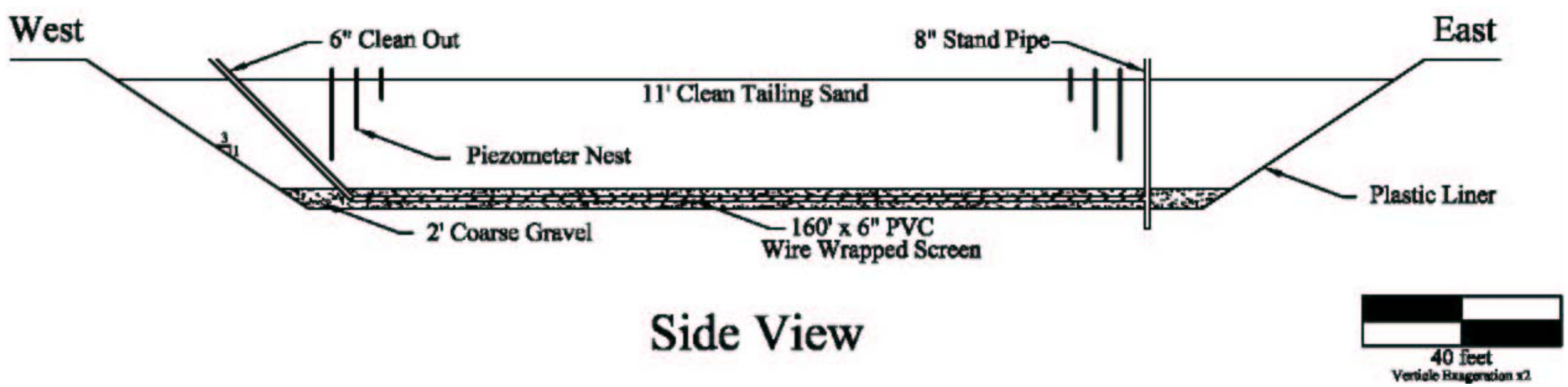


Figure B-4B. East/West View of the Filter Basin in Cross-Section.

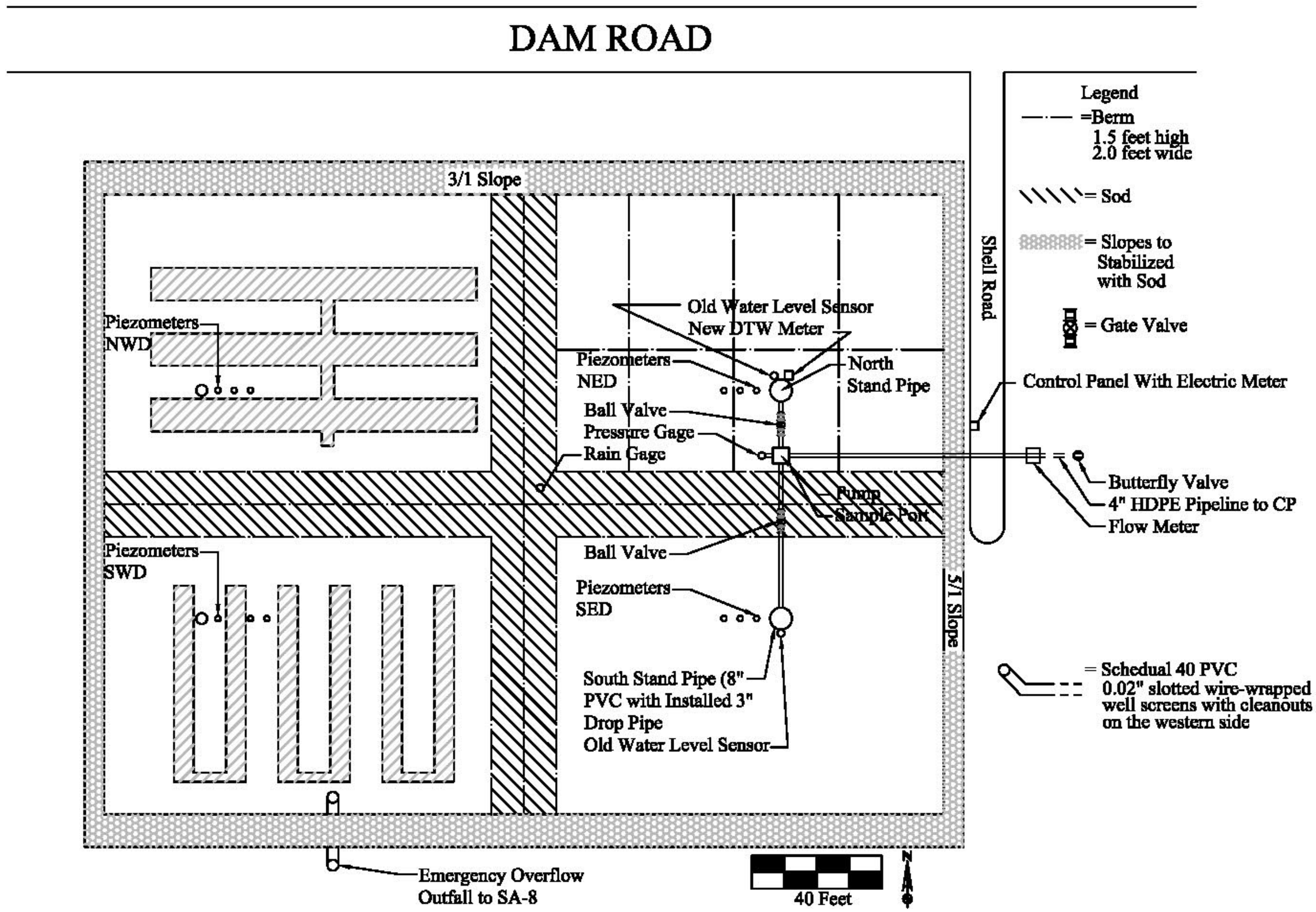


Figure B-5. Monitoring and Data Collection Points Map.

Appendix C

PROJECT CONSTRUCTION INFORMATION

PROJECT CONSTRUCTION INFORMATION

CONSTRUCTION OF PROJECT ELEMENTS

The construction consisted of three major parts: (1) the improvement of an existing wetland; (2) the construction of a tailing sand filter and distribution system; and (3) installation of pumping stations at the wetland, the basin, the cooling pond, the effluent discharge, the Plant Island drainage ditch and the SA-8 CSA.

Sand Tailing Filter Basin and Pumping Station

Construction of the basin started in March of 2000 and was completed in July of 2000. Tailing sand was selectively excavated from the northwestern corner of SA-8, which is to the west of the basin excavation, and used to fill the basin. Selectively excavated implies that a hydrogeologist directed the excavation of the tailing sand based on boring information collected and analyzed before the construction began. It is estimated that 18,717 cubic yards were excavated to construct the basin. The filter pack was formed with 483 cubic yards of gravel and 14,000 cubic yards of tailing sand were placed to complete the construction of the basin. The walls and bottom of the entire basin were lined with polyethylene sheeting by overlapping each sheet by 2 feet. During the deposition of the tailing sand, water was pumped into the basin to aid with the settlement of the sand. Previous test indicated that a settlement of as much as 15% could occur if the sand was placed dry and wetted afterwards.

Low dams were installed on the surface of the basin, which divided it into four quadrants of equal size as shown in Figure B-1. The surface area in the southeast quadrant was left entirely flat. Three east-west ditches were excavated in the northwestern quadrant. Five north-south ditches were excavated in the southwestern quadrant and eight shallow rectangular depressions were excavated in the northeastern quadrant. A water distribution system, attached to the 4-inch HDPE main wetland water distribution pipeline with cast iron flanges, was installed on the basin surface using 2-inch diameter PVC pipe and fittings sufficient to provide 23 distribution points. The discharge of wetland water can be manually shunted or reduced to a particular quadrant of the basin. Another method of controlling the distribution of wetland water onto the surface of the basin is to plug each distribution point. PVC caps were purchased to specifically fit each distribution point, which stops the water flow to a particular section in each of the four quadrants.

In September 2000, a 4-inch HDPE pipeline was installed to transfer the filtered water from basin back to the cooling pond. The return pipeline is located parallel to the wetland transfer line on the south side of the linear wetland. The pipeline from the basin to the cooling pond was buried under the service road to allow for vehicle access. To avoid any potential washout of the basin's dams resulting from a malfunction of the pumping system controls or excessively heavy rainfall, an emergency overflow outfall was constructed to the SA-8 clay settling area (CSA) in September 2000 as shown in Figure B-1.

In December 2000, a pumping system, which consists of a 7.5 hp pump, was installed at the basin on a concrete pad in the center of the east side of the basin to withdraw filtered water from both 8-inch standpipes connected to the horizontal filter pipes as seen in Figure C-1. There are two ball valves on the PVC intake pipes to the basin pump. These valves control the removal of water from the basin and can force the separate withdrawal of water from only the north or only the south standpipe of the basin. A flow meter and a butterfly control valve were installed just on the east side of the service road. The butterfly valve can reduce or completely stop the amount of filtered water being pumped out of the basin. A service box was installed and power poles were relocated to the east side of the basin along with an electric meter. The electric utility is shown in Figure C-2.

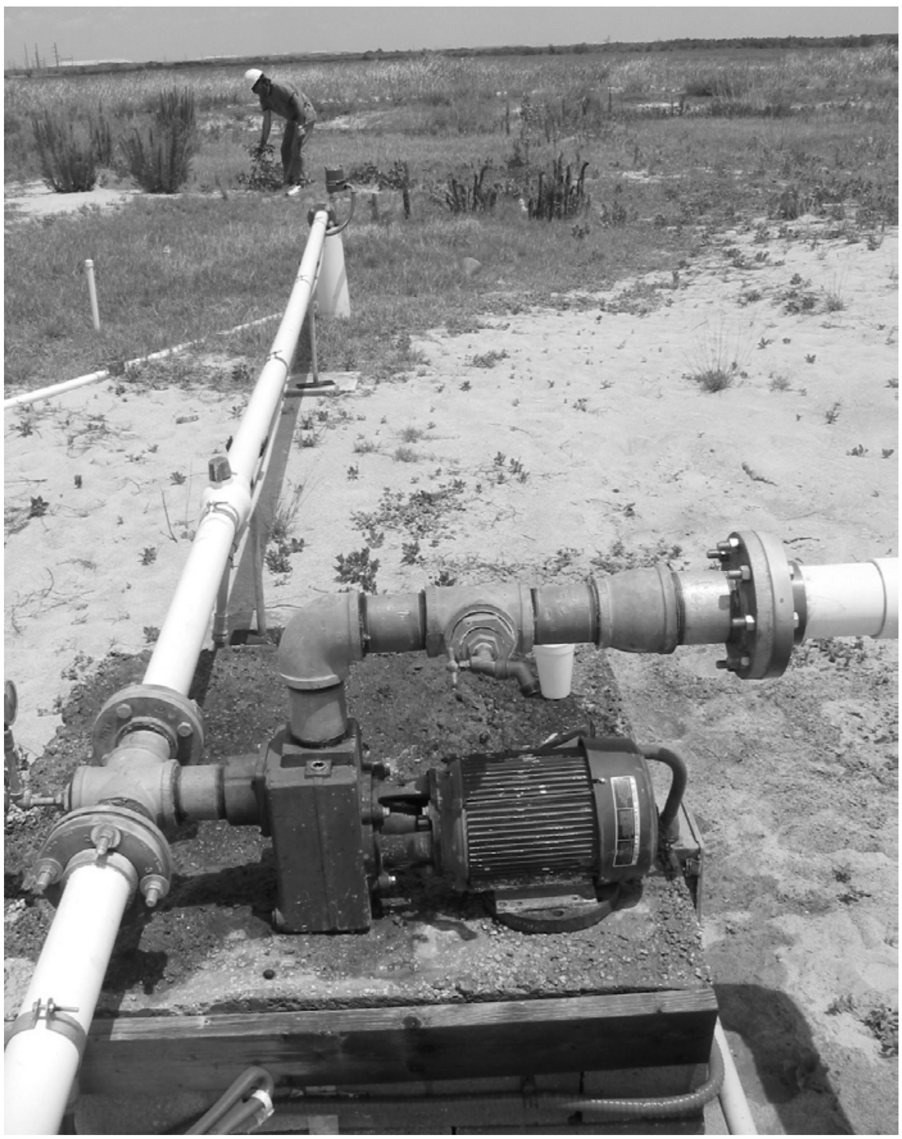


Figure C-1. Tailing Sand Filter Basin Pumping Station.

Figure C-2. Filter Basin Looking East Showing Electric Equipment.

In February 2001, RSS Field Services contoured and stabilized the basin surface. Bahia grass seed was sown around the basin perimeter and on the interior berms, and wooden walkways were constructed to facilitate access to the basin interior.

Approximately 430,000 gallons of water were pumped onto the surface of the basin at a rate of 200 gpm for 2 days to bring the water level in the basin up to the 6' to 8' below land surface (bls) operation level. The water level rose 5.5 feet in the basin, and the basin pump was primed and started. The system was put into operation on March 13, 2001 with a balanced flow of 200 gpm of effluent entering the wetland, 200 gpm of wetland water being pumped to the tailing sand basin, and 200 gpm of treated water being pumped from the basin back to the cooling pond. In April 2001, a series of checks were conducted to test the capacity of the basin pumping system.

During the first six months of operation, SI staff took a series of repeated photographs of each of the quadrants in the filter basin. These photographs were taken from the same location to enable comparisons from one time period to another. The purpose of this photographic record was to obtain a qualitative record of the expanding wetted area on the surface of the filter basin as an indication of the clogging potential of the sand surface.

To estimate the filtering capacity of the basin, the total wetted area was estimated and related to the application rate of water to the surface of the basin. Using the photographic record and field observations, the total surface of the actual wetted areas was found to be 8,700 $feet^2$. The average water application rate is 140 gallons per minute. Thus, the actual average vertical hydraulic conductivity (K_v) is calculated to be 3.1 feet/day. Using this vertical hydraulic conductivity rate, the "theoretical" percolation over the entire 49,400 $feet^2$ surface area of the filter basin could be as high as 1.1 million gallons per day or 0.98 million gallons per day per acre.

Linear Wetland System and Pumping Station

The average depth of the northern ditch ranges from 2.5 to 5 feet, with an average width ranging from 20 to 35 feet. The average depth on the southern ditch ranges from 2 to 3 feet, with a width ranging from 15 to 30 feet. In July 2000, the two ditches were connected on the west side by a channel dug by FPC, making a U-shape that doubles back between the N-15 and SA-8 CSA on the Hines site just west of the northwestern corner of the cooling pond. A sump was also completed in July 2000 in the southeast corner of the wetland, which consists of a perforated 20-inch diameter HDPE pipe placed in a north-south direction horizontally below the water line. The pipe is embedded in 57-limestone gravel placed all around it. In February 2001, additional 57-limestone gravel was set on top of the sump, and a staff gage was installed just east of it.

The wetland pumping station (Figure C-3) was completed in July of 2000, which consists of two pumps, the wetland pump and Randy's pump, that are located at the southeastern corner of the wetland. The wetland pump, a surface centrifugal pump capable of pumping at 300 gpm at a TDH of 100 feet, pumps water from the wetland to the distribution system of the basin. Randy's pump, a centrifugal pump similar to the wetland pump, pumps water from the wetland to the cooling, which maintains a continual circulation through the wetland to help minimize the dilution impacts from rain by pumping excess water into the cooling pond. This pump was also to prevent the wetland from flooding. The intake pipes for the wetland pump and Randy's pump located inside the wetland filter were initially covered with a mesh basket to avoid any debris from entering the pumps. That mesh cover has been replaced by a solid cover.

In September of 2000, a 4500-foot long HDPE 4 inch diameter pipeline conveyance system was installed, which runs along the length of the wetland, then turns 90° to run up the SA-8 berm to the basin distribution system. A flow meter and a butterfly valve were installed in the pipeline from the wetland to the basin to monitor and control the water flow to the basin. A 4-inch HDPE pipeline was installed to transfer water from the wetland to the cooling pond utilizing Randy's pump. The lines to and from the cooling pond were buried under the service road to allow for vehicle access. All discharge of source water was to the northeast corner of the wetland, which is the deeper ditch, from where the water flowed westward to the shallower section, the southern ditch. The water covered a distance of approximately 8400 ft. before being removed from the wetland within a fourteen-day period. The input from either the cooling pond or the effluent sources is sometimes greater than the output from the basin. To prevent the surface water levels in the wetland from rising too high, particularly after a heavy rainfall, Randy's pump is used to discharge water from the wetland to the cooling pond. The outflow from the basin is rather constant but less than the inflow of the wetland.

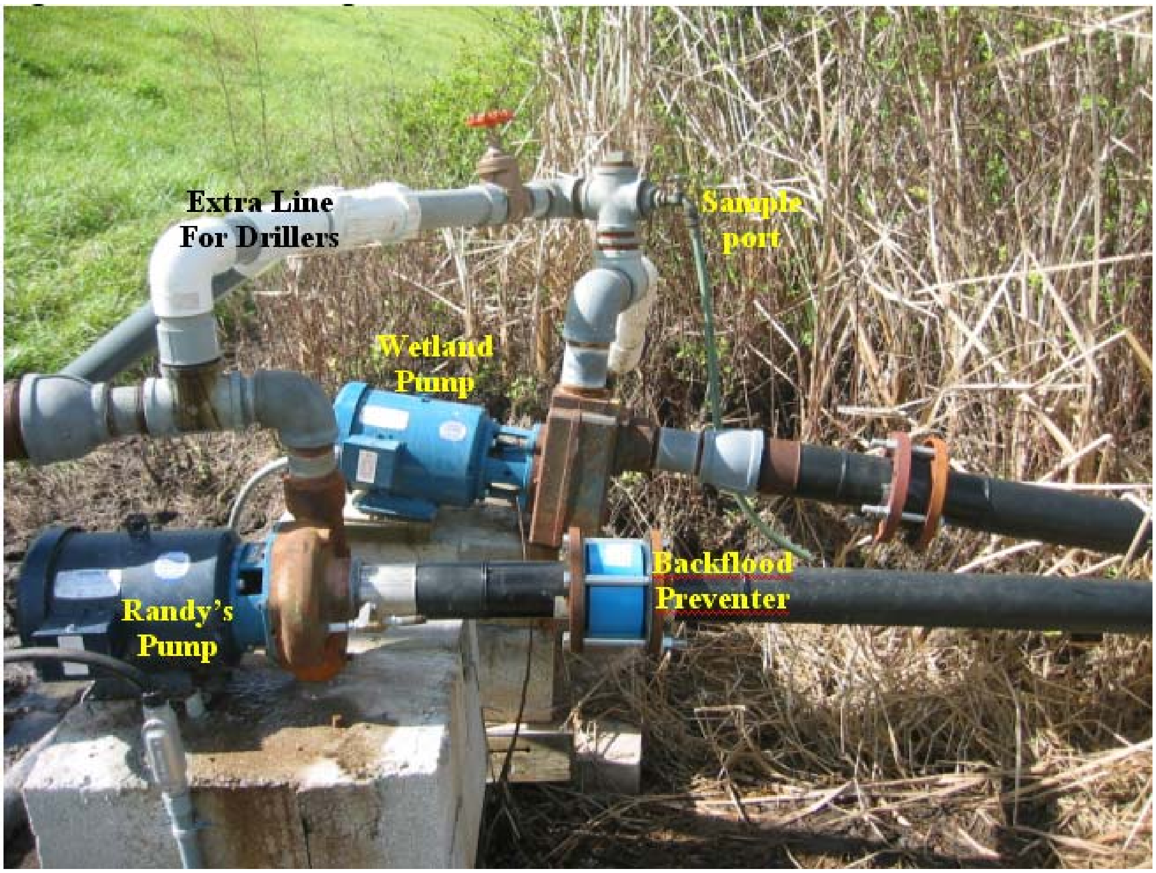


Figure C-3. Wetland System Pumping Station.

To maintain the water levels in the basin to operate within a pre-set narrow range, a water level control system was installed regulating the flow from the wetland. To do that a 4500 control cable was installed along with water level sensors in the basin and an operational control for the wetland pump. The control cable connects the two systems. The system is able to maintain a rather constant flow of water from the basin within a narrow ground water level range even during major rainfall events by regulating the inflow from the wetland. This system was designed to accommodate the impact that rainfall had on the levels of the ground water in the basin.

In February 2001, water from the cooling pond and from the effluent line was used to raise the water in the linear wetland by about 2.5 feet to its operational level. When the water level in the linear wetland reached the operational level of the gravel/culvert sump, the effluent pump was turned off, and the circulating (Randy's) pump was turned on, allowing water from the cooling pond to circulate through the wetland and back into the cooling pond. Approximately 6.6 million gallons (20.3 acre feet) were pumped from the cooling pond. This circulation continued for 10 days while the final modifications to the basin were completed. When pumping from the wetland to the basin began, the cooling pond pump was utilized to maintain the operating water level in the linear wetland.

Late in April of 2002, the perforated intake pipe of the wetland pump was replaced with a conventional strainer to ensure that the pumping capacity was not being restricted by the lack of available intake area. In addition, the fused attachments at each pumping station were replaced with flange attachments to allow any work that maybe required without mobilizing a pipe fusing crew to the site.

In July of 2002, numerous lightning strikes, power surges and strikes, blown fuses, and other electrical problems that resulted in the malfunction of the wetland pumping station. To help control this issue, a red light was installed at the wetland pumping station to notify the security guards of any problems. If for any reason electrical problem would occur, the light would flash. The light was checked on the daily rounds of the security guards, and SI was notified immediately if there was any problem.

Due to excessive rain in the summer of 2003, the wetland pumping station was submerged. Concrete blocks were constructed to elevate the pumps. During October of 2003, the wetland pumping station was modified. The modifications (Figure C-3) included a connection from the wetland pump to Randy's pump with a gate valve between the pumps, a butterfly valve on the output of Randy's pump, and a connection for the wetland water to be outsourced for other construction projects, primarily the drilling of the ARRP well. These modifications allow the wetland pumping system to pump separately, i.e. the wetland pump pumping water to the basin and Randy's pump pumping to the cooling pond, or simultaneously with both pumps pumping water to the basin, or simultaneously with both pumps pumping to the cooling pond. One reason for the modification was to ensure a supply of water from the wetland to the basin if one of the pumps broke down. Due to these modifications, the amount of water pumped to the basin may be doubled.

During the drilling of the ARRP exploratory well in November and December of 2003, the wetland pumping station was being manually changed to an improperly setting on a daily basis. To avoid further complications, a key switch was installed on the electrical box of the wetland pumping station.

Cooling Pond Pumping Station

The cooling pond is a 722-acre cooling reservoir of the Hines power plant, which is surrounded by a soil concrete liner. The pumping station is placed on this soil cement base as shown in Figure C-4, along with an alligator to the left of the pump intake. A 7.5 hp pump was installed at the northwest corner of the cooling pond to continuously pump source water into the wetland.

Figure C-4. Cooling Pond Design.

In December 2000, a 4-inch HDPE pipeline was installed to replace the damaged FL Power 3-inch PVC pipeline, which transfers water from the cooling pond to the northeast side of the linear wetland. The 4-inch HDPE pipe was buried under the service road to allow for vehicle access.

In February 2001, water from the cooling pond and from the effluent line was used to raise the water in the wetland to its operational level. Continuous operation of the cooling pond pump began in May 2001.

Effluent Pumping Station

In December of 2000, a pumping station consisting of a 7.5 hp pump was installed at the Bartow effluent discharge location on the southeast corner of the cooling pond as seen in Figure C-5. This pump was connected to the 24-inch discharge line, which discharges treated effluent (domestic wastewater) directly into the cooling pond to replace any evaporative loss. A 90-degree flanged elbow was fitted to the existing effluent line to discharge the effluent vertically, providing a standing head of water in the effluent line when effluent delivery is interrupted or reduced.

Figure C-5. Effluent Design.

As shown in Figure C-4, a 4-inch HDPE pipeline was installed to the cooling pond intake on the southwest corner along the south side of the cooling pond on the upper lip of the cement liner, which connects the effluent source to the existing 12-inch HDPE line that discharges into the linear wetland system. The pipeline was secured by drilling coated rebar into the cement liner. Orange safety caps were placed on the top of each rebar. Where the 4-inch effluent line crosses the cooling pond intake structure, metal brackets were fabricated to suspend the effluent line along the top of the sheet piling. This was completed in February of 2001. The effluent line was connected to the SA-8 supply line with a Y-fitting, and the resultant single line was run through a flow meter prior to attaching it to the existing 12-inch line through a saddle tap. A butterfly valve was installed in the 4-inch line to prevent back-flow when the high-volume SA-8 pumps are used, and back-flow preventer valves were installed on both the effluent and SA-8 supply lines. A flow meter was installed before the back-flow preventers on the effluent supply lines in July of 2003.

In February 2001, the effluent pump was operated for 29 days to fill the linear wetland system. During the first few days of trial operation, the water level within the effluent pipeline was monitored during flow and non-flow conditions to verify that a standing head of water remained in the terminal elbow of the effluent line when effluent delivery is interrupted or reduced. The operation schedule of the City of Bartow WWTP was also monitored, to determine the length of any flow interruptions. The longest flow interruption recorded during normal operations was approximately six hours. In this six-hour period, the standing head of water in the terminal elbow dropped less than one inch in the first hour, and remained essentially stable for the following five hours. The results of this operational test provided the assurance that was needed to allow the effluent pump to run unattended other than spot checks on the pump, water level in the effluent pipe, and frequent updates on the WWTP operations. Approximately 8.4 million gallons (25.6 acre feet) of effluent was thus transferred to the linear wetland system over the course of one month.

SA-8 Pumping Station

In December of 2000, a control panel was constructed at the SA-8, and electricity was run to the control panel. In February 2001, a pumping station, which consisted of a 7.5 hp pump, was installed with a mounting plate to the existing float that supports the high-volume SA-8 pump (see Figure C-6). A floating intake was fabricated and placed in readiness for pumping from SA-8. During the course of the 2000-2001 drought, water levels in SA-8 declined significantly. The shallow water conditions in SA-8 required the implementation of a back-up storm water source from the Plant Island storm water Retention Area and the SA-8 pump was relocated to the Plant Island Storm water drainage ditch. The connections and mounting plates for the pump were retained at SA-8 for later use, as water levels were expected to return to operable depths in the future. SA-8 is the preferred storm water source, as run-off from the plant island during the rainy season may warrant additional water quality monitoring.

Figure C-6. SA-8 Pumping Station.

Plant Island Stormwater Drainage Ditch Pumping Station

The Plant Island storm water ditch contains water in near equilibrium with other storm water sources on the site. As stated previously, a back-up source of storm water was established at the north end of the Plant Island storm water drainage ditch, which is located south of the cooling pond and east of the office building at Hines (see Figure C-7). In February of 2001, the storm water supply pump from SA-8 was moved to the existing float in the Plant Island ditch, and a 4-inch HDPE line was installed to connect this pump to the effluent supply line. Back-flow preventer valves were installed in both lines. The source of storm water may be shifted back to SA-8 by simply disconnecting and moving the pump and float to the mounting plate on the SA-8 float.

Figure C-7. Plant Island Stormwater Drainage Ditch Pumping Station.

Appendix D

OPERATIONAL CONSTRAINTS

OPERATIONAL CONSTRAINTS

EQUIPMENT

On March 28 2001, a certified electrician conducted a site safety inspection of the electrical wiring of all pumping stations and determined that the wiring was incorrect. In early April 2001, and further modifications, which include over- and under-load protection, were made. The system was proven to work on May 16, 2001 when the control panel at the wetland pumping station was struck by lightning. After resetting the relay, the pump was back in service.

From August through November 2001, the pumps were found not functional on three separate occasions due to phase losses from the power source. The load protection system for the pumps worked, and each time, the power was restored to the site. In December of 2001, there were two occasions were the pumping station were receiving a single phase instead of three phase power. FPC, now Progress Energy Florida, repaired the line service and the stations were operational. In January of 2002, there were additional power losses to the pumping stations, which were repaired. Blown fuses were the cause of power failure to the wetland pumping station in March of 2002.

Throughout all of March 2002, there were numerous site visits to analyze the power problems to the pumping stations, primarily the filter basin and wetland pumping stations. These fluctuating power issues were due to a single-phase power supply running to the pumping stations instead of a three phases power supply. In April of 2002, the pumps from the filter basin and wetland pumping stations were removed, repaired, and reinstalled. The system continued to have power problems.

From January through July 2002, the system was not operating properly due to power fluctuations. The sampling schedule was discontinued until all repairs were finished and reasonable time had passed with the system operating fully. Because of the vulnerability of the pumping system to changes in the electrical power supply, an electrical load control system was installed to allow the system to be maintained with the correct thickness of the unsaturated zone within the filter basin. A stable unsaturated zone is necessary to provide the most efficient filtering capacity of the tailing sands. The electrical load control system protects both the filter basin pump and the wetland pump from power fluctuations using over and under load protection.

In July of 2002, a water level float control system was installed to establish a minimum and maximum water level in the filter basin. This system was designed to allow the unsaturated zone to be maintained at a depth of six to eight feet below the filter basin surface. It allows the filter basin pump to be continuously running, which the water level float system turns on and off the wetland pump to maintain this unsaturated zone. The water levels control system elevations were surveyed by SI personnel to assure an accurate measurement of the unsaturated zone below land surface. The initial water level float control system contained a manufacturer's defect and was replaced in August of 2002.

In early September 2002, Randy's pump at the wetland pumping station was inoperable due to a faulty intake pipe, which was replaced. Then in late September, the wiring in the wetland control panel had become loose, which restricted the pump from receiving the signal from the water level float control system. The wiring was repaired immediately.

In October 2002, the wetland filter basin system was shut down due to the lack of power to all pumping stations. Due to construction work around the Hines site, three feeder fuses were disconnected in the power line to the wetland and filter basin pumping stations. The system was soon returned to normal operation.

During the summer of 2002, the water level in the wetland was higher than normal operational levels. This high water level resulted in the submersion of the flow meter at the wetland pumping station. In November of 2002, the flow meter at the wetland pumping station was replaced. In addition, in November 2002, all of the pumping stations were having electrical problems. Again, a single-phase power supply instead of a three-phase power supply was shutting off the pumps.

In December of 2002 with high water levels in the wetland, the wetland pumping station was blowing the fuses in both the wetland and Randy's pump. Upon closer examination, the wetland pump had been submerged, causing damage to the motor, which was replaced on January 10, 2003.

In mid March 2003, the filter basin pumping station began leaking due to weak, rusted areas in the pipes. The pump from the Plant Island Storm Water Ditch was removed and replaced the pump of the filter basin pumping station. In April 2003, Randy's pump in the wetland pumping station was not running. Due to the high water level in the wetland in the earlier months, the wetland pumping station was submerged. Eventually the motor wore out in Randy's pump and was replaced. A few stones of the gravel surrounding the wetland sump were found in Randy's pump.

In June of 2003, lightning blew the fuses of the filter basin pumping station, which were replaced. Excessive rain during the summer and fall season of 2003 caused many problems and repairs to the wetland and filter basin. Due to location of the wetland between to CSA berms, the wetland collects all the excess water as it drains the surrounding area causing a variable water level in the wetland. Randy's pump was installed in the wetland to control the variation in the wetland, but it could not sufficiently to keep up with the natural rain cycles. In June 2003, both pumps at the wetland pumping station were submerged. To prevent this from occurring, concrete blocks were built in July 2003 to raise the pumps, and the motors of the wetland and Randy's pump were replaced in August of 2003. There have not been any problems with the flooding of the pumps since then.

CLIMATIC

In May of 2001, both the filter basin and wetland flow meters were not functioning. Both flow meters were disconnected and debris that was fouling the impellers was removed. The debris in the wetland flow meter was found to be HDPE shavings from the installation of the flanged connections in April 2001, while the debris in the filter basin flow meter appeared to be of animal, specifically fish, origin. Visual examination of the system suggested that birds were perching on the standpipes and dropping fish remains, fecal material, and other debris into the standpipes. Vented well seals were installed on the standpipes in the filter basin to prevent the future entry of additional foreign material. The discovery of the piscine debris in the filter basin flow meter in May 2001 preceded a detection of low counts of total and fecal coliform bacteria in the filter basin samples.

As a precaution against the establishment of bacteria in the system, the intake pipes and screens in the filter basin were sanitized with a chlorine bleach solution with an initial concentrations of 800 ppm, followed by a six day non-pumping residence time, and a concentration of 3 ppm residual upon the re-starting of the system. In June 2001, 5 gallons of 5% bleach solution was poured in each one of the two clean-outs at the west-end of the filter basin. In addition, 2.5 gallons were poured into each standpipe. Some time later an additional 2 gallons were poured in each one of the two clean-outs. In spite of this effort, microorganisms were still found present in the filter basin.

Because of continual findings of coliform, SI met with Dr. Lillian Stark, the Biological Administrator for the Florida Department of Health In July 2001. After discussing these results with Dr. Stark, she felt the chlorination procedure loosened up some of the material that was attached to the walls of the piping and was collected in the samples. After a review of the water quality data collected to date in comparison to the water levels in the filter basin, the fecal coliform hits occur after the unsaturated zone decreased. A previous FIPR study by Schreuder and Stark established that the thickness of the unsaturated zone correlates directly with the microorganism removal capacity of the filter basin.

Due to the fact that the system was not running for a long period of time, it was thought best to have the basin disinfected and cleaned of any bacteria and/or viruses that may have accumulated while the system was being modified. The filter basin was disinfected and cleaned using a jetting tool connected to a water truck with a 500ppm concentration of chlorine mixed with potable water. The jetting tool was inserted into the clean out openings located on the west end of the filter basin. The chlorinated water was jetted into both the north and south wire-wrapped screens. A trash pump was used at the standpipes to remove water. The basin was jetted for 8 hours. Additional chlorine was placed into the filter basin upon the completion of jetting, to maintain an adequate residual of chlorine during the required 24-hour (minimum) contact time. The repaired filter basin pump was relocated to the north side of the east/west divider berm, perpendicular the stand pipes. The filter basin pump was also installed with new drop pipes with foot valves, which were thoroughly disinfected with 12% chlorine before installation in the standpipes. The suction and discharge lines are designed to be air tight to prevent any loss of prime in the pump.

It is essential to maintain a 6 ft. unsaturated zone in the filter basin to allow for the proper removal of certain types of viruses and bacteria, such as *Cryptosporidium* and *Giardia*, as well as total and fecal coliform. There are two mechanisms to control the discharge of the wetland water and the withdrawal of the filtered water from the basin. The first mechanism is the flow control valves and the water distribution system of the filter basin, as previously described. The second mechanism consists of a water level control system, which consists of two water level sensors that were installed the standpipes of the filter basin. When the water level in the filter basin draws down to 8 ft. below land surface, the water level sensor triggers the wetland pump to turn on. As the water percolates through the sand and the water level rises to 6 ft. below land surface, the water level sensor triggers the wetland pump to turn off.

SI personnel, to assure an accurate measurement of the unsaturated zone below land surface, surveyed the standpipes in the filter basin. The water levels in both standpipes were measured at every site visit to verify the correct operation of the water level control system. This system allows for the filter basin pump to be continuously running, while the water level control system actively turns on and off the wetland pump to maintain the six to eight feet of unsaturated zone. Upon completion of the float level control installation the system was put into full operation on July 24, 2002, and the sampling schedule resumed.

Lightning causes major problems, such as power overloads and surges, with the wetland-filter basin system. There have been numerous lightning strikes during the pilot project (May 2001, June 2001, July 2002, August 2002, July 2003, and August 2003). Between July 1, 2003 and August 1, 2003, lightning near the filter basin permanently damaged both water level sensor controllers. The new water level sensor to control the operation of the wetland pump was installed in the north standpipe of the filter basin in September 2003, and the water level control system was calibrated.

Excessive rain during the summer and fall season of 2002 and 2003 caused many problems and repairs to the wetland and filter basin. As discussed prior in the report, both pumps at the wetland pumping station were submerged on several occasions, and both pumps and motors were either repaired or completely replaced a number of times. Concrete blocks were built in July 2003 to raise the pumps, and since then there have not been any problems with the flooding of the pumps.

In December of 2003, the flow meter at the effluent became clogged with plastic materials, ranging from feminine pads to cigarette wrappers and candy bar wrappers. Twice, the effluent flow meter was disconnected and the debris removed.

OPERATIONAL

Beginning in September of 2002, a significant difference in the water levels of the filter basin between the north and south stand pipes. To correct the difference in water levels, the controls in the distribution system were manipulated on several different occasions to attempt to even out the water levels. On October 24, 2002, a primary test was conducted to resolve the issue of differing water levels in the filter basin. It was concluded at this time that there was some sort of obstruction clogging the foot valve of the south standpipe. Through out November and December the controls of the distribution system in the filter basin were manipulated in different ways to try to control the difference in water levels between the north and south standpipes.

At the end of the 2002 year, the water level float control system was not turning the wetland pump on and off at the appropriate water levels. To correct the issue, the water level float control system was calibrated to the six and eight foot turn on/off water levels on several occasions. The sensors of the water level float control system had been originally been set to function as a result of the change in specific conductivity, but since the cooling pond has relatively high specific conductance, it was falsely triggering the water levels sensors, which would signal the wetland pump to turn on and off at inappropriate water levels. The sensor of water level float control system was changed to read the pressure inside the standpipes instead of the specific electrical conductance of the water. In November of 2002, the water level float control system was calibrated.

Throughout January 2003, the difference in water levels between the north and south standpipes was causing the water level float control system to malfunction. Since the water level in the south stand pipe remained at or above the eight feet BLS while the north stand pipe was being drawn down to levels of 10 to 13 feet BLS, the water level float control system was not signaling the wetland pump to turn on. The extremely low water level in the north standpipe was causing the pump to surge and pull air, which could eventually break the pump. After much data analysis and manipulation of the valves controlling the water discharge and pump suction, it was concluded that there was an obstruction blocking the passage of water in the south standpipe.

In February 2003, a pump crew pulled the south standpipe. A glob of orange-colored, viscous material was found around the foot valve of the south standpipe. The material was removed from the foot valve of the south standpipe, and the standpipe was chlorinated as the standpipe was replaced to avoid contamination. The filter basin pumping station purged the remaining orange material before the pumping station was returned to its normal operation. To further remedy the obstruction in the south standpipe, both sumps of the standpipes were cleaned by the air injection method. Using an air compressor, air was blown through a long pipe into the bottom of the sump, the rose up through the water column, dislodging the sediments, which were pulled through the foot valve and discharged onto the open ground. Both stand pipes and sumps were thoroughly chlorinated.

Immediately following this procedure, the water level float control system was falsely signaling the 11 feet BLS, which turns off the filter basin pumping station. The 11 feet BLS water level was used as an emergency cut off point to save the basin from any damage from low water levels in the filter basin. This control was temporarily disconnected from the water level float control system. In May of 2003, the emergency 11 feet BLS water level was again falsely signaling the filter basin to turn off. After inspection of both water level sensors, it was determined one was functional, but the other needed repairs. The functional water level sensor was placed in the north standpipe, and the broken water level was sent to the manufacturer for repairs.

In June 2003, lightning permanently damaged the water level control system. The water level sensors were removed, sent to the manufacturer for repairs, but neither one could be repaired. Only one water level sensor was replaced due to continuous problems and repairs to the water level sensors. To determine which standpipe to install the new water level sensor, several operational tests were conducted. The results show a potential for groundwater seepage on the southern side of the filter basin, therefore north standpipe was chosen to be more realistic of the inflowing water from the wetland. There was a delay in the installation of the new water level sensor due to warranty issues and wrong equipment being sent, but the new water level sensor was installed in September 2003. In October 2003, the water level control system was calibrated to turn off the wetland pump at 7 feet BLS and on at 9 feet BLS. This was done to increase the thickness of the unsaturated zone.

Appendix E

RESULTS OF ANALYSES PER GROUPING AND SOURCE

RESULTS OF ANALYSES PER GROUPING AND SOURCE

PERFORMANCE STANDARDS

Cooling Pond

The results of the chemical analyses of water samples collected when the cooling pond was used as a source of water as part of the Performance Standard evaluation is presented in Table E-1.

Effluent

The results of the chemical analyses of water samples collected when the effluent was used as a source of water as part of the Performance Standard evaluation is presented in Table E-2.

Table E-1. Results of the Performance Standards from the Cooling Pond.

Performance Standards									
Parameter	Iron			Manganese			Fluoride		
DWS (DL):	0.3 mg/l (0.02 mg/l)			0.05 mg/l (0.01 mg/l)			4.0/2.0 mg/l for 1°/2° (0.003 mg/l)		
Date	CP	W	B	CP	W	B	CP	W	B
05/03/01	0.05	0.05	1.10	0.02	0.03	0.090	2.6	2.2	1.8
05/10/01	0.08	0.06	1.10	0.01	0.02	0.060	2.6	2.3	2.0
05/17/01	0.12	0.07	1.80	0.01	0.02	0.100	2.8	2.4	1.9
05/24/01	0.04	0.08	0.95	0.01	0.01	0.030	2.5	2.7	2.2
05/31/01	0.04	0.1	1.20	0.01	0.04	0.090	2.7	2.7	2.2
06/15/01	ND	0.1	0.90	ND	0.06	0.080	2.3	1.8	2.0
06/21/01	0.05	0.11	4.70	0.01	0.07	0.130	2.4	1.5	2.0
06/28/01	0.03	0.11	0.33	0.01	0.06	0.050	2.5	1.8	2.3
07/05/01	ND	0.12	0.75	ND	0.06	0.060	2.4	1.6	2.2
07/19/01	0.04	0.12	1.60	0.01	0.04	0.070	2.5	1.8	2.3
08/02/01	0.04	0.13	1.40	0.01	0.04	0.080	2.4	1.8	2.3
08/16/01	ND	0.13	0.77	0.01	0.03	0.070	2.6	1.1	2.5
08/29/01	0.02	0.13	1.00	0.01	0.03	0.080	2.6	2.1	2.3
09/27/01	ND	0.14	1.20	0.01	0.04	0.070	2.3	1.2	2.1
10/11/01	0.06	0.14	1.50	0.01	0.03	0.080	2.3	1.2	1.9
10/30/01	0.07	0.15	2.70	0.01	0.04	0.110	2.5	2.1	1.8
11/14/01	0.11	0.15	2.30	0.01	0.02	0.100	2.3	2.3	1.7
12/04/01	0.12	0.15	2.30	0.01	0.03	0.090	2.4	2.4	1.8
08/06/02	0.03	0.16	3.00	0.01	0.02	0.070	2.6	1.2	2.2
09/20/02	0.06	0.16	2.30	0.01	0.03	0.060	2.6	1.3	1.7
10/18/02	ND	0.17	0.58	ND	0.02	0.020	2.6	1.5	1.4
11/01/02	0.02	0.2	0.48	0.01	0.03	0.040	2.5	2.0	1.8
11/15/02	0.04	0.2	1.00	0.01	0.01	0.030	2.6	2.4	1.6
12/06/02	0.1	0.2	1.20	0.01	0.01	0.040	2.7	2.3	1.9
12/19/02	0.08	0.22	0.57	0.01	0.02	0.020	2.5	1.8	1.8
02/03/03		0.26	2.20			0.040			1.9
02/26/03	0.06	0.27	0.57	0.01	0.04	0.020	2.7	2.2	1.7
03/26/03	ND		0.70	ND	0.02	0.040	2.7	2.0	2.3

Note: CP = cooling pond, W = wetland and B = sand basin.

Table E-1 (Cont.). Results of the Performance Standards from the Cooling Pond.

Performance Standards									
Parameter	Sulfate			Unionized Ammonia			Nitrate		
DWS (DL):	250 mg/l (0.1 mg/l)			(0.01 mg/l as N)			10 mg/l as N (0.002 mg/l)		
Date	CP	W	B	CP	W	B	CP	W	B
05/03/01	100	100	96	0.01		0.01	0.071	0.025	0.056
05/10/01	100	95	91				0.002	0.002	0.059
05/17/01	95	100	92				0.009	0.002	0.070
05/24/01	100	98	100				0.002	0.007	0.080
05/31/01	100	92	88				0.002	0.002	0.074
06/15/01	110	37	53				ND	0.002	0.170
06/21/01	100	48	59				0.002	0.002	0.140
06/28/01	100	46	51				0.002	0.002	0.210
07/05/01	97	47	48				ND	0.002	0.140
07/19/01	100	60	59				0.002	0.005	0.120
08/02/01	100	52	49				0.004	0.018	0.110
08/16/01	110	28	48				ND	0.002	0.019
08/29/01	110	56	50				0.01	0.01	0.024
09/27/01	100	26	27	7.1		0.01	0.002	0.002	0.031
10/11/01	100	23	22				0.007	0.002	0.011
10/30/01	110	71	64				0.004	0.002	0.033
11/14/01		100	93					0.008	0.032
12/04/01	110	100	100				0.025	0.036	0.110
08/06/02	110	9.4	40				0.009	0.019	0.009
09/20/02	110	19	22				0.002	0.012	0.043
10/18/02	110	48	43				0.002	0.15	0.041
11/01/02	110	52	53				0.003	0.013	0.100
11/15/02	120	96	90				0.002	0.002	0.280
12/06/02	120	97	75				0.002	0.002	0.087
12/19/02	110	66	58				0.026	0.002	0.130
02/03/03			44						
02/26/03	110	85	79	0.01		ND	0.002	0.002	0.180
03/26/03	110	64	59	0.01		ND	ND	ND	0.110

Note: CP = cooling pond, W = wetland and B = sand basin.

Table E-1 (Cont.). Results of the Performance Standards from the Cooling Pond.

Performance Standards									
Parameter	Nitrite			Total Phosphorus			Suspended Solids		
DWS (DL):	1 mg/l (00.005 mg/l)			(0.03 mg/l as P)			500 mg/l (2 mg/l)		
Date	CP	W	B	CP	W	B	CP	W	B
05/03/01	0.005	0.005	0.005	0.6	0.69	0.23			
05/10/01	0.005	0.005	0.005	1.3	0.8	0.35	21	5	4
05/17/01	0.005	0.005	0.005	1.5	1.2	0.73	15	2	5
05/24/01	0.005	0.005	0.005	0.54	0.75	0.49	16	2	3
05/31/01	0.005	0.005	0.005	0.84	1	0.47	12	2	2
06/15/01	ND	0.005	0.005	0.4	1.5	0.45	11	3	3
06/21/01	0.005	0.005	0.007	0.57	2.2	0.23	10	5	40
06/28/01	0.005	0.005	0.005	0.18	1.2	0.28	12	2	2
07/05/01	ND	0.005	0.005						
07/19/01	0.005	0.005	0.005	0.38	1.2	0.58	10	2	4
08/02/01	0.005	0.005	0.005	0.37	1.1	0.64	8	2	5
08/16/01	ND	0.005	0.005	0.76	1.8	0.97	10	2	2
08/29/01	0.005	0.005	0.005	0.35	0.82	0.83	8	2	4
09/27/01	0.005	0.005	0.010	0.26	1.3	0.96			
10/11/01	0.005	0.005	0.005	0.65	1.4	0.96	29	3	2
10/30/01	0.005	0.005	0.006	1	0.66	0.41	2	2	3
11/14/01		0.005	0.005						
12/04/01	0.014	0.006	0.009	0.7	0.39	0.88	14	2	6
08/06/02	0.005	0.005	0.005	0.27	1.6	0.60	9	2	4
09/20/02	0.005	0.005	0.005	0.38	1.1	0.76	8	2	2
10/18/02	0.005	0.005	ND	0.41	0.78	0.73	10	2	2
11/01/02	0.005	0.005	ND	0.4	1.1	0.59	8	2	3
11/15/02	0.005	0.005	ND	0.45	0.41	0.52	13	2	2
12/06/02	0.006	0.005	ND	0.58	0.59	0.46	14	2	2
12/19/02	0.017	0.005	ND	0.59	1.1	0.47	14	2	2
02/03/03									
02/26/03	0.005	0.005	ND	0.69	0.88	0.56			
03/26/03	ND	ND	ND	0.03	0.74	0.59			

Note: CP = cooling pond, W = wetland and B = sand basin.

Table E-1 (Cont.). Results of the Performance Standards from the Cooling Pond.

Performance Standards									
Parameter	Gross Alpha			pH			Temperature		
DWS (DL):	15 pCi/l (1.3 mg/l)			6.5-7.5			°C		
Date	CP	W	B	CP	W	B	CP	W	B
05/03/01	14.4 ± 2.2	<1.9 ± 1.3	4.3 ± 1.4	8.37	6.99	6.90	849	938	872
05/10/01	9.8 ± 1.8	1.8 ± 1.2	2.2 ± 1.1	8.83	7.12	7.24	861	923	863
05/17/01	13.8 ± 2.0	1.9 ± 1.1	2.9 ± 1.2	8.39	6.81	7.30	993	1067	1033
05/24/01	9.9 ± 1.6	2.7 ± 1.1	3.4 ± 1.4	8.87	6.94	7.00	877	943	833
05/31/01	11.3 ± 1.7	4.7 ± 1.2	6.8 ± 1.6	9.05	7.03	7.15	898	963	850
06/15/01	2.8 ± 1.2	1.6 ± 1.0	2.3 ± 1.2	8.59	6.64	6.81	717	716	825
06/21/01	9.6 ± 1.3	2.8 ± 0.8	1.6 ± 0.9	8.22	6.29	6.26	677	599	802
06/28/01	8.8 ± 1.9	<1.3 ± .9	4.5 ± 1.1	8.31	6.69	6.77	627	653	781
07/05/01				8.20	6.65	6.75	608	586	782
07/19/01	12.3 ± 1.5	3.9 ± 0.9	1.9 ± 1.0	8.37	6.97	6.69	569	586	781
08/02/01	9.3 ± 2.4	2.2 ± 1.2	<1.6 ± 1.2			6.96	529		
08/16/01	9.9 ± 2.5	1.7 ± 1.1	3.5 ± 1.6	8.38	6.89	6.85	493	497	775
08/29/01	10.5 ± 2.0	2.3 ± 1.2	4.0 ± 1.3	8.43	6.85	6.74	548	592	763
09/27/01	11.2± 1.7	<1.8 ± 1.3	3.2 ± 1.6	8.25	6.47	6.54	387	367	733
10/11/01	9.0 ± 1.5	2.6 ± 0.8	<1.2 ± 0.7	8.26	6.27	6.31	372	320	701
10/30/01	11.8 ± 1.5	<1.7 ± 1.1	3 ± 1.4	7.99	6.53	6.25	608	665	742
11/14/01				7.79	6.97	6.91	868	900	879
12/04/01	6.8 ± 1.0	2.0 ± 1.0	3.7 ± 1.1	8.44	7.55	7.24	891	938	887
08/06/02	4.6 ±1.5	<1.5 ±1.0	<1.6 ±1.0						
09/20/02	6.5 ±1.3	<1.3 ±0.9	<2.9 ±0.8	9.29	7.18	6.92	492	467	1039
10/18/02	10.9 ±1.2	<1.4 ±0.9	4.2 ± 0.6	9.27	7.18	6.91	557	568	990
11/01/02	9.0 ±1.7	2.1 ±1.3	<1.4 ±0.9	9.28	7.58	6.97	593	726	994
11/15/02	7.5 ±1.7	<2.3 ±1.3	<2.9 ±1.0	9.16	7.19	6.88	784	825	948
12/06/02	10.4 ±2.0	2.2 ±1.2	<2.7 ±1.5	9.12	7.15	6.78	709	821	911
12/19/02	8.3 ±1.2	<1.3 ±0.6	1.6 ±0.9	8.88	6.94	6.78	560	603	886
02/03/03				8.89	7.25	6.98	477	592	877
02/26/03	7.5 ±1.4	3.0 ±1.3	2.9 ±1.1	9.07	7.19	6.93	746	816	869
03/26/03	7.5 ±1.10	<2.1 ±1.4	2.4 ±1.4	9.07	7.29	6.83	592	630	800

Note: CP = cooling pond, W = wetland and B = sand basin.

Table E-1 (Cont.). Results of the Performance Standards from the Cooling Pond.

Performance Standards						
Parameter	Specific Electrical Conductance			Turbidity		
	µS			NTU		
Date	CP	W	B	CP	W	B
05/03/01	23.5	22.6	26.1			5.1
05/10/01	23.5	22.9	27.2			
05/17/01	20.3	20.1	22.8			
05/24/01	25.9	25.1	30.8			
05/31/01	26.4	25.7	33.2			
06/15/01	27.9	26.7	33.8			
06/21/01	27.3	27.1	33.5			
06/28/01	27.3	26	32.3			
07/05/01	28	26.9	34			
07/19/01	27.8	26.7	33.2			
08/02/01	26.3					
08/16/01	29.3	27.9	35.4			
08/29/01	29.5	27.1	35.6			
09/27/01	26.6	25	30			3.7
10/11/01	25.6	26	29.5			
10/30/01	21.7	20.9	25.9			
11/14/01	19.8	19.2	22.1			
12/04/01	21.1	20.6	24.6			
08/06/02						
09/20/02	27.3	27.0	32.5			
10/18/02	24.3	22.8	29.1			
11/01/02	25.5	24.2	29.1			
11/15/02	22.9	20.1	26.6			
12/06/02	19.0	15.8	19.3			
12/19/02	19.2	17.1	22.4			
02/03/03	20.0	14.0	20.0			
02/26/03	19.7	19.0	25.2	9.5		2.6
03/26/03	23.3	21.7	28.2	6.1		5

Note: CP = cooling pond, W = wetland and B = sand basin.

Table E-1 (Cont.). Results of the Performance Standards from the Cooling Pond.

Performance Standards						
Parameter	Specific Electrical Conductance			Turbidity		
	µS			NTU		
Date	CP	W	B	CP	W	B
05/03/01	23.5	22.6	26.1			5.1
05/10/01	23.5	22.9	27.2			
05/17/01	20.3	20.1	22.8			
05/24/01	25.9	25.1	30.8			
05/31/01	26.4	25.7	33.2			
06/15/01	27.9	26.7	33.8			
06/21/01	27.3	27.1	33.5			
06/28/01	27.3	26	32.3			
07/05/01	28	26.9	34			
07/19/01	27.8	26.7	33.2			
08/02/01	26.3					
08/16/01	29.3	27.9	35.4			
08/29/01	29.5	27.1	35.6			
09/27/01	26.6	25	30			3.7
10/11/01	25.6	26	29.5			
10/30/01	21.7	20.9	25.9			
11/14/01	19.8	19.2	22.1			
12/04/01	21.1	20.6	24.6			
08/06/02						
09/20/02	27.3	27.0	32.5			
10/18/02	24.3	22.8	29.1			
11/01/02	25.5	24.2	29.1			
11/15/02	22.9	20.1	26.6			
12/06/02	19.0	15.8	19.3			
12/19/02	19.2	17.1	22.4			
02/03/03	20.0	14.0	20.0			
02/26/03	19.7	19.0	25.2	9.5		2.6
03/26/03	23.3	21.7	28.2	6.1		5

Note: CP = cooling pond, W = wetland and B = sand basin.

Table E-1 (Cont.). Results of the Performance Standards from the Cooling Pond.

Performance Standards						
Parameter	Fecal Coliform			Total Coliform		
DWS (DL):	0 MPN/100 l (2MPN/100 l)			4 MPN/100 l (2 MPN/100 l)		
Date	CP	W	B	CP	W	B
05/03/01	<2	13	<2	<2	300	30
05/10/01	<2	900	30	<2	900	500
05/17/01	<2	23	2	<2	500	170
05/24/01	4	<2	<2	50	>1600	900
05/31/01	<2	2	<2	17	280	23
06/15/01	30	170	2			
06/21/01	<2	1600	<2	7	>1600	11
06/28/01	<2	300	7	300	900	170
07/05/01	11	1600	2	110	1600	23
07/19/01	<2	13	<2	7	1600	17
08/02/01	23	1600	17	80	1600	900
08/16/01	<2	110	2	2	900	70
08/29/01	<2	30	<2	4	1600	>1600
09/27/01	<2	<2	2	8	1600	13
10/11/01						
10/30/01	<1	30	4	2	500	1600
11/14/01	<2	40	2	8	500	1600
12/04/01	13	240	170	13	300	170
08/06/02						
09/20/02	<2	30	13	<2	>1600	240
10/18/02	<2	4	4	2	500	70
11/01/02	<2	13	<2	4	1600	17
11/15/02	<2	13	<2	2	300	2
12/06/02	<2	4	34	<2	30	>1600
12/19/02	<2	11	23	2	34	70
02/03/03	<2	14		2	300	
02/26/03	<2	<2		23	50	
03/26/03	<2	17	8	8	500	17

Note: CP = cooling pond, W = wetland and B = sand basin.

Table E-2. Results of the Performance Standards from the Effluent.

Performance Standards									
Parameter	Iron			Manganese			Fluoride		
DWS (DL):	0.3 mg/l (0.02 mg/l)			0.05 mg/l (0.01 mg/l)			4.0 and 2.0 mg/l for 1° and 2° (0.003 mg/l)		
Date	E	W	B	E	W	B	E	W	B
5/8/2003	0.23	0.11	0.35	0.01	0.03	0.040	0.23	2.2	2.3
05/15/03	0.06	0.07	0.37	U	0.03	0.040	0.21	2.1	2.2
05/22/03	0.06	0.06	0.33	0.03	0.03	0.040	0.23	2.0	2.2
06/03/03	0.14	0.08	0.05	0.03	0.03	ND	0.26	1.9	2.2
06/25/03	0.08	0.15	0.19	0.04	0.03	0.020	0.38	0.7	2.2
07/01/03	0.078		0.20	0.033		0.025	0.3		1.9
08/06/03	0.062	0.26	6.00	0.015	0.026	0.060	0.28	1.0	2.3
08/13/03	0.078	0.3	0.04	0.026	0.029	ND	0.24	0.9	2.0
08/21/03	0.089	0.23	0.25	0.076	0.021	0.030	0.3	1.0	1.8
08/28/03	0.49	0.37	0.20	0.052	0.022	0.016	0.29	0.9	1.8
09/09/03	0.11	0.2	0.22	0.022	0.02	0.020	0.25	0.9	2.0
09/16/03	0.13	0.15	0.33	0.031	0.014	0.029	0.32	0.9	1.7
09/24/03	0.11	0.18	1.50	0.031	0.015	0.030	0.28	0.9	1.7
09/29/03	0.1	0.11	0.76	U	ND	0.035	0.23	0.9	1.7
10/07/03	0.062	0.11	0.16	0.017	0.019	0.027	0.41	1.0	1.4
10/14/03	0.042	0.12	0.16	U	0.019	0.019	0.32	1.1	1.4
10/21/03	0.073	0.1	0.24	0.026	0.017	ND	0.27	1.1	1.3
10/28/03	0.0999	0.1	0.16	U	0.015	0.019	0.32	1.2	1.5
11/13/03	0.054	0.12	0.37	U	ND	0.033	0.28	0.9	1.4
11/18/03	0.061	0.093	0.28	0.018	0.027	0.021	0.26	0.9	1.6
11/24/03	0.067	0.067	0.73	0.017	0.026	ND	0.24	0.9	1.4
12/03/03	0.053	0.062	0.21	0.017	0.024	ND	0.25	0.9	1.2
12/10/03	0.091	0.058	0.09	0.014	0.018	0.018	0.26	0.8	1.1
12/17/03	0.11	0.18	0.08	0.013	0.029	0.012	0.25	0.9	1.4

Note: E = effluent, W = wetland and B = sand basin.

Table E-2 (Cont.). Results of the Performance Standards from the Effluent.

Performance Standards									
Parameter	Nitrite as N			Total Phosphorus			Suspended Solids		
DWS (DL):	1 mg/l as N (0.005 mg/l)			(0.03 mg/l as P)			500 mg/l (2 mg/l)		
Date	E	W	B	E	W	B	E	W	B
5/8/2003	0.005	ND	ND	1.9	0.56	0.61	U	3	U
05/15/03	0.006	ND	ND						440
05/22/03	0.005	ND	ND	0.62	0.96	0.52	2	U	U
06/03/03	0.005	0.013	ND	0.65	0.98	4.30	4	3	U
06/25/03	0.007	ND	ND	0.81	1.2	0.66			
07/01/03	0.036		ND						
08/06/03	0.023	ND	0.013	2.6	1.7	0.72	4	4	14
08/13/03	0.006	ND	ND						
08/21/03	0.03	ND	ND	0.63	1.5	1.10			
08/28/03	0.029	ND	ND	1.3	1.8	1.10	8	8	U
09/09/03	0.13	ND	ND						
09/16/03	0.042	ND	ND	2.3	1.5	1.30	U	U	U
09/24/03	0.034	ND	ND	2.7	1.5	1.40	5	U	8
09/29/03	0.018	ND	ND						
10/07/03	U	ND	ND	2.7	1.7	1.10	3	U	U
10/14/03	U	ND	ND	2.2	1.7	0.94			
10/21/03							U	U	3
10/28/03	U	ND	ND						
11/13/03							4	U	U
11/18/03	0.016	ND	0.019	4	2	0.83			
11/24/03	U	0.007	ND						
12/03/03							U	U	U
12/10/03							7	U	U
12/17/03	U	0.007	0.020	2.7	3.1	0.97			

Note: E = effluent, W = wetland and B = sand basin.

Table E-2 (Cont.). Results of the Performance Standards from the Effluent.

Performance Standards									
Parameter	Gross Alpha			pH			Temperature		
DWS (DL):	15 pCi/l 1.3 mg/l)			6.5-7.5			°C		
Date	E	W	B	E	W	B	E	W	B
5/8/2003	<1.7 ± 1.1	<2.1 ±1.4	2.5 ±1.3	7.54	7.35	6.85	29.5	26.1	24.8
05/15/03	<1.5 ± 1.0	<2.1 ±1.3	4.4 ±1.3	7.25	7.32	6.88	30.6	26.3	27.1
05/22/03	<1.6 ±0.9	5.7 ±1.9	3.5 ±1.5	7.57	7.38	6.80	30.3	25.7	26.0
06/03/03	<1.8 ± 1.2	2.4 ±1.3	5.0±1.2	7.44	7.32	6.85	30.6	25.7	26.2
06/25/03	1.7 ± 0.4	<2.1 ±1.3	3.8±0.6	7.69	6.97	6.85	30.0	27.1	26.4
07/01/03	1.3 ± 0.8		<1.4±0.9	7.19		6.77	30.0		26.9
08/06/03	<1.7 ± 1.0	1.5 ±0.6	4.8±1.1	7.60	6.68	6.70	31.4	27.5	26.2
08/13/03	<0.8 ± 0.5	1.5 ±0.8	3.7±0.9	7.25	6.49	7.00	29.7	25.8	27.1
08/21/03	<2.0 ±1.2	<1.6 ±1.1	6.6±1.3	7.23	6.28	6.89	29.7	25.5	26.6
08/28/03	<1.2 ±0.7	1.3 ±0.9	5.8±1.1	7.58	6.47	6.61	36.1	26.3	27.0
09/09/03	1.1 ±0.7	1.4 ±0.8	3.7±1.1	7.97	6.49	6.67	30.3	26.5	27.3
09/16/03	1.0 ±0.7	<1.3 ±1.0	2.9±0.9	7.80	6.58	6.57	30.0	25.7	26.3
09/24/03	<1.6 ± 1.1	<1.2 ±0.8	3.4±1.1	8.16	6.57	6.74	31.3	27.0	26.6
09/29/03	1.8 ± 0.8	1.0 ±0.6	3.7±1.1	8.00	6.81	6.69	28.6	24.9	26.1
10/07/03	<1.3 ± 0.8	<1.3 ±0.9	3.5±1.2	8.09	6.88	6.45	29.5	24.7	26.7
10/14/03	<0.7 ± 0.5	1.2 ±0.6	2.8±1.0	7.35	7.00	6.86	29.4	25.3	25.9
10/21/03	<1.7 ± 1.1	1.9 ±1.0	3.7±0.8	7.24	7.29	6.71	29.2	23.7	24.3
10/28/03	18.1 ± 2.6	4.0 ±1.0	0.7±0.5	7.76	7.30	6.78	28.2	22.9	24.0
11/13/03	0.8 ±0.67	2.0 ±1.2	<1.3±0.8	7.25	6.79	7.03	27.5	22.0	24.8
11/18/03	<1.4 ±0.7	<1.4 ±0.9	2.4±0.8	7.45	6.95	6.86	27.7	20.6	24.0
11/24/03	<2.0 ±1.1	<1.6 ±1.1	<2.3±1.4	7.31	7.04	6.77	26.5	18.9	23.0
12/03/03	<0.8 ±0.5	1.4 ±1.0	2.5±0.9	7.17	7.03	6.73	25.2	19.4	19.3
12/10/03	<1.6 ±0.9	2.3 ±0.9	<1.3±0.8	7.41	7.02	6.33	23.6	14.5	18.2
12/17/03	<3.0 ±1.9	<1.7 ±1.3	2.4±1.0	7.24	7.14	6.70	22.4	14.9	18.0

Note: E = effluent, W = wetland and B = sand basin.

Table E-2 (Cont.). Results of the Performance Standards from the Effluent.

Performance Standards									
Parameter	Sulfate			Unionized Ammonia			Nitrate as N		
DWS (DL):	250 mg/l (0.1 mg/l)			(0.01 mg/l as N)			10 mg/l as N (0..02 mg/l)		
Date	E	W	B	E	W	B	E	W	B
5/8/2003	62	64	70				2.2	ND	0.320
05/15/03	53	66	64				2.7	0.005	0.170
05/22/03	53	55	67				2.1	ND	0.110
06/03/03	56	62	63				5	0.13	0.042
06/25/03	50	39	37	U	ND	ND	1.3	ND	0.530
07/01/03	46		38				1.1		0.061
08/06/03	57	20	41				2.4	ND	0.230
08/13/03	56	21	21				3.9	ND	0.690
08/21/03	46	16	19	U		ND	0.68	0.008	0.130
08/28/03	50	9.7	14				0.77	ND	0.083
09/09/03	46	10	10				1.4	0.044	0.086
09/16/03	52	10	11				3	ND	0.063
09/24/03	46	15	14				4.1	ND	0.065
09/29/03	49	15	15				2.2	0.01	0.078
10/07/03	49	10	15				4.1	ND	0.380
10/14/03	48	7.7	14	U	ND	ND	2.7	0.041	0.430
10/21/03									
10/28/03	54	6.5	18				2.9	0.004	0.210
11/13/03									
11/18/03	49	21	23	0.16	ND	ND	7.1	0.08	0.430
11/24/03	50	23	24				6.3	0.007	0.420
12/03/03									
12/10/03									
12/17/03	47	35	38	U	ND	ND	4.2	ND	0.320

Note: E = effluent, W = wetland and B = sand basin.

Table E-2 (Cont.). Results of the Performance Standards from the Effluent.

Performance Standards						
Parameter	Specific Electrical Conductance			Turbidity		
	µS			NTU		
Date	E	W	B	E	W	B
5/8/2003	650	756	727			
05/15/03	673	767	711			
05/22/03	584	781	751			
06/03/03	557	755	714			
06/25/03	416	420	480		5.1	2.3
07/01/03	480		512			
08/06/03	617	388	515			
08/13/03	448	329	349			
08/21/03	478	324	358			1.6
08/28/03	474	286	309			
09/09/03	482	279	301			
09/16/03	300	315	487			
09/24/03	575	366	349			
09/29/03	507	440	364			
10/07/03	520	401	396			
10/14/03	496	415	407		2.7	1.9
10/21/03	541	415	405			
10/28/03	612	567	464			
11/13/03	672	600	497			
11/18/03	570	521	448		2.4	2.7
11/24/03	683	594	536			
12/03/03	644	574	542			
12/10/03	604	611	592			
12/17/03	567	655	568		2.8	0.62

Note: E = effluent, W = wetland and B = sand basin.

Table E-2 (Cont.). Results of the Performance Standards from the Effluent.

Performance Standards						
Parameter	Fecal Coliform			Total Coliform		
DWS (DL):	0 MPN/100 l (2 MPN/100 l)			4 MPN/100 l (2 MPN/100 l)		
Date	E	W	B	E	W	B
05/08/03	90	50	<2	>1600	>1600	<2
05/15/03	70	13	<2	900	>1600	<2
05/22/03	22	>1600	<2	>1600	22	<2
06/03/03	170	170	2	900	1600	13
06/25/03	130	>1600	<2	240	50	50
07/01/03	50		<2	500		26
08/06/03	1600	500	<2	>1600	>1600	<2
08/13/03	300	130	2	900	1600	50
08/21/03	>1600	80	<2	>1600	240	7
08/28/03	300		4	>1600	>1600	170
09/09/03	900	8	<2	>1600	900	30
09/16/03						
09/24/03	110	50	<2	>1600	1600	23
09/29/03	30	900	<2	>1600	>1600	<2
10/07/03	300	500	<2	500	500	<2
10/14/03	900	1600	2	900	1600	2
10/21/03	280	300	<2	280	300	<2
10/28/03	240	2	<2	>1600	300	4
11/13/03	500	13	<2	>1600	500	4
11/18/03	<2	20	<2	500	300	<2
11/24/03	>1600	33	<2	>1600	170	<2
12/03/03	70	<2	<2	220	80	<2
12/10/03	>1600	2	<2	>1600	80	22
12/17/03	220	1600	<2	>1600	>1600	2

Note: E = effluent, W = wetland and B = sand basin.

Appendix F

PRIMARY/SECONDARY STANDARDS

PRIMARY/SECONDARY STANDARDS

COOLING POND

The results of the chemical analyses of water samples collected when the cooling pond was used as a source of water as part of the Performance Standard evaluation is presented in Table F-1.

EFFLUENT

The results of the chemical analyses of water samples collected when the effluent was used as a source of water as part of the Performance Standard evaluation is presented in Table F-2.

Table F-1. Results of the Primary and Secondary Drinking Water Standards from the Cooling Pond.

Primary Drinking Water Standards									
Parameter	Antimony			Arsenic			Asbestos		
DWS (DL):	0.006 mg/l (0.001 mg/l)			0.05 mg/l (0.0005 mg/l)			7 Million Fibers/l (0.78 MFL)		
Date	CP	W	B	CP	W	B	CP	W	B
05/03/01	ND	ND	ND	ND	ND	0.001	ND		ND
07/05/01	ND	ND	ND	0.0029	ND	0.0014	ND	ND	ND
09/27/01	ND	ND	ND	0.0024	ND	0.0026	ND	ND	ND
11/14/01	ND	ND	ND	0.0017	ND	ND	ND	ND	ND
01/24/03			ND			ND			
02/26/03	ND	ND	ND	0.0011	ND	ND			
03/26/03	ND	ND	ND	0.002	0.0015	0.0012			

Primary Drinking Water Standards									
Parameter	Barium			Beryllium			Cadmium		
DWS (DL):	2 mg/l (0.01 mg/l)			0.004 mg/l (0.002 mg/l)			0.005 mg/l (0.001 mg/l)		
Date	CP	W	B	CP	W	B	CP	W	B
05/03/01	ND	ND	ND	ND	ND	ND	ND	ND	ND
07/05/01	ND	ND	ND	ND	ND	ND	ND	ND	ND
09/27/01	ND	ND	ND	ND	ND	ND	ND	ND	ND
11/14/01	ND	ND	ND	ND	ND	ND	ND	ND	ND
01/24/03			ND			ND			ND
02/26/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
03/26/03	ND	ND	ND	ND	ND	ND	ND	ND	ND

Primary Drinking Water Standards									
Parameter	Chromium			Cyanide			Fluoride		
DWS (DL):	0.1 mg/l (0.01 mg/l)			0.2 mg/l (0.0005 mg/l)			4.0 mg/l (0.003 mg/l)		
Date	CP	W	B	CP	W	B	CP	W	B
05/03/01	ND	ND	ND	ND	ND	ND	2.6	2.2	1.8
07/05/01	ND	ND	ND	ND	ND	ND	2.4	1.6	2.2
09/27/01	ND	ND	ND	ND	ND	ND	2.3	1.2	2.1
11/14/01	ND	ND	ND	ND	ND	ND	2.3	2.3	1.7
01/24/03			ND			ND			
02/26/03	ND	ND	ND	ND	ND	ND	2.7	2	1.7
03/26/03	ND	ND	ND	ND	ND	ND	2.7	2.1	2.3

Note: CP = cooling pond, W = wetland and B = sand basin.

Table F-1 (Cont.). Results of the Primary and Secondary Drinking Water Standards from the Cooling Pond.

Primary Drinking Water Standards									
Parameter	Lead			Mercury			Nickel		
DWS (DL):	0.015 mg/l (0.001 mg/l)			0.002 mg/l (0.0001 mg/l)			0.1 mg/l (0.02 mg/l)		
Date	CP	W	B	CP	W	B	CP	W	B
05/03/01	ND	0.001	ND	ND	ND	ND	ND	ND	ND
07/05/01	ND	ND	ND	ND	ND	ND	ND	ND	ND
09/27/01	ND	ND	ND	ND	ND	ND	ND	ND	ND
11/14/01	ND	ND	ND	ND	ND	ND	ND	ND	ND
01/24/03			ND			ND			ND
02/26/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
03/26/03	ND	0.0042	ND	ND	ND	ND	ND	ND	ND
Primary Drinking Water Standards									
Parameter	Nitrate-N			Nitrite-N			Selenium		
DWS (DL):	10 mg/l as N (0.002 mg/l)			1 mg/l as N (0.005 mg/l)			0.05 mg/l (0.001 mg/l)		
Date	CP	W	B	CP	W	B	CP	W	B
05/03/01	0.071	0.025	0.056	ND	ND	ND	ND	ND	ND
07/05/01	ND	ND	0.14	ND	ND	ND	ND	ND	ND
09/27/01	ND	ND	0.031	ND	ND	0.01	ND	ND	ND
11/14/01	0.021	ND	0.032	0.008	ND	ND	ND	ND	ND
01/24/03									ND
02/26/03	ND	ND	0.18	ND	ND	ND	ND	ND	ND
03/26/03	ND	ND	0.11	ND	ND	ND	ND	ND	0.01

Primary Drinking Water Standards						
Parameter	Sodium			Thallium		
DWS (DL):	160 mg/l (0.1 mg/l)			0.002 mg/l (0.001 mg/l)		
Date	CP	W	B	CP	W	B
05/03/01	77	72	79	ND	ND	ND
07/05/01	76	48	55	ND	ND	ND
09/27/01	85	34	35	ND	ND	ND
11/14/01	78	80	75	ND	ND	ND
01/24/03			37			ND
02/26/03	77	72	65	ND	ND	ND
03/26/03	78	67	61	ND	ND	ND

Note: CP = cooling pond, W = wetland and B = sand basin.

Table F-1 (Cont.). Results of the Primary and Secondary Drinking Water Standards from the Cooling Pond.

Secondary Drinking Water Standards									
Parameter	Aluminum			Chloride			Copper		
DWS (DL):	0.2 mg/l (0.1 mg/l)			250 mg/l (0.1 mg/l)			1.0 mg/l (0.005 mg/l)		
Date	CP	W	B	CP	W	B	CP	W	B
05/03/01	0.45	ND	ND	96	100	96	ND	ND	0.01
07/05/01	ND	ND	ND	93	63	67	ND	ND	0.01
09/27/01	0.13	ND	ND	100	38	37	ND	ND	0.01
11/14/01	0.73	ND	0.1	100	100	96	ND	ND	0.01
02/03/03			0.9			49			0.10
02/24/03		ND	ND		110	71		ND	0.01
02/26/03	ND	ND	ND	120	110	100	ND	ND	ND
03/03/03		ND	ND		95	81		ND	ND
03/10/03		ND	ND		97	80		ND	0.03
03/26/03	0.21	0.12	0.1	120	85	78	0.01	0.01	0.01
Secondary Drinking Water Standards									
Parameter	Fluoride			Iron			Manganese		
DWS (DL):	2.0 mg/l (0.003 mg/l)			0.3 mg/l (0.02 mg/l)			0.05 mg/l (0.01 mg/l)		
Date	CP	W	B	CP	W	B	CP	W	B
05/03/01	2.6	2.2	1.8	0.05	0.11	1.10	0.02	0.030	0.090
07/05/01	2.4	1.6	2.2	0.02	0.14	0.75	ND	0.060	0.060
09/27/01	2.3	1.2	2.1	0.02	0.26	1.20	ND	0.040	0.070
11/14/01	2.3	2.3	1.7	0.11	0.08	2.30	ND	0.020	0.100
02/03/03			1.9			2.20			0.040
02/24/03		2.2	1.6		0.20	1.80		0.100	0.040
02/26/03	2.7	2.2	1.7	0.06	0.12	0.57	ND	0.040	0.020
03/03/03		2.0	2.0		0.17	1.50		0.070	0.040
03/10/03		2.1	2.0		0.14	0.09		0.040	0.020
03/26/03	2.7	2.0	2.3	ND	0.07	0.70	ND	0.020	0.040

Note: CP = cooling pond, W = wetland and B = sand basin.

Table F-1 (Cont.). Results of the Primary and Secondary Drinking Water Standards from the Cooling Pond.

Secondary Drinking Water Standards									
Parameter	Silver			Sulfate			Zinc		
DWS (DL):	0.1 mg/l (0.01 mg/l)			250 mg/l (0.1 mg/l)			5 mg/l (0.005 mg/l)		
Date	CP	W	B	CP	W	B	CP	W	B
05/03/01	0.01	ND	ND	100	100	96	0.01	ND	ND
07/05/01	0.01	ND	ND	97	47	48	0.01	ND	ND
09/27/01	0.01	ND	ND	100	26	27	0.01	ND	ND
11/14/01	0.01	ND	ND	100	100	93	0.01	ND	ND
02/03/03			ND			44			0.12
02/24/03		ND	ND		77	54		ND	ND
02/26/03	ND	ND	ND	110	85	79	ND	ND	ND
03/03/03		ND	ND		63	64		ND	ND
03/10/03		ND	ND		68	60		ND	0.01
03/26/03	ND	ND	ND	110	64	59	ND	ND	ND
Secondary Drinking Water Standards									
Parameter	Color			Odor			pH		
DWS (DL):	15 PCU (5 PCU)			3 TON (1 TON)			6.5 - 8.5		
Date	CP	W	B	CP	W	B	CP	W	B
05/03/01	10	50	15	120	100	50	9.3	7.20	7.0
07/05/01	10	100	20	35	50	50	9.1	6.90	7.1
09/27/01	10	100	35	12	100	12	8.9	7.10	7.3
11/14/01	10	25	20	35	100	50	9	7.40	7.5
02/03/03			15						7.2
02/24/03		60	20		12	24		7.20	7.1
02/26/03	10	60	30	6	12	70	9.3	7.30	7.1
03/03/03		50	20		200	50		7.20	7.1
03/10/03		75	20		100	35		7.21	6.8
03/26/03	10	70	20	8	50	35	9.1	7.30	6.8

Table F-1 (Cont.). Results of the Primary and Secondary Drinking Water Standards from the Cooling Pond.

Secondary Drinking Water Standards						
Parameter	Total Dissolved Solids			Foaming Agents		
DWS (DL):	500 mg/l (10 mg/L)			0.5 mg/l (0.05 mg/l)		
Date	CP	W	B	CP	W	B
05/03/01	530	570	500	0.05	ND	ND
07/05/01	510	380	360	0.05	ND	ND
09/27/01	520	260	250	0.05	ND	ND
11/14/01	530	520	470	0.05	ND	ND
02/03/03			260			ND
02/24/03		440	310		ND	ND
02/26/03	520	480	420	ND	ND	ND
03/03/03		410	370		ND	ND
03/10/03		430	360		0.07	ND
03/26/03	520	400	360	ND	ND	ND

Note: CP = cooling pond, W = wetland and B = sand basin.

Table F-2. Results of the Primary and Secondary Drinking Water Standards from the Effluent.

Primary Drinking Water Standards									
Parameter	Antimony			Arsenic			Asbestos		
DWS (DL):	0.006 mg/l (0.001 mg/l)			0.05 mg/l (0.0005 mg/l)			7 Million Fibers/l (0.78 MFL)		
Date	E	W	B	E	W	B	E	W	B
05/15/03	ND	ND	ND	ND	ND	0.001			
06/25/03	ND	ND	ND	ND	ND	ND			
07/01/03	ND		ND	0.0024		0.005			
08/13/03	ND	ND	ND	0.0015	ND	ND			
08/21/03	ND	ND	ND	0.0018	ND	0.0012			
09/09/03	ND	ND	ND	0.0018	ND	0.0012			
09/29/03	ND	ND	ND	0.0018	ND	0.0016	ND	ND	ND
10/14/03	ND	ND	ND	0.0023	ND	0.0011	ND	ND	ND
10/28/03	ND	ND	ND	0.0079	ND	0.00067	ND	ND	ND
11/18/03	ND	ND	ND	0.00054	ND	0.00059			
11/24/03	ND	ND	ND	0.00071	ND	0.00079			
12/17/03	ND	ND	ND	0.00075	0.00068	0.00073			
Primary Drinking Water Standards									
Parameter	Barium			Beryllium			Cadmium		
DWS (DL):	2 mg/l (0.01 mg/l)			0.004 mg/l (0.002 mg/l)			0.005 mg/l (0.001 mg/l)		
Date	E	W	B	E	W	B	E	W	B
05/15/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
06/25/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
07/01/03	ND		ND	ND		ND	ND		ND
08/13/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
08/21/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
09/09/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
09/29/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
10/14/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
10/28/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
11/18/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
11/24/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
12/17/03	ND	ND	ND	ND	ND	ND	ND	ND	ND

Note: E = effluent, W = wetland and B = sand basin.

Table F-2 (Cont.). Results of the Primary and Secondary Drinking Water Standards from the Effluent.

Primary Drinking Water Standards									
Parameter	Chromium			Cyanide			Fluoride		
DWS (DL):	0.1 mg/l (0.01 mg/l)			0.2 mg/l (0.0005 mg/l)			4.0 mg/l (0.003 mg/l)		
Date	E	W	B	E	W	B	E	W	B
05/15/03	ND	ND	ND	ND	ND	ND	0.2	2.1	2.2
06/25/03	ND	ND	ND	0.007	ND	ND	0.4	0.7	2.2
07/01/03	ND		ND	ND		ND	0.3		1.9
08/13/03	ND	ND	ND	ND	ND	ND	0.2	0.1	2.0
08/21/03	ND	ND	ND	ND	ND	ND	0.3	1.0	1.8
09/09/03	ND	ND	ND	ND	ND	ND	0.3	0.9	2.0
09/29/03	ND	ND	ND	ND	ND	ND	0.2	0.9	1.7
10/14/03	ND	ND	ND	ND	ND	ND	0.3	1.1	1.4
10/28/03	ND	ND	ND	ND	ND	ND	0.3	1.2	1.5
11/18/03	ND	ND	ND	ND	ND	ND	0.3	0.9	1.6
11/24/03	ND	ND	ND	ND	ND	ND	0.2	0.9	1.4
12/17/03	ND	ND	ND	0.005	ND	ND	0.3	0.9	1.4
Primary Drinking Water Standards									
Parameter	Lead			Mercury			Nickel		
DWS (DL):	0.015 mg/l (0.001 mg/l)			0.002 mg/l (0.0001 mg/l)			0.1 mg/l (0.02 mg/l)		
Date	E	W	B	E	W	B	E	W	B
05/15/03	0.0011	ND	ND	ND	ND	ND	ND	ND	ND
06/25/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
07/01/03	ND		0.0011	ND		ND	ND		ND
08/13/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
08/21/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
09/09/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
09/29/03	0.0012	ND	ND	ND	ND	ND	ND	ND	ND
10/14/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
10/28/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
11/18/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
11/24/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
12/17/03	0.002	ND	ND	ND	ND	ND	ND	ND	ND

Note: E = effluent, W = wetland and B = sand basin.

Table F-2 (Cont.). Results of the Primary and Secondary Drinking Water Standards from the Effluent.

Primary Drinking Water Standards									
Parameter	Nitrate-N			Nitrite-N			Selenium		
DWS (DL):	10 mg/l as Nitrogen (0.002 mg/l)			1 mg/l as Nitrogen (0.005 mg/l)			0.05 mg/l (0.001 mg/l)		
Date	E	W	B	E	W	B	E	W	B
05/15/03	2.7	0.005	0.17	0.006	ND	ND	ND	ND	ND
06/25/03	1.3	ND	0.53	0.007	ND	ND	0.001	ND	0.001
07/01/03	1.1		0.061	0.036		ND	ND		ND
08/13/03	3.9	ND	0.69	0.006	ND	ND	ND	ND	ND
08/21/03	0.68	0.008	0.13	0.03	ND	ND	0.001	ND	ND
09/09/03	1.4	0.008	0.086	0.013	ND	ND	ND	ND	ND
09/29/03	2.2	0.01	0.078	0.018	ND	ND	ND	ND	ND
10/14/03	2.7	0.041	0.43	ND	ND	0.011	ND	ND	ND
10/28/03	2.9	0.004	0.21	ND	ND	ND	ND	ND	ND
11/18/03	7.1	0.08	0.43	0.016	ND	0.019	ND	ND	ND
11/24/03	6.3	0.007	0.42	ND	0.007	ND	ND	ND	ND
12/17/03	4.2	ND	0.32	ND	0.007	0.02	ND	ND	ND

Primary Drinking Water Standards						
Parameter	Sodium			Thallium		
DWS (DL):	160 mg/l (0.1 mg/l)			0.002 mg/l (0.001 mg/l)		
Date	E	W	B	E	W	B
05/15/03	85	86	75	ND	ND	ND
06/25/03	37	42	46	ND	ND	ND
07/01/03	50		48	ND		ND
08/13/03	45	40	38	ND	ND	ND
08/21/03	55	38	39	ND	ND	ND
09/09/03	53	31	32	ND	ND	ND
09/29/03	64	43	39	ND	ND	ND
10/14/03	55	42	41	ND	ND	ND
10/28/03	62	43	42	ND	ND	ND
11/18/03	68	54	46	ND	ND	ND
11/24/03	75	56	53	ND	ND	ND
12/17/03	63	63	60	ND	ND	ND

Note: E = effluent, W = wetland and B = sand basin.

Table F-2 (Cont.). Results of the Primary and Secondary Drinking Water Standards from the Effluent.

Secondary Drinking Water Standards									
Parameter	Aluminum			Chloride			Copper		
DWS (DL):	0.2 mg/l (0.1 mg/l)			250 mg/l (0.1 mg/l)			1.0 mg/l (0.005 mg/l)		
Date	E	W	B	E	W	B	E	W	B
05/15/03	ND	ND	ND	140	110	98	ND	ND	ND
06/25/03	ND	ND	0.14	61	64	57	ND	ND	0.0062
07/01/03	ND		ND	85		70	ND		0.0082
08/13/03	ND	0.29	0.33	66	55	49	ND	ND	0.0065
08/21/03	ND	0.57	0.13	90	54	54	ND	ND	ND
09/09/03	ND	ND	0.12	88	41	40	ND	ND	ND
09/29/03	ND	ND	ND	100	63	54	0.0110	ND	ND
10/14/03	ND	ND	ND	80	65	63	ND	ND	0.0055
10/21/03									
10/28/03	ND	ND	ND	88	66	65	ND	ND	0.0057
11/13/03									
11/18/03	ND	ND	ND	110	90	75	ND	ND	0.0056
11/24/03	ND	ND	ND	120	95	91	ND	ND	0.0079
12/03/03									
12/10/03									
12/17/03	0.11	ND	ND	100	110	140	0.0060	ND	0.0069
Secondary Drinking Water Standards									
Parameter	Fluoride			Iron			Manganese		
DWS (DL):	2.0 mg/l (0.003 mg/l)			0.3 mg/l (0.02 mg/l)			0.05 mg/l (0.01 mg/l)		
Date	E	W	B	E	W	B	E	W	B
05/15/03	0.21	2.1	2.2	0.060	0.07	0.37	ND	0.030	0.040
06/25/03	0.38	0.7	2.2	0.080	0.15	0.19	0.040	0.030	0.020
07/01/03	0.30		1.9	0.078		0.20	0.033		0.025
08/13/03	0.24	0.9	2.0	0.078	0.30	0.04	0.026	0.029	ND
08/21/03	0.30	1.0	1.8	0.089	0.23	0.25	0.076	0.021	0.030
09/09/03	0.25	0.9	2.0	0.110	0.22	0.22	0.022	0.020	0.020
09/29/03	0.23	0.9	1.7	0.100	0.11	0.76	ND	ND	0.035
10/14/03	0.32	1.1	1.4	0.042	0.12	0.16	ND	0.019	0.019
10/21/03	0.27			0.073			0.026		
10/28/03	0.32	1.2	1.5	0.099	0.10	0.02	ND	0.015	0.019
11/13/03		0.9	1.4		0.12	0.37		0.030	0.033
11/18/03	0.26	0.9	1.6	0.061	0.09	0.28	0.018	0.027	0.021
11/24/03	0.24	0.9	1.4	0.067	0.07	0.73	0.017	0.026	ND
12/03/03	0.25	0.9	1.2	0.053	0.06	0.21	0.017	0.024	ND
12/10/03	0.26	0.8	1.1	0.091	0.06	0.09	0.014	0.018	0.018
12/17/03	0.11	0.9	1.4	0.110	0.18	0.08	0.013	0.03	0.012

Note: E = effluent, W = wetland and B = sand basin.

Table F-2 (Cont.). Results of the Primary and Secondary Drinking Water Standards from the Effluent.

Secondary Drinking Water Standards									
Parameter	Silver			Sulfate			Zinc		
DWS (DL):	0.1 mg/l (0.01 mg/l)			250 mg/l (0.1 mg/l)			5 mg/l (0.005 mg/l)		
Date	E	W	B	E	W	B	E	W	B
05/15/03	ND	ND	ND	53	66	75	0.060	ND	ND
06/25/03	ND	ND	ND	50	39	37	0.020	ND	ND
07/01/03	ND		ND	46		38	0.034		ND
08/13/03	ND	ND	ND	56	21	38	0.039	ND	ND
08/21/03	ND	ND	ND	46	16	39	0.025	0.02	ND
09/09/03	ND	ND	ND	46	10	10	0.045	0.11	ND
09/29/03	ND	ND	ND	49	15	15	0.056	0.02	ND
10/14/03	ND	ND	ND	48	7.7	14	0.047	ND	ND
10/21/03									
10/28/03	ND	ND	ND	54	6.5	18	0.059	0.04	0.0077
11/13/03									
11/18/03	ND	ND	ND	49	54	23	ND	ND	ND
11/24/03	ND	ND	ND	50	23	24	0.056	ND	ND
12/03/03									
12/10/03									
12/17/03	ND	ND	ND	47	35	38	0.062	ND	ND
Secondary Drinking Water Standards									
Parameter	Color			Odor			pH		
DWS (DL):	15 PCU (5 PCU)			3 TON (1 TON)			6.5 - 8.5		
Date	E	W	B	E	W	B	E	W	B
05/15/03	10	50	25	35	35	50	7.25	7.32	
06/25/03	20	70	45	100	140	12	7.69	6.97	6.90
07/01/03	25		35	8		3	7.19		6.75
08/13/03	20	120	50	50	35	2	7.25	6.49	6.86
08/21/03	20	125	75	12	17	8	7.23	6.28	6.74
09/09/03	20	120	60	100	24	12	7.97	6.49	6.89
09/29/03	15	100	40	35	24	5.7	8.00	6.81	6.71
10/14/03	15	100	50	50	24	2	7.35	7.00	6.58
10/21/03	15	100	60	70	17	17	7.24	7.29	
10/28/03	10	100	60	17	100	4	7.76	7.30	6.82
11/13/03		100	45		35	2		6.79	6.92
11/18/03	15	100	35	200	35	3	7.45	6.95	6.79
11/24/03	15	75	40	140	70	17	7.31	7.04	6.78
12/03/03	5	80	50	50	50	6	7.17	7.03	6.86
12/10/03	10	45	45	24	70	100	7.41	7.02	7.30
12/17/03	5	70	30	35	140	3	7.24	7.14	6.75

Note: E = effluent, W = wetland and B = sand basin.

Table F-2 (Cont.). Results of the Primary and Secondary Drinking Water Standards from the Effluent.

Secondary Drinking Water Standards						
Parameter	Total Dissolved Solids			Foaming Agents		
DWS (DL):	500 mg/l (10 mg/l)			0.5 mg/l (0.05 mg/l)		
Date	E	W	B	E	W	B
05/15/03	410	490	440	ND	ND	ND
06/25/03	290	280	260	ND	ND	ND
07/01/03	440		310	ND		ND
08/13/03	280	200	200	ND	ND	ND
08/21/03	300	220	230	ND	0.22	ND
09/09/03	280	180	180	ND	0.1	ND
09/29/03	340	280	220	0.06	0.13	ND
10/14/03	290	260	240	ND	0.11	ND
10/21/03						
10/28/03	340	330	250	ND	0.17	ND
11/13/03						
11/18/03	290	310	260	ND	ND	ND
11/24/03	350	290	260	ND	ND	ND
12/03/03						
12/10/03						
12/17/03	270	350	300	ND	0.06	ND

Note: E = effluent, W = wetland and B = sand basin.

Appendix G

FULL SUITE

FULL SUITE

COOLING POND

The results of the chemical analyses of water samples collected when the cooling pond was used as a source of water as part of the Performance Standard evaluation is presented in Table G-1.

EFFLUENT

The results of the chemical analyses of water samples collected when the effluent was used as a source of water as part of the Performance Standard evaluation is presented in Table G-2.

Table G-1. Results of the Full Suite from the Cooling Pond.

Volatile Organic Contaminants									
Parameter	1,1-Dichloroethylene			1,1,1-Trichloroethane			1,1,2-Trichloroethane		
MCL (DL):	0.007 mg/l (0.3 μg/l)			0.2 mg/l (0.3 μg/l)			0.005 mg/l (0.3 μg/l)		
Date	CP	W	B	CP	W	B	CP	W	B
05/03/01	ND	ND	ND	ND	ND	ND	ND	ND	ND
09/27/01	ND	ND	ND	ND	ND	ND	ND	ND	ND
02/26/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
03/26/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
Volatile Organic Contaminants									
Parameter	1,2-Dichloroethane			1,2-Dichloropropane			1,2,4-Trichlorobenzene		
MCL (DL):	0.003 mg/l (0.2 μg/l)			0.005 mg/l (0.3 μg/l)			0.07 mg/l (0.5 μg/l)		
Date	CP	W	B	CP	W	B	CP	W	B
05/03/01	ND	ND	ND	ND	ND	ND	ND	ND	ND
09/27/01	ND	ND	ND	ND	ND	ND	ND	ND	ND
02/26/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
03/26/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
Volatile Organic Contaminants									
Parameter	Benzene			Carbon tetrachloride			cis-1,2-Dichloroethylene		
MCL (DL):	0.001 mg/l (0.5 μg/l)			0.003 mg/l (0.3 μg/l)			0.07 mg/l (0.2 μg/l)		
Date	CP	W	B	CP	W	B	CP	W	B
05/03/01	ND	ND	ND	ND	ND	ND	ND	ND	ND
09/27/01	ND	ND	ND	ND	ND	ND	ND	ND	ND
02/26/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
03/26/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
Volatile Organic Contaminants									
Parameter	Dichloromethane			Ethylbenzene			Monochlorobenzene		
MCL (DL):	0.005 mg/l (0.5 μg/l)			0.7 mg/l (0.5 μg/l)			0.1 mg/l (0.5 μg/l)		
Date	CP	W	B	CP	W	B	CP	W	B
05/03/01	ND	ND	ND	ND	ND	ND	ND	ND	ND
09/27/01	ND	ND	ND	ND	ND	ND	ND	ND	ND
02/26/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
03/26/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
Volatile Organic Contaminants									
Parameter	O-Dichlorobenzene			para-Dichlorobenzene			Styrene		
MCL (DL):	0.6 mg/l (0.5 μg/l)			0.1 mg/l (0.5 μg/l)			0.1 mg/l (0.5 μg/l)		
Date	CP	W	B	CP	W	B	CP	W	B
05/03/01	ND	ND	ND	ND	ND	ND	ND	ND	ND
09/27/01	ND	ND	ND	ND	ND	ND	ND	ND	ND
02/26/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
03/26/03	ND	ND	ND	ND	ND	ND	ND	ND	ND

Note: CP = cooling pond, W = wetland and B = sand basin.

Table G-1 (Cont.). Results of the Full Suite from the Cooling Pond.

Volatile Organic Contaminants									
Parameter	Tetrachloroethylene			Toluene			trans-1,2-Dichloroethylene		
MCL (DL):	0.003 mg/l (0.2 μg/l)			1 mg/l (0.5 μg/l)			0.1 mg/l (0.5 μg/l)		
Date	CP	W	B	CP	W	B	CP	W	B
05/03/01	ND	ND	ND	ND	ND	ND	ND	ND	ND
09/27/01	ND	ND	ND	ND	ND	ND	ND	ND	ND
02/26/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
03/26/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
Volatile Organic Contaminants									
Parameter	Trichloroethylene			Vinyl chloride			Xylenes (total)		
MCL (DL):	0.003 mg/l (0.2 μg/l)			0.001 mg/l (0.5 μg/l)			10 mg/l (0.5 μg/l)		
Date	CP	W	B	CP	W	B	CP	W	B
05/03/01	ND	ND	ND	ND	ND	ND	ND	ND	ND
09/27/01	ND	ND	ND	ND	ND	ND	ND	ND	ND
02/26/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
03/26/03	ND	ND	ND	ND	ND	ND	ND	ND	ND

Synthetic Organic Contaminants									
Parameter	2,3,7,8-TCDD (Dioxin)			2,4-D			2,4,5-TP (Silvex)		
MCL (DL):	3 X 10E-8 mg/l			0.07 mg/l (1 g/l)			0.05 mg/l (0.25 μg/l)		
Date	CP	W	B	CP	W	B	CP	W	B
05/03/01	ND	ND	ND	ND	ND	ND	ND	ND	ND
09/27/01	ND	ND	ND	ND	ND	ND	ND	ND	ND
02/26/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
03/26/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
Synthetic Organic Contaminants									
Parameter	Alachlor			Atrazine			Benzo(a)pyrene		
MCL (DL):	0.002 mg/l (0.2 μg/l)			0.003 mg/l (0.06 μg/l)			0.0002 mg/l (0.1 μg/l)		
Date	CP	W	B	CP	W	B	CP	W	B
05/03/01	ND	ND	ND	ND	ND	ND	ND	ND	ND
09/27/01	ND	ND	ND	ND	ND	ND	ND	ND	ND
02/26/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
03/26/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
Synthetic Organic Contaminants									
Parameter	Carbofuran			Chlordane			Dalapon		
MCL (DL):	0.04 mg/l (0.5 μg/l)			0.002 mg/l (0.05 μg/l)			0.2 mg/l (1 μg/l)		
Date	CP	W	B	CP	W	B	CP	W	B
05/03/01	ND	ND	ND	ND	ND	ND	ND	ND	ND
09/27/01	ND	ND	ND	ND	ND	ND	ND	ND	ND
02/26/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
03/26/03	ND	ND	ND	ND	ND	ND	ND	ND	ND

Note: CP = cooling pond, W = wetland and B = sand basin.

Table G-1 (Cont.). Results of the Full Suite from the Cooling Pond.

Synthetic Organic Contaminants									
Parameter	Di(2-ethylhexyl)adipate			Di(2-ethylehexyl) phthalate			Dibromochloropropane (DBCP)		
MCL (DL):	0.4 mg/l (0.3 µg/l)			0.006 mg/l (1 µg/l)			0.0002 mg/l (0.005 µg/l)		
Date	CP	W	B	CP	W	B	CP	W	B
05/03/01	ND	ND	ND	ND	ND	ND	ND	ND	ND
09/27/01	ND	ND	ND	ND	ND	ND	ND	ND	ND
02/26/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
03/26/03	ND	ND	ND	ND	ND	ND	ND	ND	ND

Synthetic Organic Contaminants									
Parameter	Dinoseb			Diquat			Endothall		
MCL (DL):	0.007 mg/l (0.5 µg/l)			0.02 mg/l 91 µg/l)			0.1 mg/l (20 µg/l)		
Date	CP	W	B	CP	W	B	CP	W	B
05/03/01	ND	ND	ND	ND	ND	ND	ND	ND	ND
09/27/01	ND	ND	ND	ND	ND	ND	ND	ND	ND
02/26/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
03/26/03	ND	ND	ND	ND	ND	ND	ND	ND	ND

Synthetic Organic Contaminants									
Parameter	Endrin			Ethylene dibromide (EDB)			Glyphosate		
MCL (DL):	0.002 mg/l (0.1 µg/l)			0.00002 mg/l (0.005 µg/l)			0.7 mg/l (10 µg/l)		
Date	CP	W	B	CP	W	B	CP	W	B
05/03/01	ND	ND	ND	ND	ND	ND	ND	ND	ND
09/27/01	ND	ND	ND	ND	ND	ND	ND	ND	ND
02/26/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
03/26/03	ND	ND	ND	ND	ND	ND	ND	ND	ND

Synthetic Organic Contaminants									
Parameter	Heptachlor			Heptachlor epoxide			Heptachlorobenzene		
MCL (DL):	0.0004 mg/l (0.008 µg/l)			0.0002 mg/l (0.1 µg/l)			0.001 mg/l (0.05 µg/l)		
Date	CP	W	B	CP	W	B	CP	W	B
05/03/01	ND	ND	ND	ND	ND	ND	ND	ND	ND
09/27/01	ND	ND	ND	ND	ND	ND	ND	ND	ND
02/26/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
03/26/03	ND	ND	ND	ND	ND	ND	ND	ND	ND

Synthetic Organic Contaminants									
Parameter	Heptachlorocyclo-pentadiene			Lindane			Methoxychlor		
MCL (DL):	0.05 mg/l (0.2 µg/l)			0.0002 mg/l (0.06 µg/l)			0.04 mg/l (0.05 µg/l)		
Date	CP	W	B	CP	W	B	CP	W	B
05/03/01	ND	ND	ND	ND	ND	ND	ND	ND	ND
09/27/01	ND	ND	ND	ND	ND	ND	ND	ND	ND
02/26/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
03/26/03	ND	ND	ND	ND	ND	ND	ND	ND	ND

Note: CP = cooling pond, W = wetland and B = sand basin.

Table G-1 (Cont.). Results of the Full Suite from the Cooling Pond.

Synthetic Organic Contaminants									
Parameter	Oxamyl (vydate)			Pentachlorophenol			Picloram		
MCL (DL):	0.2 mg/l (0.5 µg/l)			0.001 mg/l (0.1 µg/l)			0.5 mg/l (0.75 µg/l)		
Date	CP	W	B	CP	W	B	CP	W	B
05/03/01	ND	ND	ND	ND	ND	ND	ND	ND	ND
09/27/01	ND	ND	ND	ND	ND	ND	ND	ND	ND
02/26/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
03/26/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
Synthetic Organic Contaminants									
Parameter	Polychlorinated biphenyl (PCB)			Simazine			Toxaphene		
MCL (DL):	0.0005 mg/l			0.004 mg/l (0.07 µg/l)			0.003 mg/l (0.5 µg/l)		
Date	CP	W	B	CP	W	B	CP	W	B
05/03/01	ND	ND	ND	ND	ND	ND	ND	ND	ND
09/27/01	ND	ND	ND	ND	ND	ND	ND	ND	ND
02/26/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
03/26/03	ND	ND	ND	ND	ND	ND	ND	ND	ND

Group 1 Unregulated									
Parameter	3-Hydroxy carbofuran			Aldicarb			Aldicarb sulfone		
DL:	0.5 µg/l			0.5 µg/l			0.5 µg/l		
Date	CP	W	B	CP	W	B	CP	W	B
05/03/01	ND	ND	ND	ND	ND	ND	ND	ND	ND
09/27/01	ND	ND	ND	ND	ND	ND	ND	ND	ND
02/26/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
03/26/03	ND	ND	ND	ND	ND	ND	ND	ND	ND

Note: CP = cooling pond, W = wetland and B = sand basin.

Table G-1 (Cont.). Results of the Full Suite from the Cooling Pond.

Group 1 Unregulated									
Parameter	Aldicarb sulfoxide			Butachlor			Carbaryl		
DL:	0.5 µg/l			0.06 µg/l			0.5 µg/l		
Date	CP	W	B	CP	W	B	CP	W	B
05/03/01	ND	ND	ND	ND	ND	ND	ND	ND	ND
09/27/01	ND	ND	ND	ND	ND	ND	ND	ND	ND
02/26/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
03/26/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
Group 1 Unregulated									
Parameter	Dicamba			Dieldrin			Methomyl		
DL:	0.5 µg/l			0.5 µg/l			0.5 µg/l		
Date	CP	W	B	CP	W	B	CP	W	B
05/03/01	ND	ND	ND	ND	ND	ND	ND	ND	ND
09/27/01	ND	ND	ND	ND	ND	ND	ND	ND	ND
02/26/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
03/26/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
Group 1 Unregulated									
Parameter	Metolachlor			Metribuzin			Propachlor		
DL:	0.05 µg/l			0.1 µg/l			0.07 µg/l		
Date	CP	W	B	CP	W	B	CP	W	B
05/03/01	ND	ND	ND	ND	ND	ND	ND	ND	ND
09/27/01	ND	ND	ND	ND	ND	ND	ND	ND	ND
02/26/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
03/26/03	ND	ND	ND	ND	ND	ND	ND	ND	ND

Group 2 Unregulated									
Parameter	1,1,1,2-tetrachloroethane			1,1,2,2-tetrachloroethane			1,1-dichloroethane		
DL:	0.3 µg/l			0.3 µg/l			0.3 µg/l		
Date	CP	W	B	CP	W	B	CP	W	B
05/03/01	ND	ND	ND	ND	ND	ND	ND	ND	ND
09/27/01	ND	ND	ND	ND	ND	ND	ND	ND	ND
02/26/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
03/26/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
Group 2 Unregulated									
Parameter	1,1-dichloropropylene			1,2,3-trichloropropane			1,3-dichloropropane		
DL:	0.3 µg/l			0.3 µg/l			0.3 µg/l		
Date	CP	W	B	CP	W	B	CP	W	B
05/03/01	ND	ND	ND	ND	ND	ND	ND	ND	ND
09/27/01	ND	ND	ND	ND	ND	ND	ND	ND	ND
02/26/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
03/26/03	ND	ND	ND	ND	ND	ND	ND	ND	ND

Note: CP = cooling pond, W = wetland and B = sand basin.

Table G-1 (Cont). Results of the Full Suite from the Cooling Pond.

Group 2 Unregulated									
Parameter	1,3-dichloropropene, Total			2,2-dichloropropane			Bromobenzene		
DL:	0.3 µg/l			0.3 µg/l			0.5 µg/l		
Date	CP	W	B	CP	W	B	CP	W	B
05/03/01	ND	ND	ND	ND	ND	ND	ND	ND	ND
09/27/01	ND	ND	ND	ND	ND	ND	ND	ND	ND
02/26/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
03/26/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
Group 2 Unregulated									
Parameter	Bromodichloromethane			Bromoform			Bromomethane		
DL:	0.3 µg/l			0.5 µg/l			0.5 µg/l		
Date	CP	W	B	CP	W	B	CP	W	B
05/03/01	ND	ND	ND	ND	ND	ND	ND	ND	ND
09/27/01	ND	ND	ND	ND	ND	ND	ND	ND	ND
02/26/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
03/26/03	ND	ND	ND	ND	ND	ND	ND	ND	ND

Group 2 Unregulated									
Parameter	Chloroethane			Chloroform			Chloromethane		
DL:	0.5 µg/l			0.2 µg/l			0.5 µg/l		
Date	CP	W	B	CP	W	B	CP	W	B
05/03/01	ND	ND	ND	ND	ND	ND	ND	ND	ND
09/27/01	ND	ND	ND	ND	ND	ND	ND	ND	ND
02/26/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
03/26/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
Group 2 Unregulated									
Parameter	Dibromochloromethane			Dibromomethane			Dichlorofluoromethane		
DL:	0.5 µg/l			0.5 µg/l			0.5 µg/l		
Date	CP	W	B	CP	W	B	CP	W	B
05/03/01	ND	ND	ND	ND	ND	ND	ND	ND	ND
09/27/01	ND	ND	ND	ND	ND	ND	ND	ND	ND
02/26/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
03/26/03	ND	ND	ND	ND	ND	ND	ND	ND	ND

Group 2 Unregulated									
Parameter	m-dichlorobenzene			Methyl-tert-butyl-ether (MTBE)			o-chlorotoluene		
DL:	0.5 µg/l			0.5 µg/l			0.5 µg/l		
Date	CP	W	B	CP	W	B	CP	W	B
05/03/01	ND	ND	ND	ND	ND	ND	ND	ND	ND
09/27/01	ND	ND	ND	ND	ND	ND	ND	ND	ND
02/26/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
03/26/03	ND	ND	ND	ND	ND	ND	ND	ND	ND

Note: CP = cooling pond, W = wetland and B = sand basin.

Table G-1 (Cont.). Results of the Full Suite from the Cooling Pond.

Group 2 Unregulated									
Parameter	p-chlorotoluene			Trichlorofluoromethane			Total Trihalomethanes		
DL:	0.5 µg/l			0.5 µg/l			0.0002 mg/l		
Date	CP	W	B	CP	W	B	CP	W	B
05/03/01	ND	ND	ND	ND	ND	ND	ND	ND	ND
09/27/01	ND	ND	ND	ND	ND	ND	ND	ND	ND
02/26/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
03/26/03	ND	ND	ND	ND	ND	ND	ND	ND	ND

Group 3 Unregulated									
Parameter	2-methyl-4,6-dinitrophenol			2,4,6-trichlorophenol			2,4-dinitrotoluene		
DL:	0.8 µg/l			0.8 µg/l			3 µg/l		
Date	CP	W	B	CP	W	B	CP	W	B
05/03/01	ND	ND	ND	ND	ND	ND	ND	ND	ND
09/27/01	ND	ND	ND	ND	ND	ND	ND	ND	ND
02/26/03	*	ND	ND	ND	ND	ND	ND	ND	ND
03/26/03	*	ND	ND	ND	ND	ND	ND	ND	ND
* Not included in Southern Analytical Testing Method 625, but was included in Testing Method 604 which was used on the first 2 samples.									
Group 3 Unregulated									
Parameter	2-chlorophenol			4,6-Dinitrotoluene			Butylbenzylphthalate		
DL:	1 µg/l			1 µg/l			2 µg/l		
Date	CP	W	B	CP	W	B	CP	W	B
05/03/01	ND	ND	ND	ND	ND	ND	ND	ND	ND
09/27/01	ND	ND	ND	ND	ND	ND	ND	ND	ND
02/26/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
03/26/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
Group 3 Unregulated									
Parameter	Diethylphthalate			Dimethylphthalate			Di-n-butylphthalate		
DL:	1 µg/l			1 µg/l			2 µg/l		
Date	CP	W	B	CP	W	B	CP	W	B
05/03/01	ND	ND	ND	ND	ND	ND	ND	ND	ND
09/27/01	ND	ND	ND	ND	ND	ND	ND	ND	ND
02/26/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
03/26/03	ND	ND	ND	ND	ND	ND	ND	ND	ND

Group 3 Unregulated									
Parameter	D-n-octylphthalate			Isophorone			Phenol		
DL:	2 µg/l			2 µg/l			0.8 µg/l		
Date	CP	W	B	CP	W	B	CP	W	B
05/03/01	ND	ND	ND	ND	ND	ND	ND	ND	ND
09/27/01	ND	ND	ND	ND	ND	ND	ND	ND	ND
02/26/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
03/26/03	ND	ND	ND	ND	ND	ND	ND	ND	ND

Note: CP = cooling pond, W = wetland and B = sand basin.

Table G-2. Results of the Full Suite from the Effluent.

Volatile Organic Contaminants									
Parameter	1,1-Dichloroethylene			1,1,1-Trichloroethane			1,1,2-Trichloroethane		
MCL (DL):	0.007 mg/l (0.3 μg/l)			0.2 mg/l (0.3 μg/l)			0.005 mg/l (0.3 μg/l)		
Date	E	W	B	E	W	B	E	W	B
05/15/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
06/25/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
07/01/03	ND		ND	ND		ND	ND		ND
08/13/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
08/21/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
09/09/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
09/29/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
10/14/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
10/28/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
11/18/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
11/24/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
12/17/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
Volatile Organic Contaminants									
Parameter	1,2-Dichloroethane			1,2-Dichloropropane			1,2,4-Trichlorobenzene		
MCL (DL):	0.003 mg/l (0.2 μg/l)			0.005 mg/l (0.3 μg/l)			0.07 mg/l (0.5 μg/l)		
Date	E	W	B	E	W	B	E	W	B
05/15/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
06/25/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
07/01/03	ND		ND	ND		ND	ND		ND
08/13/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
08/21/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
09/09/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
09/29/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
10/14/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
10/28/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
11/18/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
11/24/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
12/17/03	ND	ND	ND	ND	ND	ND	ND	ND	ND

Note: E = effluent, W = wetland and B = sand basin.

Table G-2 (Cont.). Results of the Full Suite from the Effluent.

Volatile Organic Contaminants									
Parameter	Benzene			Carbon Tetrachloride			cis-1,2-Dichloroethylene		
MCL (DL):	0.001 mg/l (0.5 µg/l)			0.003 mg/l (0.3 µg/l)			0.07 mg/l (0.2 µg/l)		
Date	E	W	B	E	W	B	E	W	B
05/15/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
06/25/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
07/01/03	ND		ND	ND		ND	ND		ND
08/13/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
08/21/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
09/09/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
09/29/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
10/14/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
10/28/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
11/18/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
11/24/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
12/17/03	ND	ND	ND	ND	ND	ND	ND	ND	ND

Volatile Organic Contaminants									
Parameter	Dichloromethane			Ethylbenzene			Monochlorobenzene		
MCL (DL):	0.005 mg/l (0.5 µg/l)			0.7 mg/l (0.5 µg/l)			0.1 mg/l (0.5 µg/l)		
Date	E	W	B	E	W	B	E	W	B
05/15/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
06/25/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
07/01/03	ND		ND	ND		ND	ND		ND
08/13/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
08/21/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
09/09/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
09/29/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
10/14/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
10/28/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
11/18/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
11/24/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
12/17/03	ND	ND	ND	ND	ND	ND	ND	ND	ND

Note: E = effluent, W = wetland and B = sand basin.

Table G-2 (Cont.). Results of the Full Suite from the Effluent.

Volatile Organic Contaminants									
Parameter	o-Dichlorobenzene			para-Dichlorobenzene			Styrene		
MCL (DL):	0.6 mg/l (0.5 μg/l)			0.75 mg/l (0.5 μg/l)			0.1 mg/l (0.5 μg/l)		
Date	E	W	B	E	W	B	E	W	B
05/15/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
06/25/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
07/01/03	ND		ND	ND		ND	ND		ND
08/13/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
08/21/03	ND	ND	ND	0.00058	ND	ND	ND	ND	ND
09/09/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
09/29/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
10/14/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
10/28/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
11/18/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
11/24/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
12/17/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
Volatile Organic Contaminants									
Parameter	Tetrachloroethylene			Toluene			trans-1,2-Dichloroethylene		
MCL (DL):	0.003 mg/l (0.2 μg/l)			1 mg/l (0.5 μg/l)			0.1 mg/l (0.5 μg/l)		
Date	E	W	B	E	W	B	E	W	B
05/15/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
06/25/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
07/01/03	ND		ND	ND		ND	ND		ND
08/13/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
08/21/03	ND	ND	ND	ND	0.00092	ND	ND	ND	ND
09/09/03	ND	ND	ND	ND	0.00051	ND	ND	ND	ND
09/29/03	ND	ND	ND	ND	0.0005	ND	ND	ND	ND
10/14/03	ND	ND	ND	ND	0.0012	ND	ND	ND	ND
10/28/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
11/18/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
11/24/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
12/17/03	ND	ND	ND	ND	ND	ND	ND	ND	ND

Note: E = effluent, W = wetland and B = sand basin.

Table G-2 (Cont.). Results of the Full Suite from the Effluent.

Volatile Organic Contaminants									
Parameter	Trichloroethylene			Vinyl chloride			Xylenes (total)		
MCL (DL):	0.003 mg/l (0.2 μg/l)			0.001 mg/l (0.5 μg/l)			10 mg/l (0.5 μg/l)		
Date	E	W	B	E	W	B	E	W	B
05/15/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
06/25/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
07/01/03	ND		ND	ND		ND	ND		ND
08/13/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
08/21/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
09/09/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
09/29/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
10/14/03	ND	ND	ND	ND	ND	ND	0.002	ND	ND
10/28/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
11/18/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
11/24/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
12/17/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
Synthetic Organic Contaminants									
Parameter	2,3,7,8-TCDD (Dioxin)			2,4-D			2,4,5-TP (Silvex)		
MCL (DL):	3 x 10E^{-8} mg/l			0.07 mg/l (1 μg/l)			0.05 mg/l (0.25 μg/l)		
Date	E	W	B	E	W	B	E	W	B
05/15/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
06/25/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
07/01/03	ND		ND	ND		ND	ND		ND
08/13/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
08/21/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
09/09/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
09/29/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
10/14/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
10/28/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
11/18/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
11/24/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
12/17/03	ND	ND	ND	ND	ND	ND	ND	ND	ND

Table G-2 (Cont.). Results of the Full Suite from the Effluent.

Synthetic Organic Contaminants									
Parameter	Alachlor			Atrazine			Benzo(a)pyrene		
MCL (DL):	0.002 mg/l (0.2 μg/l)			0.003 mg/l (0.06 μg/l)			0.0002 mg/l (0.1 μg/l)		
Date	E	W	B	E	W	B	E	W	B
05/15/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
06/25/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
07/01/03	ND		ND	ND		ND	ND		ND
08/13/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
08/21/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
09/09/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
09/29/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
10/14/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
10/28/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
11/18/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
11/24/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
12/17/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
Synthetic Organic Contaminants									
Parameter	Carbofuran			Chlordane			Dalapon		
MCL (DL):	0.04 mg/l (0.5 μg/l)			0.002 mg/l (0.05 μg/l)			0.2 mg/l (1 μg/l)		
Date	E	W	B	E	W	B	E	W	B
05/15/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
06/25/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
07/01/03	ND		ND	ND		ND	ND		ND
08/13/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
08/21/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
09/09/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
09/29/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
10/14/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
10/28/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
11/18/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
11/24/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
12/17/03	ND	ND	ND	ND	ND	ND	ND	ND	ND

Note: E = effluent, W = wetland and B = sand basin.

Table G-2 (Cont.). Results of the Full Suite from the Effluent.

Synthetic Organic Contaminants									
Parameter	Di(2-ethylhexyl)adipate			Di(2-ethylehexyl)phthalate			Dibromochloropropane (DBCP)		
MCL (DL):	0.4 mg/l (0.3 µg/l)			0.006 mg/l (1 µg/l)			0.0002 mg/l (0.005 µg/l)		
Date	E	W	B	E	W	B	E	W	B
05/15/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
06/25/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
07/01/03	ND		ND	ND		ND	ND		ND
08/13/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
08/21/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
09/09/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
09/29/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
10/14/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
10/28/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
11/18/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
11/24/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
12/17/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
Synthetic Organic Contaminants									
Parameter	Dinoseb			Diquat			Endothall		
MCL (DL):	0.007 mg/l (0.5 µg/l)			0.02 mg/l(1 µg/l)			0.1 mg/l (20 µg/l)		
Date	E	W	B	E	W	B	E	W	B
05/15/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
06/25/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
07/01/03	ND		ND	ND		ND	ND		ND
08/13/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
08/21/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
09/09/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
09/29/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
10/14/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
10/28/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
11/18/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
11/24/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
12/17/03	ND	ND	ND	ND	ND	ND	ND	ND	ND

Note: E = effluent, W = wetland and B = sand basin.

Table G-2 (Cont.). Results of the Full Suite from the Effluent.

Synthetic Organic Contaminants									
Parameter	Endrin			Ethylene Dibromide (EDB)			Glyphosate		
MCL (DL):	0.002 mg/l (0.1 μg/l)			0.00002 mg/l (0.005 μg/l)			0.7 mg/l (10 μg/l)		
Date	E	W	B	E	W	B	E	W	B
05/15/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
06/25/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
07/01/03	ND		ND	ND		ND	ND		ND
08/13/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
08/21/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
09/09/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
09/29/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
10/14/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
10/28/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
11/18/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
11/24/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
12/17/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
Synthetic Organic Contaminants									
Parameter	Heptachlor			Heptachlor Epoxide			Heptachlorobenzene		
MCL (DL):	0.0004 mg/l (0.008 μg/l)			0.0002 mg/l (0.1 μg/l)			0.001 mg/l (0.05 μg/l)		
Date	E	W	B	E	W	B	E	W	B
05/15/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
06/25/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
07/01/03	ND		ND	ND		ND	ND		ND
08/13/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
08/21/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
09/09/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
09/29/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
10/14/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
10/28/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
11/18/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
11/24/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
12/17/03	ND	ND	ND	ND	ND	ND	ND	ND	ND

Note: E = effluent, W = wetland and B = sand basin.

Table G-2 (Cont.). Results of the Full Suite from the Effluent.

Synthetic Organic Contaminants									
Parameter	Heptachlorocyclopentadiene			Lindane			Methoxychlor		
MCL (DL):	0.05 mg/l (0.2 µg/l)			0.0002 mg/l (0.06 µg/l)			0.04 mg/l (0.05 µg/l)		
Date	E	W	B	E	W	B	E	W	B
05/15/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
06/25/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
07/01/03	ND		ND	ND		ND	ND		ND
08/13/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
08/21/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
09/09/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
09/29/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
10/14/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
10/28/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
11/18/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
11/24/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
12/17/03	ND	ND	ND	ND	ND	ND	ND	ND	ND

Note: E = effluent, W = wetland and B = sand basin.

Table G-2 (Cont.). Results of the Full Suite from the Effluent.

Synthetic Organic Contaminants									
Parameter	Oxamyl (vydate)			Pentachlorophenol			Picloram		
MCL (DL):	0.2 mg/l (0.5 µg/l)			0.001 mg/l (0.1 µg/l)			0.5 mg/l (0.75 µg/l)		
Date	E	W	B	E	W	B	E	W	B
05/15/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
06/25/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
07/01/03	ND		ND	ND		ND	ND		ND
08/13/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
08/21/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
09/09/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
09/29/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
10/14/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
10/28/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
11/18/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
11/24/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
12/17/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
Synthetic Organic Contaminants									
Parameter	Polychlorinated Biphenyl (PCB)			Simazine			Toxaphene		
MCL (DL):	0.0005 mg/l			0.004 mg/l (0.07 µg/l)			0.003 mg/l (0.5 µg/l)		
Date	E	W	B	E	W	B	E	W	B
05/15/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
06/25/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
07/01/03	ND		ND	ND		ND	ND		ND
08/13/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
08/21/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
09/09/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
09/29/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
10/14/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
10/28/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
11/18/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
11/24/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
12/17/03	ND	ND	ND	ND	ND	ND	ND	ND	ND

Note: E = effluent, W = wetland and B = sand basin.

Table G-2 (Cont.). Results of the Full Suite from the Effluent.

Group 1 Unregulated									
Parameter	3-Hydroxy carbofuran			Aldicarb			Aldicarb sulfone		
DL:	0.5 μg/l			0.5 μg/l			0.5 μg/l		
Date	E	W	B	E	W	B	E	W	B
05/15/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
06/25/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
07/01/03	ND		ND	ND		ND	ND		ND
08/13/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
08/21/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
09/09/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
09/29/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
10/14/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
10/28/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
11/18/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
11/24/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
12/17/03	ND	ND	ND	ND	ND	ND	ND	ND	ND

Note: E = effluent, W = wetland and B = sand basin.

Table G-2 (Cont.). Results of the Full Suite from the Effluent.

Group 1 Unregulated									
Parameter	Aldicarb sulfoxide			Butachlor			Carbaryl		
DL:	0.5 µg/l			0.06 µg/l			0.5 µg/l		
Date	E	W	B	E	W	B	E	W	B
05/15/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
06/25/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
07/01/03	ND		ND	ND		ND	ND		ND
08/13/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
08/21/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
09/09/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
09/29/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
10/14/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
10/28/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
11/18/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
11/24/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
12/17/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
Group 1 Unregulated									
Parameter	Dicamba			Dieldrin			Methomyl		
DL:	0.5 µg/l			0.5 µg/l			0.5 µg/l		
Date	E	W	B	E	W	B	E	W	B
05/15/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
06/25/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
07/01/03	ND		ND	ND		ND	ND		ND
08/13/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
08/21/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
09/09/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
09/29/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
10/14/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
10/28/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
11/18/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
11/24/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
12/17/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
Group 1 Unregulated									
Parameter	Metolachlor			Metribuzin			Propachlor		
DL:	0.05 µg/l			0.1 µg/l			0.07 µg/l		
Date	E	W	B	E	W	B	E	W	B
05/15/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
06/25/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
07/01/03	ND		ND	ND		ND	ND		ND
08/13/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
08/21/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
09/09/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
09/29/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
10/14/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
10/28/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
11/18/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
11/24/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
12/17/03	ND	ND	ND	ND	ND	ND	ND	ND	ND

Note: E = effluent, W = wetland and B = sand basin.

Table G-2 (Cont.). Results of the Full Suite from the Effluent.

Group 1 Unregulated									
Parameter	Aldicarb sulfoxide			Butachlor			Carbaryl		
DL:	0.5 µg/l			0.06 µg/l			0.5 µg/l		
Date	E	W	B	E	W	B	E	W	B
05/15/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
06/25/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
07/01/03	ND		ND	ND		ND	ND		ND
08/13/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
08/21/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
09/09/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
09/29/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
10/14/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
10/28/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
11/18/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
11/24/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
12/17/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
Group 1 Unregulated									
Parameter	Dicamba			Dieldrin			Methomyl		
DL:	0.5 µg/l			0.5 µg/l			0.5 µg/l		
Date	E	W	B	E	W	B	E	W	B
05/15/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
06/25/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
07/01/03	ND		ND	ND		ND	ND		ND
08/13/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
08/21/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
09/09/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
09/29/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
10/14/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
10/28/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
11/18/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
11/24/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
12/17/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
Group 1 Unregulated									
Parameter	Metolachlor			Metribuzin			Propachlor		
DL:	0.05 µg/l			0.1 µg/l			0.07 µg/l		
Date	E	W	B	E	W	B	E	W	B
05/15/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
06/25/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
07/01/03	ND		ND	ND		ND	ND		ND
08/13/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
08/21/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
09/09/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
09/29/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
10/14/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
10/28/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
11/18/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
11/24/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
12/17/03	ND	ND	ND	ND	ND	ND	ND	ND	ND

Note: E = effluent, W = wetland and B = sand basin.

Table G-2 (Cont.). Results of the Full Suite from the Effluent.

Group 2 Unregulated									
Parameter	1,1,1,2-tetrachloroethane			1,1,2,2-tetrachloroethane			1,1-dichloroethane		
DL:	0.3 μg/l			0.3 μg/l			0.3 μg/l		
Date	E	W	B	E	W	B	E	W	B
05/15/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
06/25/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
07/01/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
08/13/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
08/21/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
09/09/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
09/29/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
10/14/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
10/21/03									
10/28/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
11/13/03									
11/18/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
11/24/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
12/03/03									
12/10/03									
12/17/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
Group 2 Unregulated									
Parameter	1,1-dichloropropylene			1,2,3-trichloropropane			1,3-dichloropropane		
DL:	0.3 μg/l			0.3 μg/l			0.3 μg/l		
Date	E	W	B	E	W	B	E	W	B
05/15/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
06/25/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
07/01/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
08/13/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
08/21/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
09/09/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
09/29/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
10/14/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
10/21/03									
10/28/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
11/13/03									
11/18/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
11/24/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
12/03/03									
12/10/03									
12/17/03	ND	ND	ND	ND	ND	ND	ND	ND	ND

Note: E = effluent, W = wetland and B = sand basin.

Table G-2 (Cont.). Results of the Full Suite from the Effluent.

Group 2 Unregulated									
Parameter	1,3-dichloropropene, Total			2,2-dichloropropane			Bromobenzene		
DL:	0.3 µg/l			0.3 µg/l			0.5 µg/l		
Date	E	W	B	E	W	B	E	W	B
05/15/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
06/25/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
07/01/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
08/13/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
08/21/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
09/09/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
09/29/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
10/14/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
10/21/03									
10/28/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
11/13/03									
11/18/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
11/24/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
12/03/03									
12/10/03									
12/17/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
Group 2 Unregulated									
Parameter	Bromodichloromethane			Bromoform			Bromomethane		
DL:	0.3 µg/l			0.5 µg/l			0.5 µg/l		
Date	E	W	B	E	W	B	E	W	B
05/15/03	16	ND	ND	ND	ND	ND	ND	ND	ND
06/25/03	7.4	ND	ND	ND	ND	ND	ND	ND	ND
07/01/03	2.6	ND	ND	ND	ND	ND	ND	ND	ND
08/13/03	7.2	ND	ND	ND	ND	ND	ND	ND	ND
08/21/03	12	ND	ND	ND	ND	ND	ND	ND	ND
09/09/03	2	ND	ND	ND	ND	ND	ND	ND	ND
09/29/03	4.8	ND	ND	ND	ND	ND	ND	ND	ND
10/14/03	5	ND	ND	ND	ND	ND	ND	ND	ND
10/21/03	2.2	ND	ND	ND	ND	ND			
10/28/03	9.3	ND	ND	ND	ND	ND	ND	ND	ND
11/13/03	3.6	ND	ND	ND	ND	ND			
11/18/03	3.6	ND	ND	1.1	ND	ND	ND	ND	ND
11/24/03	5.7	ND	ND	ND	ND	ND	ND	ND	ND
12/03/03	15	ND	ND	ND	ND	ND			
12/10/03	13	ND	ND	ND	ND	ND			
12/17/03	9.8	ND	ND	ND	ND	ND	ND	ND	ND

Note: E = effluent, W = wetland and B = sand basin.

Table G-2 (Cont.). Results of the Full Suite from the Effluent.

Group 2 Unregulated									
Parameter	Chloroethane			Chloroform			Chloromethane		
DL:	0.5 µg/l			0.2 µg/l			0.5 µg/l		
Date	E	W	B	E	W	B	E	W	B
05/15/03	ND	ND	ND	44	ND	ND	ND	ND	ND
06/25/03	ND	ND	ND	26	5.5	ND	ND	ND	ND
07/01/03	ND		ND	11		0.83	ND		ND
08/13/03	ND	ND	ND	14	ND	ND	ND	ND	ND
08/21/03	ND	ND	ND	32	ND	ND	ND	ND	ND
09/09/03	ND	ND	ND	5.5	ND	ND	ND	ND	ND
09/29/03	ND	ND	ND	1	ND	ND	ND	ND	ND
10/14/03	ND	ND	ND	14	ND	ND	ND	ND	ND
10/21/03				8.5	ND	ND			
10/28/03	ND	ND	ND	26	ND	ND	ND	ND	ND
11/13/03				10	ND	ND			
11/18/03	ND	ND	ND	8.3	ND	ND	ND	ND	ND
11/24/03	ND	ND	ND	13	ND	0.52	ND	ND	ND
12/03/03				42	ND	ND			
12/10/03				25	ND	ND			
12/17/03	ND	ND	ND	21	ND	ND	ND	ND	ND

Group 2 Unregulated									
Parameter	Dibromochloromethane			Dibromomethane			Dichlorofluoromethane		
DL:	0.5 µg/l			0.5 µg/l			0.5 µg/l		
Date	E	W	B	E	W	B	E	W	B
05/15/03	4	ND	ND	ND	ND	ND	ND	ND	ND
06/25/03	0.88	ND	ND	ND	ND	ND	ND	ND	ND
07/01/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
08/13/03	2	ND	ND	ND	ND	ND	ND	ND	ND
08/21/03	1.7	ND	ND	ND	ND	ND	ND	ND	ND
09/09/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
09/29/03	12	ND	ND	ND	ND	ND	ND	ND	ND
10/14/03	0.94	ND	ND	ND	ND	ND	ND	ND	ND
10/21/03	ND	ND	ND						
10/28/03	1.9	ND	ND	ND	ND	ND	ND	ND	ND
11/13/03	0.73	ND	ND						
11/18/03	1	ND	ND	ND	ND	ND	ND	ND	ND
11/24/03	0.13	ND	ND	ND	ND	ND	ND	ND	ND
12/03/03	1.6	ND	ND						
12/10/03	2	ND	ND						
12/17/03	1.3	ND	ND	ND	ND	ND	ND	ND	ND

Note: E = effluent, W = wetland and B = sand basin.

Table G-2 (Cont.). Results of the Full Suite from the Effluent.

Group 2 Unregulated									
Parameter	m-dichlorobenzene			Methyl-tert-butyl-ether (MTBE)			o-chlorotoluene		
DL:	0.5 µg/l			0.5 µg/l			0.5 µg/l		
Date	E	W	B	E	W	B	E	W	B
05/15/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
06/25/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
07/01/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
08/13/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
08/21/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
09/09/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
09/29/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
10/14/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
10/21/03									
10/28/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
11/13/03									
11/18/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
11/24/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
12/03/03									
12/10/03									
12/17/03	ND	ND	ND	ND	ND	ND	ND	ND	ND

Group 2 Unregulated									
Parameter	p-chlorotoluene			Trichlorofluoromethane			Total Trihalomethanes		
DL:	0.5 µg/l			0.5 µg/l			0.0002 mg/l		
Date	E	W	B	E	W	B	E	W	B
05/15/03	ND	ND	ND	ND	ND	ND	0.064	ND	ND
06/25/03	ND	ND	ND	ND	ND	ND	0.034	ND	ND
07/01/03	ND	ND	ND	ND	ND	ND	0.014	6	0.83
08/13/03	ND	ND	ND	ND	ND	ND	0.023	ND	ND
08/21/03	ND	ND	ND	ND	ND	ND	0.046	ND	ND
09/09/03	ND	ND	ND	ND	ND	ND	0.075	ND	ND
09/29/03	ND	ND	ND	ND	ND	ND	0.018	ND	ND
10/14/03	ND	ND	ND	ND	ND	ND	0.02	ND	ND
10/21/03							0.011	ND	ND
10/28/03	ND	ND	ND	ND	ND	ND	0.037	ND	ND
11/13/03							0.014	ND	ND
11/18/03	ND	ND	ND	ND	ND	ND	0.014	ND	ND
11/24/03	ND	ND	ND	ND	ND	ND	0.02	ND	0.52
12/03/03							0.059	ND	ND
12/10/03							0.04	ND	ND
12/17/03	ND	ND	ND	ND	ND	ND	0.032	ND	ND

Note: E = effluent, W = wetland and B = sand basin.

Table G-2 (Cont.). Results of the Full Suite from the Effluent.

Group 3 Unregulated									
Parameter	2-methyl-4,6-dinitrophenol			2,4,6-trichlorophenol			2,4-dinitrotoluene		
DL:	0.8 µg/l			0.8 µg/l			3 µg/l		
Date	E	W	B	E	W	B	E	W	B
05/15/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
06/25/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
07/01/03	ND		ND	ND		ND	ND		ND
08/13/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
08/21/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
09/09/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
09/29/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
10/14/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
10/28/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
11/18/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
11/24/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
12/17/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
Group 3 Unregulated									
Parameter	2-chlorophenol			4,6-Dinitrotoluene			Butylbenzylphthalate		
DL:	1 µg/l			1 µg/l			2 µg/l		
Date	E	W	B	E	W	B	E	W	B
05/15/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
06/25/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
07/01/03	ND		ND	ND		ND	ND		ND
08/13/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
08/21/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
09/09/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
09/29/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
10/14/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
10/28/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
11/18/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
11/24/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
12/17/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
Group 3 Unregulated									
Parameter	Diethylphthalate			Dimethylphthalate			Di-n-butylphthalate		
DL:	1 µg/l			1 µg/l			2 µg/l		
Date	E	W	B	E	W	B	E	W	B
05/15/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
06/25/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
07/01/03	ND		ND	ND		ND	ND		ND
08/13/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
08/21/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
09/09/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
09/29/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
10/14/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
10/28/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
11/18/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
11/24/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
12/17/03	ND	ND	ND	ND	ND	ND	ND	ND	ND

Note: E = effluent, W = wetland and B = sand basin.

Table G-2 (Cont.). Results of the Full Suite from the Effluent.

Group 3 Unregulated									
Parameter	D-n-octylphthalate			Isophorone			Phenol		
DL:	2 µg/l			2 µg/l			0.8 µg/l		
Date	E	W	B	E	W	B	E	W	B
05/15/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
06/25/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
07/01/03	ND		ND	ND		ND	ND		ND
08/13/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
08/21/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
09/09/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
09/29/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
10/14/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
10/28/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
11/18/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
11/24/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
12/17/03	ND	ND	ND	ND	ND	ND	ND	ND	ND

Note: E = effluent, W = wetland and B = sand basin.

Appendix H

MICROORGANISMS

MICROORGANISMS

COOLING POND

The results of the total and fecal coliform bacteria analyses of water samples collected when the cooling pond was used as a source of water as part of the Performance Standard evaluation is presented in Table H-1. The results of the analyses for the presence and concentration of *Cryptosporidium* and *Giardia* in water samples collected when the cooling pond was used as a source of water as part of the Performance Standard evaluation is presented in Table H-3.

EFFLUENT

The results of the total and fecal coliform bacteria analyses of water samples collected when the effluent was used as a source of water as part of the Performance Standard evaluation is presented in Table H-2. The results of the analyses for the presence and concentration of *Cryptosporidium* and *Giardia* in water samples collected when the effluent was used as a source of water as part of the Performance Standard evaluation is presented in Table H-3.

Table H-1. Results of Microorganisms from the Cooling Pond.

Date	Fecal Coliform					Total Coliform				
	Basin	NS	SS	Wetland	CP	Basin	NS	SS	Wetland	CP
05/03/01	<2			13	0	<2			300	30
05/10/01	<2			900	30	<2			900	500
05/17/01	<2			23	2	<2			500	170
05/24/01	4			<2	<2	50			>1600	900
05/31/01	<2			2	<2	17			280	23
06/15/01	30			170	2					
06/21/01	<2			1600	<2	7			>1600	11
06/28/01	<2			300	7	300			900	170
07/05/01	11			1600	2	110			1600	23
07/19/01	<2			13	<2	7			1600	17
08/02/01	23			1600	17	80			1600	900
08/16/01	<2			110	2	2			900	70
08/29/01	<2			30	<2	4			1600	>1600
09/27/01	<2			<2	2	8			1600	13
10/30/01	<1			30	4	2			500	1600
11/14/01	<2			40	2	8			500	1600
12/04/01	13			240	170	13			300	170
09/20/02	<2			30	13	<2			>1600	240
09/27/02	4			300	80	4			>1600	170
10/03/02	2			23	2	170			500	30
10/11/02	<2			11	9	<2			1600	900
10/17/02	<2			4	4	2			500	70
10/31/02	<2			13	<2	4			1600	17
11/08/02	<2			34	2	<2			900	900
11/14/02	<2			13	<2	2			300	2
11/21/02	<2			4	36	<2			900	36
12/05/02	<2			4	34	<2			30	>1600
12/12/02	<2			240	70	<2			1600	240
12/19/02	<2			11	23	2			34	70
12/20/02										
12/26/02	<2			<2	4	<2			>1600	110
01/10/03	<2					<2				
01/20/03	<2			11		<2			900	
01/24/03	2					4				
01/29/03	<2					<2				
02/03/03	<2			14		2			300	
02/24/03	<2	<2	<2	<2		23	500	50	50	
03/03/03	<2	<2	<2	900		2	<2	50	>1600	
03/10/03	<2	<2	<2	130		4	8	2	1600	
03/17/03		<2	<2	300			4	8	1600	
03/26/03	<2	<2		17	8	8	23		500	17

Table H-2. Results of Microorganisms from the Effluent.

Date	Fecal Coliform					Total Coliform				
	Basin	NS	SS	Wetland	Eff.	Basin	NS	SS	Wetland	Eff.
04/02/03	<2	<2		13		<2	2		900	
04/11/03	<2	<2		6	<2	<2	<2		80	900
04/16/03	<2	<2		<2	2	<2	<2		130	130
04/21/03	<2	<2			P**	<2	<2			P**
04/28/03	<2	<2		22	50	<2	<2		300	50
05/08/03	<2	<2		50	90	<2	<2		>1600	>1600
05/15/03	<2	<2		13	70	<2	<2		>1600	900
05/22/03	<2	<2		>1600	22	<2	4		22	>1600
05/28/03	<2			30	170	<2			500	500
06/03/03	2	<2		170	170	13	11		1600	900
06/25/03	<2	2		>1600	130	50	50		50	240
07/01/03	<2	8			50	26	8			500
08/06/03	<2	<2		500	1600	<2	<2		>1600	>1600
08/13/03	2	<2		130	300	50	13		1600	900
08/21/03	<2	<2		80	>1600	7	7		240	>1600
08/28/03	4	2			300	170	300		>1600	>1600
09/09/03	<2	<2		8	900	30	22		900	>1600
09/24/03	<2	<2		50	110	23	30		1600	>1600
09/29/03	<2	<2		900	30	<2	<2		>1600	>1600
10/07/03	<2	<2		500	300	<2	8		500	500
10/14/03	2	4		1600	900	2	4		1600	900
10/21/03	<2	<2		300	280	<2	2		300	280
10/28/03	<2	<2		2	240	4	23		300	>1600
11/13/03	<2	<2		13	500	4	<2		500	>1600
11/17/03	<2	<2		20	<2	<2	<2		300	500
11/24/03	<2	<2		33	>1600	<2	<2		170	>1600
12/03/03	<2	<2		<2	70	<2	<2		80	220
12/10/03	<2	<2		2	>1600	22	7		80	>1600
12/17/03	<2	<2		1600	220	2	2		>1600	>1600

**P indicates that the parameter was detected and present in the lab analysis of the sample.

Table H-3. Results for Microorganisms.

Date	Filter Basin		Wetland		Cooling Pond		Effluent	
	Crypto	*Giardia*	*Crypto*	*Giardia*	*Crypto*	*Giardia*	*Crypto*	*Giardia*
04/07/03	<1.95/100 L	<1.95/100 L	5.6/100 L	5.6/100 L	<17.2/100 L	<17.2/100 L		
08/11/03	<4.96/100 L	<4.96/100 L	3.9/100 L	3.9/100 L			<1.86/100 L	9.3/100 L
09/29/03	<3.97/100 L	<3.97/100 L	7.71/100 L	7.71/100 L			<6.22/100 L	2,567/100 L
10/27/03	<1.95/100 L	<1.95/100 L	3.89/100 L	1.95/100 L			1,848/100 L	7.77/100 L
11/18/03	<0.54/100 L	<0.54/100 L	8.79/100 L	0.98/100 L			4,601/100 L	20.3/100 L
12/01/03	<0.82/100 L	<0.82/100 L	2.11/100 L	2.11/100 L			1,994/100 L	1.68/100 L

< Denotes the parameter was undetected in the lab analysis of the sample.

Appendix I

PHYSICAL PARAMETERS

PHYSICAL PARAMETERS

The results of the physical parameters (or field measurements) for pH, specific electrical conductance, and temperature from the cooling pond and effluent are presented in Tables I-1 and Table I-2, respectively. The information on the flow and electrical meter readings are presented in Tables I-3 and Table I-4, respectively.

Table I-1. Results of the pH, Specific Electrical Conductance, and Temperature from the Cooling Pond.

Physical Parameters									
Parameter	pH			Specific Electrical Conductance			Temperature		
Units:				mS			°C		
Date	CP	W	B	CP	W	B	CP	W	B
04/23/01	8.2	6.8	6.7	885	944	900	25	17.3	20.3
04/27/01	8.5	7.1	7.2	900	955	850			
05/03/01	8.37	6.99	6.9	872	938	849	26.1	22.6	23.5
05/07/01	8.61	7.47	7.49	869	912	846	26.3	23.3	24.3
05/10/01	8.83	7.12	7.24	863	923	861	27.2	22.9	23.5
05/17/01	8.39	6.81	7.3	1033	1067	993	22.8	20.1	20.3
05/24/01	8.87	6.94	7	833	943	877	30.8	25.1	25.9
05/31/01	9.05	7.03	7.15	850	963	898	33.2	25.7	26.4
06/15/01	8.59	6.64	6.81	825	716	717	33.8	26.7	27.9
06/21/01	8.22	6.29	6.26	802	599	677	33.5	27.1	27.3
06/28/01	8.31	6.69	6.77	781	653	627	32.3	26	27.3
07/05/01	8.2	6.65	6.75	782	586	608	34	26.9	28
07/19/01	8.37	6.97	6.69	781	586	569	33.2	26.7	27.8
08/02/01			6.96			529			26.3
08/16/01	8.38	6.89	6.85	775	497	493	35.4	27.9	29.3
08/29/01	8.43	6.85	6.74	763	592	548	35.6	27.1	29.5
09/27/01	8.25	6.47	6.54	733	367	387	30	25	26.6
10/11/01	8.26	6.27	6.31	701	320	372	29.5	26	25.6
10/30/01	7.99	6.53	6.25	742	665	608	25.9	20.9	21.7
11/14/01	7.79	6.97	6.91	879	900	868	22.1	19.2	19.8
12/04/01	8.44	7.55	7.24	887	938	891	24.6	20.6	21.1
09/20/02	9.29	7.18	6.92	1039	467	492	32.5	27.0	27.3
09/24/02	9.26	7.24	6.95	910	501	509	27.2	26.8	26.9
09/27/02	9.16	7.28	7.02	1005	433	560	30.6	26.1	26.5
09/30/02	9.32	7.32	7.03	1019	475	564	32.4	27.6	26.7
10/03/02	9.28	7.32	6.91	1013	475	494	31.0	26.2	26.5
10/11/02	9.26	7.13	6.93	1044	500	540	32.1	26.4	26.2
10/14/02	9.41	7.29	6.89	1024	540	541	30.9	25.9	27.3
10/17/02	9.11	7.31	6.89	995	566	566	29.4	24.0	25.5
10/18/02	9.27	7.18	6.91	990	568	557	29.1	22.8	24.3
10/21/02	9.44	7.21	6.98	1020	629	565	30.8	23.5	26.6
10/24/02	9.24	7.16	6.89	976	596	615	29.0	23.8	24.6
10/25/02	9.35	7.12	7.30	1032	569	594	31.5	25.5	25.7
10/28/02	9.46	7.25	7.00	1041	589	586	32.0	25.0	25.2
10/31/02	9.09	7.22	6.92	1003	658	605	29.8	24.5	24.9
11/01/02	9.28	7.58	6.97	994	726	593	29.1	24.2	25.5
11/04/02	9.43	7.30	7.01	1006	671	595	29.8	23.1	26.4
11/08/02	9.38	7.38	6.96	921	822	635	27.1		24.3
11/14/02	9.11	7.18	6.88	929	824	769	26.1	20.1	22.3
11/15/02	9.16	7.19	6.88	948	825	784	26.6	20.1	22.9
11/18/02	9.17	7.30	6.93	928	617	714	23.4	17.1	22.5
11/21/02	9.14	7.24	7.00	938	662	644	24.1	18.0	21.8
11/22/02	8.98	7.27	7.03	934	671	634	24.5	19.1	22.2
11/25/02	9.22	7.27	6.96	936	709	669	23.5	17.1	21.1
12/02/02				909	783	654	19.3	15.6	21.3

Note: CP = cooling pond, W = wetland and B = sand basin.

Table I-1 (Cont.). Results of the pH, Specific Electrical Conductance, and Temperature from the Cooling Pond.

Physical Parameters									
Parameter	pH			Specific Electrical Conductance			Temperature		
Units:				mS			°C		
Date	CP	W	B	CP	W	B	CP	W	B
12/05/02				907	823	781	20.1	17.0	18.1
12/06/02	9.12	7.15	6.78	911	821	709	19.3	15.8	19.0
12/12/02	9.29	7.23	6.99	885	744	636	20.1	17.4	20.5
12/19/02	8.88	6.94	6.78	886	603	560	22.4	17.1	19.2
12/26/02	8.81	6.85	6.94	799		471	20.0	14.9	18.5
01/06/03	8.78		7.25	909		491	19.5		21.2
01/08/03	8.83	7.31	7.28	909	428	498	18.6	16.6	20.4
01/10/03	8.78	6.99	7.05	906	444	507	19.8	17.4	21.3
01/13/03	8.89	7.15	7.00	893	437	468	18.8	13.4	17.4
01/20/03	8.83	7.37	7.18	864	471	472	19.6	12.2	18.3
01/24/03	8.76	7.26	7.06	859	453	437	16.3	9.9	12.9
01/27/03	8.51	7.40	7.04	889	500	480	16.2	10.9	12.8
01/29/03	8.98	6.89	6.95	886	533	472	18.9	12.6	16.2
02/03/03	8.89	7.25	6.98	877	592	477	20.0	14.0	20.0
02/10/03	8.88	6.93	7.04	861	657	594	21.3	15.8	17.3
02/12/03	8.94	7.02	6.84	867	652	639	20.6	15.6	15.8
02/14/03	9.01	7.01	6.81	869	677	552	20.2	15.5	18.4
02/17/03	8.83	7.02	6.75	875	751	665	21.4	17.0	17.2
02/19/03			6.84			627			18.2
02/21/03	8.92	7.19	6.94	872	793	718	23.7	18.6	17.7
02/24/03	8.91	7.00	6.99	863	776	623	23.2	17.8	20.0
02/26/03	9.07	7.19	6.93	869	816	746	25.2	19.0	19.7
03/03/03	8.85	7.12	6.73	868	713	644	24.1	20.3	19.3
03/10/03	8.84	7.21	6.80	840	728	619	26.7	22.9	22.1
03/12/03	9.01	7.22	6.77	845	727	702	27.6	22.6	22.6
03/17/03	9.19	7.33	6.85	841	695	679	27.0	22.8	22.4
03/24/03	8.67	7.16	6.75	847	633	677	26.6	21.1	23.1
03/26/03	9.07	7.29	6.83	800	630	592	28.2	21.7	23.3

Note: CP = cooling pond, W = wetland and B = sand basin.

Table I-2. Results of the pH, Specific Electrical Conductance, and Temperature from the Effluent.

Physical Parameters									
Parameter	pH			Specific Electrical Conductance			Temperature		
Units:				µS			°C		
Date	E	W	B	E	W	B	E	W	B
04/07/03	*7.35*	7.46	6.89	*613*	691	588	*27.2*	21.6	21.8
04/11/03	*7.09*	7.33	6.81	*631*	663	556	*24.6*	19.5	21.5
04/14/03	*7.05*	7.31	6.91	*580*	673	604	*26.8*	20.4	22.0
04/16/03	*7.02*	7.31	6.87	*692*	681	657	*26.7*	20.8	21.7
04/21/03	*7.02*	7.19	6.89	*671*	695	616	*27.9*	23.9	22.7
04/25/03	*7.36*	7.40	6.91	*655*	742	688	*28.0*	22.9	24.6
04/28/03	*7.38*	7.41	6.89	*578*	711	676	*27.5*	22.7	23.8
05/07/03	*7.48*	7.35	6.86	*676*	741	721	*30.6*	25.0	24.6
05/08/03	*7.54*	7.35	6.85	*650*	756	727	*29.5*	26.1	24.8
05/15/03	*7.25*	7.32	6.88	*673*	767	711	*30.6*	26.3	27.1
05/19/03	*7.78*	7.38	6.88	*625*	805	776	*30.1*	26.7	27.6
05/22/03	*7.57*	7.38	6.80	*564*	781	751	*30.3*	25.7	26.0
05/28/03	*7.04*	7.26	7.00	*550*	751	714	*30.1*	25.3	26.1
06/03/03	*7.44*	7.32	6.85	*557*	755	714	*30.6*	25.7	26.2
06/18/03	*8.03*	7.33	6.99	*637*	613	610	*29.5*	27.0	27.6
06/25/03	*7.69*	6.97	6.85	*416*	420	480	*30.0*	27.1	26.4
07/01/03	*7.19*		6.77	*480*		512	*30.0*		26.9
08/06/03	*7.60*	6.68	6.70	*617*	388	515	*31.4*	27.5	26.2
08/11/03	*7.44*	6.46	6.80	*423*	305	478	*28.2*	25.0	25.7
08/13/03	*7.25*	6.49	7.00	*448*	329	349	*29.7*	25.8	27.1
08/21/03	*7.23*	6.28	6.89	*478*	324	358	*29.7*	25.5	26.6
08/28/03	*7.58*	6.47	6.61	*474*	286	309	*36.1*	26.3	27.0
09/09/03	*7.97*	6.49	6.67	*482*	279	301	*30.3*	26.5	27.3
09/16/03	*7.80*	6.58	6.57	*487*	315	300	*30.0*	25.7	26.3
09/18/03	*7.93*	6.58	6.56	*528*	329	322	*30.3*	25.4	26.4
09/24/03	*8.16*	6.57	6.74	*575*	366	349	*31.3*	27.0	26.8
09/29/03	*8.00*	6.81	6.69	*507*	440	364	*28.6*	24.9	26.1
10/07/03	*8.09*	6.88	6.45	*520*	401	396	*29.5*	24.7	26.7
10/14/03	*7.35*	7.00	6.86	*496*	415	407	*29.4*	25.3	25.9
10/21/03	*7.24*	7.29	6.71	*541*	415	405	*29.2*	23.7	24.3
10/27/03	*6.97*	6.87	7.29	*634*	469	469	*29.1*	23.3	23.7
10/28/03	*7.76*	7.30	6.78	*612*	567	464	*28.2*	22.9	24.0
11/13/03	*7.25*	6.79	7.03	*672*	600	497	*27.5*	22.0	24.8
11/17/03	*7.43*	7.18	7.06	*626*	509	463	*27.2*	20.4	24.3
11/18/03	*7.45*	6.95	6.86	*570*	521	448	*27.7*	20.6	24.0
11/24/03	*7.31*	7.04	6.77	*683*	594	536	*26.5*	18.9	23.0
12/01/03	*7.46*	6.29	7.11	*804*	565	555	*23.7*	24.3	19.9
12/03/03	*7.17*	7.03	6.73	*644*	574	542	*25.2*	19.4	19.3
12/10/03	*7.41*	7.02	6.33	*604*	611	592	*23.6*	14.5	18.2
12/17/03	*7.24*	7.14	6.70	*567*	655	568	*22.4*	14.9	18.0
12/30/03	*7.22*	7.23	6.71	*617*	546	626	*24.0*	16.8	14.4

Note: E = effluent, W = wetland and B = sand basin.

Table I-3. Turbidity Concentrations.

Turbidity														
NTU														
Date	B	W	CP	E	Date	B	W	CP	E	Date	B	W	CP	E
05/07/01	0	0	35		11/18/02	0	0	0		04/21/03	1.05	2.1		1.3
05/10/01	0	0	30		11/21/02	0	0	0		04/25/03	0.78	1.47		0.92
05/17/01	0	5	25		11/22/02	0	0	0		04/28/03	0.31	1.44		1.27
05/24/01	5	0	30		11/25/02	0	0	0		05/07/03	0	1.5		0.4
05/31/01	5	5	25		12/02/02	0	0	0		05/08/03	0	1.8		1.0
06/15/01	0	5	30		12/05/02	0	0	0		05/15/03	0.4	0.1	0.0	1.7
06/21/01	0	15	20		12/06/02	0	0	0		05/19/03	4.62	2.3	4.7	1.3
06/28/01	0	5	20		12/12/02	0	0	0		05/22/03	0.13	2.0	7.3	1.0
07/05/01	0	5	20		12/19/02	0	0	0		05/28/03	0	4.6	5.4	6.6
07/19/01	5	0	20		01/06/03	0		0		06/03/03	1.48	5.8	6.1	2.2
08/16/01	0	0	20		01/08/03	0	0	0		06/18/03	1.7	4.0	7.5	1.0
08/29/01	0	0	20		01/10/03	0	0	0		06/25/03	3.97	4.4	6.3	1.3
09/27/01	5	5	20		01/13/03	0	0	0		07/01/03	1.56			1.1
10/11/01	0	5	20		01/20/03	0	0	0		08/06/03	4.59	11.1		1.7
10/30/01	0	5	20		01/24/03	0	0	0		08/11/03	85	7.0		2.5
11/14/01	0	5	20		01/27/03	0	0	50		08/13/03	3.8	6.9	9.6	1.9
09/20/02	0	0	0		01/29/03	0	0	20		08/21/03	2.3	8.6	9.0	2.7
09/24/02	0	0	0		02/03/03	0	0	30		08/28/03	2.2	2.0	11.0	4.7
09/27/02	0	0	0		02/10/03	0	0	30		09/09/03	1.7	2.2	7.5	1.5
09/30/02	0	0	0		02/12/03	0	0	30		09/16/03	9	0.8	6.3	1.7
10/03/02	0	0	0		02/14/03	0	0	30		09/18/03	0	0.2	6.9	3.8
10/11/02	0	0	0		02/17/03	0	0	30		09/24/03	2.7	1.0	7.7	1.7
10/14/02	0	0	0		02/21/03*	0	6.36	10.5		09/29/03	1.6	2.0	6.9	2.2
10/17/02	0	0	0		02/24/03	3.5	3.41	11.2		10/14/03	0.44	1.3	6.4	1.2
10/18/02	0	0	0		02/26/03	2.1	1.6	7.6		10/21/03	2.87	0.6	10.1	1.2
10/21/02	0	0	0		03/03/03	1.8	15	8.9		10/27/03	0.39	0.2	9.4	1.1
10/24/02	0	0	0		03/10/03	3.7	7.3	8.3		10/28/03	0	1.2	25.3	2.4
10/25/02	0	0	0		03/12/03	2.5	8.8	5.6		11/13/03	0.1	0.9		1.5
10/28/02	0	0	0		03/17/03		0.1	5.2		11/17/03	1.97	2.3	2.5	
10/31/02	0	0	0		03/24/03	1.3	6.2	5.3	1.7	11/18/03	36.1	1.7	20.1	1.7
11/01/02	0	0	0		03/26/03	1.6	4.16	6.0	3.3	11/24/03	1.74	2.1	11.5	2.8
11/04/02	0	0	0		04/07/03	1.85	1.7	5.1	1.88	12/01/03	413	3.4	12.1	10.3
11/08/02	0	0	0		04/11/03	1.05	1.99		2.01	12/03/03	2.39	2.2	14.3	2.2
11/14/02	0	0	0		04/14/03	1.33	1.58		1.7	12/10/03	1.31	1.2	19.7	3.3
11/15/02	0	0	0		04/16/03	1.44	2.03		1.57					

*New turbidity meter used for the following samples.

Note: CP = cooling pond, E = effluent, W = wetland and B = sand basin.

Table I-4. Flow Meter Readings.

Flow Meter Readings Total Gallons				Flow Meter Readings Total Gallons			
Date	E	W	B	Date	E	W	B
02/13/01		18,500	3,500	11/14/01		32,473,600	49,697,100
02/15/01		18,500	3,500	11/27/01		35,026,800	50,971,400
02/16/01		18,500	3,500	11/29/01		35,044,100	50,976,300
02/19/01		18,500	3,500	12/04/01		35,984,000	52,449,400
02/21/01		18,500	3,500	12/18/01		38,694,200	53,494,000
02/22/01		18,500	3,500	12/21/01		38,694,400	53,494,000
02/28/01		18,500	3,500	01/03/02		39,912,900	53,835,600
03/02/01		18,500	3,500	08/30/02			59,033,600
03/05/01		18,500	3,500	09/04/02			59,473,700
03/07/01		447,900	3,500	09/05/02			59,737,600
03/08/01		447,900	3,500	09/09/02			60,584,700
03/12/01		447,900	3,500	09/12/02			61,189,700
03/13/01		447,900	3,500	09/19/02			63,419,100
03/14/01		447,900	3,500	09/24/02			64,630,300
03/16/01		447,900	172,700	09/27/02			65,546,500
04/19/01		1,901,600	416,400	09/30/02			66,533,500
04/20/01		2,127,500	606,500	10/03/02			67,371,800
04/23/01		2,851,000	1,204,900	10/10/02			69,547,600
04/27/01		3,733,100	1,939,200	10/11/02			69,750,300
05/03/01		3,999,900	3,052,900	10/14/02			70,837,800
05/07/01		3,999,900	3,858,100	10/17/02			71,114,500
05/10/01		3,999,900	4,438,200	10/18/02			71,444,700
05/17/01		3,999,901	5,620,300	10/21/02			72,651,300
05/24/01		5,520,000	7,039,800	10/24/02			73,545,100
05/31/01		7,052,700	8,575,200	10/25/02			73,835,200
06/11/01		7,951,300	9,558,500	10/28/02			74,534,600
06/14/01		8,340,400	9,994,100	10/31/02			75,145,900
06/15/01		8,529,900	10,179,200	11/01/02			75,385,400
06/21/01		9,059,500	11,314,600	11/04/02			76,208,000
06/25/01		9,953,500	11,335,000	11/08/02			76,900,100
06/28/01		10,576,700	11,994,300	11/11/02			77,750,300
07/03/01		11,662,200	13,152,800	11/14/02			77,788,100
07/05/01		12,058,200	13,504,500	11/15/02		43,999,900	77,855,900
07/09/01		12,926,100	14,475,700	11/18/02		44,575,900	78,640,000
07/12/01		13,099,900	15,319,200	11/19/02			78,898,600
07/19/01		13,100,200	17,263,100	11/20/02			79,132,400
08/02/01		13,999,900	20,884,800	11/21/02		44,845,700	79,324,700
08/14/01		16,472,300	23,862,600	11/22/02		44,846,900	79,605,900
08/16/01		16,835,900	24,349,900	11/25/02			80,402,800
08/29/01		19,452,500	28,092,700	12/02/02		45,888,000	82,159,800
09/06/01		20,724,000	30,227,700	12/05/02			82,513,600
09/13/01		20,724,600	30,230,400	12/06/02		46,374,800	82,831,700
09/18/01		21,730,000	31,256,000	12/12/02			84,630,400
09/27/01		23,466,000	33,326,100	12/19/02			86,050,000
10/03/01		24,655,200	35,249,100	12/26/02			87,098,600
10/11/01		26,135,900	38,033,200	01/03/03			88,215,400
10/30/01		29,479,400	43,836,200	01/06/03			88,728,000

Note: E = effluent, W = wetland and B = sand basin.

Table I-4 (Cont.). Flow Meter Readings.

Flow Meter Readings				Flow Meter Readings			
Total Gallons				Total Gallons			
Date	E	W	B	Date	E	W	B
01/08/03			88,739,700	05/08/03		59,175,200	112,033,700
01/10/03			89,065,800	05/15/03		60,043,500	113,531,500
01/13/03			89,599,900	05/19/03		60,242,900	113,973,500
01/20/03		49,012,100	90,933,800	05/22/03		60,607,600	114,584,600
01/24/03		49,347,800	91,660,300	05/28/03		61,382,600	115,977,400
01/27/03		49,930,800	92,219,400	06/03/03		62,203,400	117,426,100
01/29/03		49,974,200	92,585,500	06/18/03		63,677,900	120,304,500
02/03/03		49,975,200	93,233,000	06/25/03			121,771,100
02/04/03			93,580,100	07/01/03			123,119,400
02/07/03			93,907,600	08/06/03			125,037,600
02/10/03			94,399,400	08/11/03			125,834,100
02/12/03			94,737,600	08/13/03		64,800,800	126,217,000
02/14/03			95,071,100	08/21/03		65,608,700	127,796,200
02/17/03		51,852,200	95,633,400	08/28/03	4,200		129,079,900
02/19/03			96,016,000	09/09/03		68,459,900	132,065,200
02/21/03		52,276,000	96,359,500	09/16/03	1,095,000	69,215,800	133,779,400
02/24/03		52,276,400	96,549,900	09/18/03	1,539,500	69,531,300	134,247,000
02/26/03		52,528,700	96,868,400	09/24/03	2,940,600	70,127,900	135,619,000
03/03/03			97,715,900	09/29/03	4,227,500	70,325,200	136,840,500
03/10/03		53,495,100	99,073,000	10/07/03	6,563,600	70,675,000	137,882,800
03/12/03		53,811,200	99,473,100	10/14/03	8,834,700	71,001,100	138,698,800
03/17/03			100,513,300	10/21/03	11,104,000	71,459,300	140,104,200
03/24/03			102,066,000	10/27/03	12,968,300	72,467,800	141,410,100
03/26/03		55,588,500	102,541,400	10/28/03	13,328,100	72,485,900	141,611,500
04/02/03		55,966,400	104,257,300	11/13/03	15,813,400	72,541,800	142,372,300
04/07/03		56,314,600	105,421,600	11/17/03	17,354,200	72,796,900	143,091,700
04/11/03		56,477,100	106,401,100	11/18/03	17,697,900	72,799,300	143,237,400
04/14/03		56,759,800	107,166,300	11/24/03	19,856,200	73,188,500	144,112,200
04/16/03		56,982,400	107,676,300	12/01/03	22,317,300	74,779,200	145,361,300
04/21/03		57,403,300	109,056,600	12/03/03	23,177,900	73,896,900	145,698,700
04/25/03		57,934,300	109,773,900	12/10/03	26,222,500	75,019,900	147,033,800
04/28/03		58,259,300	110,362,100	12/17/03	29,282,200	75,337,900	148,392,300
05/07/03		59,042,500	111,824,500	12/30/03		76,849,900	151,071,800

Note: E = effluent, W = wetland and B = sand basin.

Table I-5. Electric Meter Readings.

Electric Readings kw/hr				Electric Readings kw/hr				Electric Readings kw/hr			
Date:	E	W	B	Date:	E	W	B	Date:	E	W	B
03/12/01		265	1	10/11/02		32,002	32,002	03/10/03		40,463	46,328
03/13/01		377	1	10/14/02		32,989	32,410	03/12/03		40,657	46,546
03/14/01			110	10/17/02		33,866	32,504	03/17/03		40,933	47,080
03/16/01		502	110	10/18/02		34,165	32,601	03/24/03		33,999	47,828
04/19/01				10/21/02		34,222	32,934	03/26/02		41,741	48,047
04/20/01			1,437	10/24/02		31,905	33,190	04/02/03		41,972	48,812
04/23/01		771	1,841	10/25/02		32,310	33,312	04/07/03		42,185	49,331
04/27/01		2,344		10/28/02		33,176	33,619	04/11/03		42,287	49,753
05/03/01		3,102	1,955	10/31/02		33,992	33,891	04/14/03	712	42,462	50,076
05/07/01		3,624	2,446	11/01/02		33,999	33,993	04/16/03		42,601	50,282
05/10/01		3,991	2,791	11/04/02		34,007	34,325	04/21/03	1,570	42,864	50,804
05/17/01		4,712	3,468	11/07/02		34,232	34,533	04/25/03	2,055	43,194	51,173
05/24/01		5,603	4,287	11/08/02		34,233	34,633	04/28/03	2,416	43,396	51,486
05/31/01		6,484	5,109	11/11/02		34,566	34,958	05/07/03	3,492	43,887	52,169
06/11/01		7,008	5,599	11/14/02		34,584	34,983	05/08/03	3,615	43,971	52,264
06/14/01		7,234	5,822	11/15/02		34,608	35,014	05/15/03		44,517	52,924
06/15/01		7,345	5,923	11/18/02		34,951	35,359	05/19/03	4,923	44,643	53,244
06/21/01		7,653	6,543	11/21/02		35,110	35,635	05/22/03	5,271	44,873	53,519
06/25/01		8,170	6,554	11/22/02		35,111	35,746	05/28/03	5,388	45,357	54,109
06/28/01		8,531	6,890	11/25/02		35,389	36,063	06/03/03	6,116	45,892	54,700
07/05/01		9,396	7,667	12/02/02		35,729	36,768	06/18/03	7,481	46,912	55,886
07/19/01		11,101	9,166	12/05/02		36,017	37,051	06/25/03	8,178	47,285	56,440
08/02/01		12,773	10,578	12/06/02		36,017	37,164	07/01/03	8,881	47,666	56,935
08/14/01		14,253	11,867	12/12/02		36,306	37,784	08/06/03		47,775	57,803
08/16/01		14,469	12,059	12/19/02		36,522	38,497	08/11/03	8,883	47,787	58,241
08/29/01		16,029	13,464	12/26/02		33,999	39,165	08/13/03	8,884	47,976	58,438
09/06/01		16,791		01/03/03		36,834	39,936	08/21/03	8,889	48,469	59,193
09/13/01		16,791	14,159	01/06/03		37,060	40,259	08/28/03	8,890	49,104	59,803
09/18/01		17,395	14,743	01/08/03		33,999	40,267	09/09/03	8,890	50,196	60,969
09/27/01		18,458	15,827	01/10/03		33,999	40,466	09/16/03	8,893	50,774	61,629
10/03/01		19,193	16,622	01/13/03		37,383	40,773	09/18/03	9,574	50,962	61,815
10/11/01		20,102	17,675	01/20/03		37,691	41,480	09/24/03	9,807	51,335	62,397
10/30/01		22,108	19,768	01/24/03		37,899	41,874	09/29/03	10,504	51,438	62,868
11/14/01		23,906	21,593	01/27/03		38,255	42,194	10/07/03		51,646	63,321
11/27/01		25,454		01/29/03		38,282	42,406	10/14/03	11,968	51,851	63,736
12/04/01		26,034	22,546	02/03/03		38,282	42,839	10/21/03	12,729	52,191	64,392
12/18/01		27,689	22,931	02/04/03		33,999	43,062	10/27/03	13,512	52,787	64,939
07/24/02		32,825	24,337	02/07/03		33,999	43,262	10/28/03	14,160	52,798	65,021
08/02/02		34,945	25,146	02/10/03		38,876	43,566	11/13/03	14,288	53,275	65,375
08/23/02		36,806		02/12/03		39,103	43,779	11/17/03	15,147	53,425	65,761
08/30/02		37,794		02/14/03		39,104	43,983	11/18/03	15,627	53,428	65,841
09/09/02		39,960	26,424	02/17/03		39,445	44,305	11/24/03	15,726	53,679	66,367
09/12/02		40,250	27,708	02/19/03		33,999	44,513	12/01/03	16,401	54,043	67,011
09/24/02		43,790	28,632	02/21/03		39,709	44,737	12/03/03	17,601	54,121	67,185
09/27/02		43,796	29,467	02/24/03		39,710	44,855	12/10/03	17,286	54,793	67,841
09/30/02		43,799		02/26/03		39,866	45,055	12/17/03	18,056	54,981	68,498
10/03/02		44,618	30,188	03/03/03		40,078	45,577	12/30/03	18,813	55,920	69,722

Note: E = effluent, W = wetland and B = sand basin.

Table I-6. Data Collection Results from North and South Stand Pipes in Filter Basin.

Date	North Stand Pipe					South Stand Pipe				
	Field Parameters					Field Parameters				
	pH	Cond	Temp	Iron	Turb	pH	Cond	Temp	Iron	Turb
2/21/2003	6.80	743	17.0	0.0	5.5	6.63	689	18.0	3.0	11.30
2/24/2003	7.00	742	18.5	0.2	1.4	7.06	715	20.9	3.0	13.00
2/26/2003	6.93	766	19.9	0.1	2.0	6.99	710	20.2	4.0	26.00
3/3/2003	7.00	695	19.1	0.2	1.5	7.12	713	20.3	0.2	5.00
3/10/2003	6.76	627	22.0	0.1	1.0	6.82	608	22.2	5.0	40.00
3/12/2003	6.79	718	22.4	0.1	2.9	6.83	676	22.1	2.5	75.00
3/17/2003	6.83	690	22.5	0.1	0.7	6.87	667	22.3	5.0	23.00
3/24/2003	6.76	676	23.0	0.3	1.6	6.70	667	22.6	5.0	40.00
3/26/2003	6.93	588	23.8	0.4	2.9					
4/2/2003	6.97	604		0.5	4.4					
4/7/2003	6.88	603	21.6	0.8	5.4					
4/11/2003	6.97	575	21.3	2.0	1.1					
4/14/2003	6.93	618	21.9	1.5	8.9	6.93	607	22.0	10.0	120.00
4/16/2003	6.92	665	21.7	1.5	10.1	6.88	660	21.5	10.0	88.90
4/21/2003	6.95	627	22.5	1.0	6.3	6.91	606	22.6	4.0	20.00
4/25/2003	6.92	688	23.6	0.8	5.0	6.92	689	23.3	6.0	46.60
*4/28/2003	6.94	667	23.3		1.1	6.94	682	23.2		31.50
5/7/2003	6.93	748	24.4	0.8	6.9	6.90	729	24.3	2.0	15.00
5/8/2003	6.91	722	24.9	0.4	1.3	6.87	717	25.0	2.0	7.89
5/15/2003	7.13	740	27.5	0.4	0.9	7.13	746	26.8	4.0	25.10
5/19/2003	6.85	784	27.2	0.2	0.3	6.83	772	26.8	0.8	1.13
5/22/2003	6.93	752	26.7	0.2	0.0	6.91	729	26.5	2.0	11.00
6/3/2003	6.91	717	26.0	0.2	0.4	6.86	708	26.2	1.5	5.06
6/18/2003	6.98	605	28.1	0.2	1.1	6.96	605	27.7	1.5	3.60
6/25/2003	6.90	445	26.9	0.3	1.7	6.88	527	26.6	3.0	2.11
7/1/2003	6.75	455	28.0	0.2	0.7	6.74	585	26.5	4.0	1.37
8/6/2003	6.46	517	28.3	4.5	4.7	7.22	535	26.9	7.0	8.28
8/11/2003	6.82	440	26.2	2.0	7.0	6.90	507	25.7	3.0	1.90
8/13/2003	6.86	349	27.2	0.1	4.4	6.79	352	26.8	1.0	7.60
8/21/2003	6.74	326	26.6	0.3	1.9	6.58	339	26.3	>10	280.00
8/28/2003	6.72	312	27.0	0.3	2.5	6.64	306	26.7	>10	2.70
9/9/2003	6.89	296	27.1	0.3	1.0	6.80	308	27.2	8.0	40.00
9/16/2003	6.47	301	26.5	0.4	0.0	6.64	300	26.4	3.0	18.00
9/18/2003	6.57	316	26.3	0.3	0.0	6.65	315	26.4	>10	70.00
9/24/2003	6.63	356	26.8	1.5	7.1	6.74	336	27.0	>10	70.00
9/29/2003	6.71	358	25.6	1.5	8.6	6.80	366	26.3	4.0	21.00
10/7/2003	6.55	405	26.0	0.3	-	6.50	392	26.3	2.0	-
10/14/2003	6.88	399	25.9	0.6	1.9	6.70	398	26.1	2.0	6.18
10/21/2003	6.65	411	24.0	0.3	2.6	6.56	411	24.6	1.0	3.77
10/27/2003	6.85	467	23.3	0.3	0.9	6.88	471	24.1	1.0	6.72
10/28/2003	6.82	466	24.2	1.0	5.0	6.82	460	25.0	>10	45.70
11/13/2003	6.92	505	24.3	0.8	1.7	6.94	489	25.1		3.43
11/17/2003	7.06	477	23.6		2.1					
11/18/2003	6.79	472	24.6		9.2	6.96	426	25.2		13.70
11/24/2003	6.78	565	22.5		1.7	6.87	530	23.7		4.89
12/1/2003	6.95	552	20.4		154.0	7.31	554	21.8		284.00
12/3/2003	6.86	559	19.1	0.3	2.4	6.80	559	18.4	4.0	43.70
12/10/2003	7.30	589	15.9		1.4	7.05	598	15.2		23.30
12/17/2003	6.75	569	16.8	1.0		6.78	557	19.3	10.0	
*New iron kit used starting 4-28-2003										

Note: E = effluent, W = wetland and B = sand basin.

Appendix J

SCHREUDER, INC. BARREL TEST

SCHREUDER, INC. BARREL TEST

BACKGROUND

Sand filtration methods have been used for centuries in the treatment of water to remove microorganisms from water, a well as other health hazards. When the sand bed is submerged in a shallow layer of nutrient-rich water for a prolonged period, the result is formation of a “Schmutzdecke” or a layer of biofilm (or biologically active mat) that consists of photosynthetic microorganisms and heterotrophic bacteria.

The goal of this research was: 1) determine and document the design for the development of a functional Schmutzdecke for the barrel test project and 2) determine how the developing Schmutzdecke affects the resulting hydraulic conductivity and removal of microorganisms.

This research is supplemental to the Pilot Study done at Hines Energy Complex funded by the Florida Institute of Phosphate Research (FIPR) and the Southwest Florida Water Management District. In that study, SI designed a water treatment procedure using cooling pond and later treated wastewater effluent that first ran through an 8000-foot linear wetland, then was pumped to a sand tailing filter basin for final treatment. Those same sand tailings were used in this study. The final water of the previous FIPR study was tested for numerous components, including Total Coliform. The results were sometimes somewhat puzzling and inconsistent (i.e., sometimes completely removed, other times leaking through), leading to this barrel test. It was hypothesized that the reason for this breakthrough is the lack of an established biofilm resulting from water applied to the filter basin surface intermittently to insure that groundwater levels were being kept below land surface in a range of 6 to 8 feet for virus removal.

PROJECT DESIGN

The design of this project utilized three 60-gallon HDPE barrels filled with unwashed sand tailings from the HEC filter basin. The tailing sands have a permeability (k) of roughly 1.2 x 10^{-3} cm/sec and are 92% sand, 7% silt and clay and 1% gravel (previously determined for the aforementioned FIPR study by Driggers Engineering). Figure J-1 below details the execution of the experiment, while Figure J-2 details the inner working and design and Figure J-3 shows a view with detail of where the flow measurements and water quality samples were taken.

For the duration of the test, the three barrels remained as identical as possible, with minor flow fluctuations. After roughly a month, an overflow as installed roughly 2 inches above the sand surface to allow for a constant water level without daily tweaking of the system. With 17 days remaining in the sample period, a plant light was added to the top of each barrel roughly 8 inches from the barrel lip in order to encourage the biofilm development by adding light. To avoid coliform contamination from the outside air, a piece of a cotton swab with a few drops of bleach were placed in the tops of the manometer tubes periodically to ensure there was no direct contact and still allow the tube to breathe.

SAMPLING PERIOD AND SETUP

Literature sources determined that a few to several weeks will be necessary to develop a working Schmutzdecke depending on: 1) availability of sunlight for photosynthesis, 2) water quality of influent and 3) permeability of the underlying medium. The biofilm requires a full saturation or standing water state to mature into a functioning layer for microorganism removal. To accommodate this constraint, the surface of the water was kept saturated at all times, preferably with ~2 inches of standing water on top. The period for sampling was 8 weeks. After the first two weeks of the project throughout which flow measurements were taken on sample days, it was decided that daily flow readings would be taken to track the hydraulic conductivity changes as the biofilm formed.

FLOW CALCULATIONS METHODOLOGY

Flow (Q) readings and change of head (dh) readings were taken to track the change in hydraulic conductivity throughout the experiment. Operating under the Darcy's Law equation for flow (Eq. 1), where *Q* is the flow in cubic feet per day, *K* is the hydraulic conductivity in ft per day (ft/day), *dh* is the change in head in ft and *dz* (usually referred to as *dl*) is change in vertical distance in feet and *A* is the cross-sectional area (of the barrel in this case) in ft^2. Stated plainly, *dh* is the distance from the pressure head to the standing water. To calculate *dh*, one measured from the top of the pressure head (roughly where the water in the manometer reads at resting state with ball valve open to atmospheric pressure) to the top of the barrel, then subtracts the distance to the top of the water. Stated plainly, *dz* is the length of travel through the medium. To calculate *dz*, the measurement was taken from the top of the sand to the top of the gravel. This measurement was constant throughout the sampling program.

$$Q = -K\frac{dh}{dz}A \qquad \text{Equation 1.}$$

This formula was then rearranged to Equation 2, to utilize the measurable quantities of the experiment, *Q*, *dh, dz* and *A*. The result was *K* in ft/day.

$$K = \frac{Q}{\frac{dh}{dz}A} \qquad \text{Equation 2.}$$

WATER QUALITY SAMPLING METHODOLOGY

For each sampling event, the inflow value at the end of the distribution pipe was sampled as well as all three outflow valves. The water coming in was assumed to be the same for any inflow as they are receiving water from the same source (Curiosity Creek). These were sampled according to the schedule described below. To summarize, NO_3^-, NO_2, $SO_4^=$, TSS, TOC, TP and NH_3 were sampled once a week, every other week in the first month to establish a baseline for the experiment and determine the quality of the incoming water (resulting in two samples). Total & Fecal Coliform colony forming unit (cfu) analyses will be done twice a week for the duration of the study. Field sampling was done for Temperature, pH, Specific Electrical Conductance, Turbidity and Iron (Iron was dropped after two consecutive samples with none in the Barrels and only one almost unremarkable occurrence in the Inflow). Color was sampled at three distinct dates during the program as well, separated by a couple weeks each time.

OPERATIONAL DESCRIPTION OF COMPONENTS IN BARREL TEST

Pump in Protective Screened Barrel – Small ¼ hp submersible pump was suspended in the center of 60 gallon plastic barrel that was been drilled and screened to allow free movement of water and prevent the pump from sucking up debris. The barrel was fixed in position by 3 boards of pressure treated 2” x 4” x 8’ lumber that were driven into the ground around the edges of the barrel 120° apart from the center. Also, a concrete block was inserted into the bottom of the barrel to assist submersion during installation. A grounded electrical power cable and water reservoir supply hose left the top of the barrel to their respective components on the shore.

Water Reservoir Set on Concrete Blocks – This received the water from the pump, and was elevated enough to siphon the water down to the distribution system through a barrel water supply hose. The pump pushed water faster than was needed into the reservoir, so a water reservoir overflow return hose delivers the extra water from the reservoir back to Curiosity Creek.

Water Distribution Pipe – The water moved from the Water Reservoir through the barrel water supply hose to a master water supply ball valve then into the ¾” PVC Water Distribution Pipe. The Distribution Pipe had a water sample gate valve on one end and then three gate valves, each suspended over a barrel to control flow into the barrel.

The Barrels – Each of the three barrels were assembled identically. Barrel A was 1.5” shorter then barrel B & C. The water flowed from the gate valve above the barrel onto the sand inside the barrel. Then, the water percolated through the sand until it reaches the gravel layer surrounding the screened PVC at the bottom of the barrel. The head pressure then forced the water out through the ½” PVC pipe.

The Manometer – The manometer measured the pressure head at the outflow. It was used to accurately determine the pressure head gradient (*dh*).

To Sample Water Coming Out of a Barrel – With the master water supply ball valve open and the system running, the ball valve was closed on the ½” pipe leaving the barrel and then the Sample Faucet was opened, while making sure to leave some water in the manometer tube at all times to avoid contamination of outside air into the sample.

The barrel-filtered water flowed out of the barrel at the bottom and spilled onto the ground. That water was then absorbed into the soil and (through natural underground conveyance) eventually the filtered water returned to Curiosity Creek. The overflow water (i.e., any water above ~2 inches over the sand in the barrels) simply flowed out the back of the barrels through the hose and returned to Curiosity Creek naturally as well.

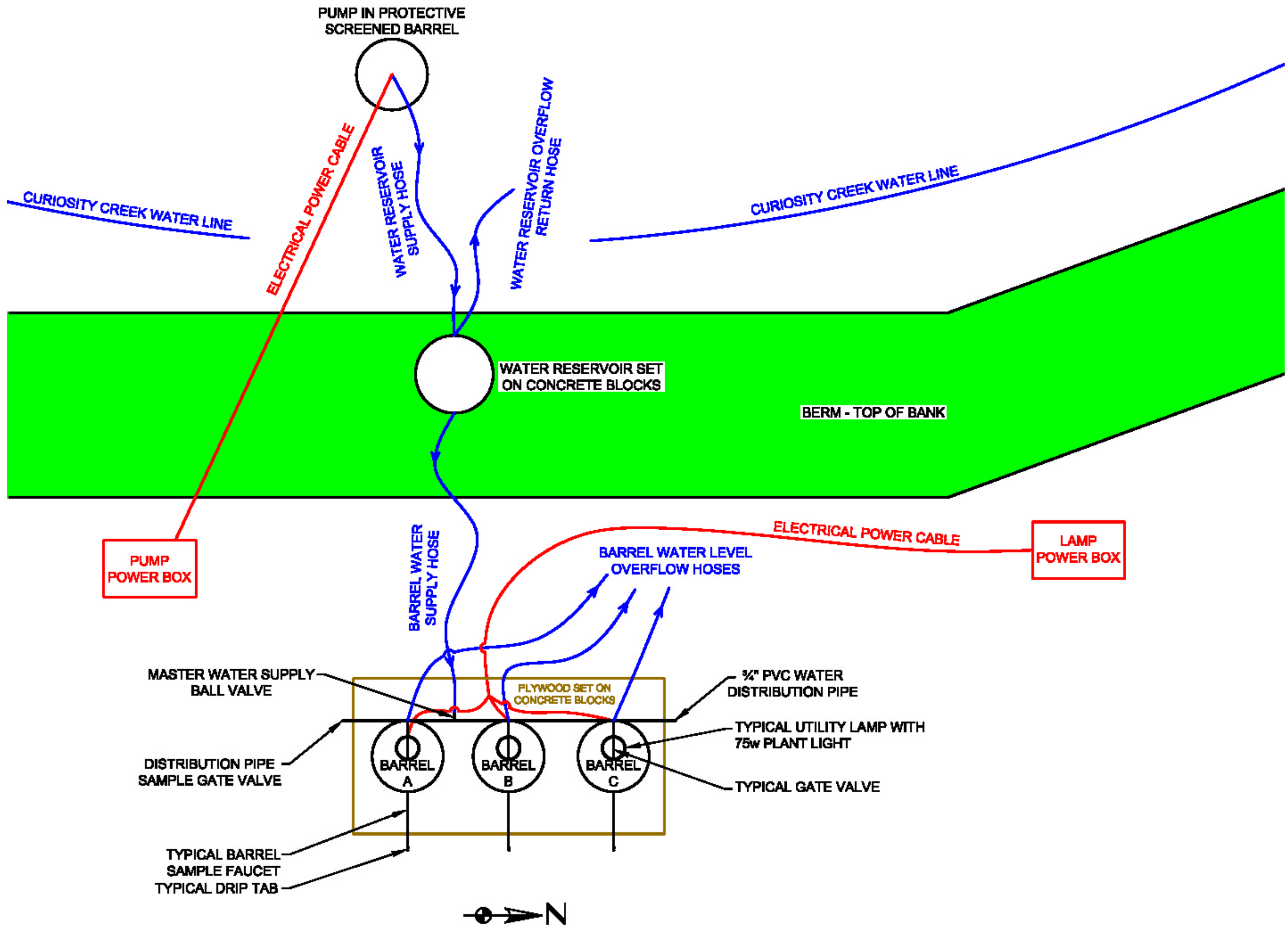


Figure J-1. Top View of Barrel Test Set-Up.

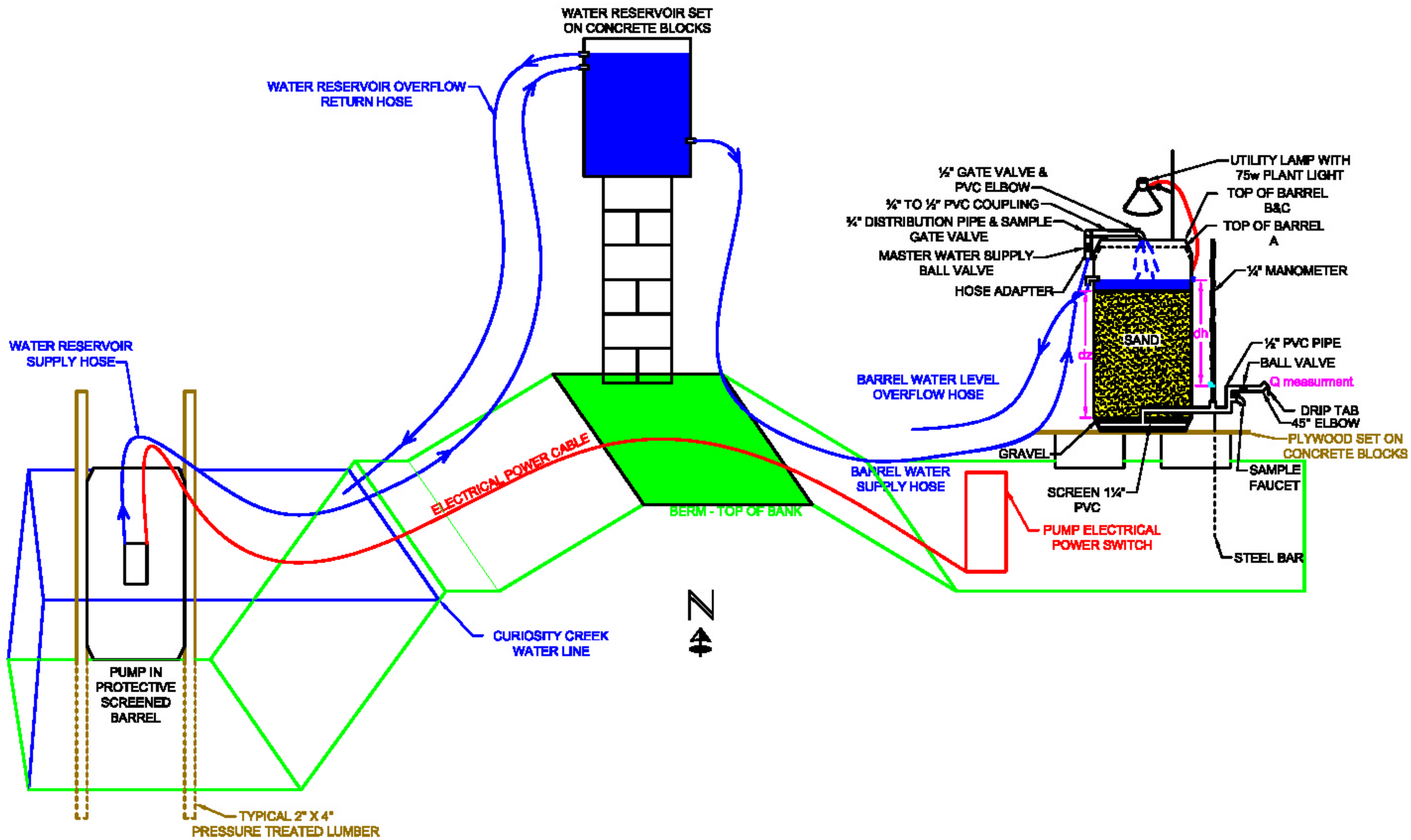


Figure J-2. Side View of Barrel Test Set-Up.

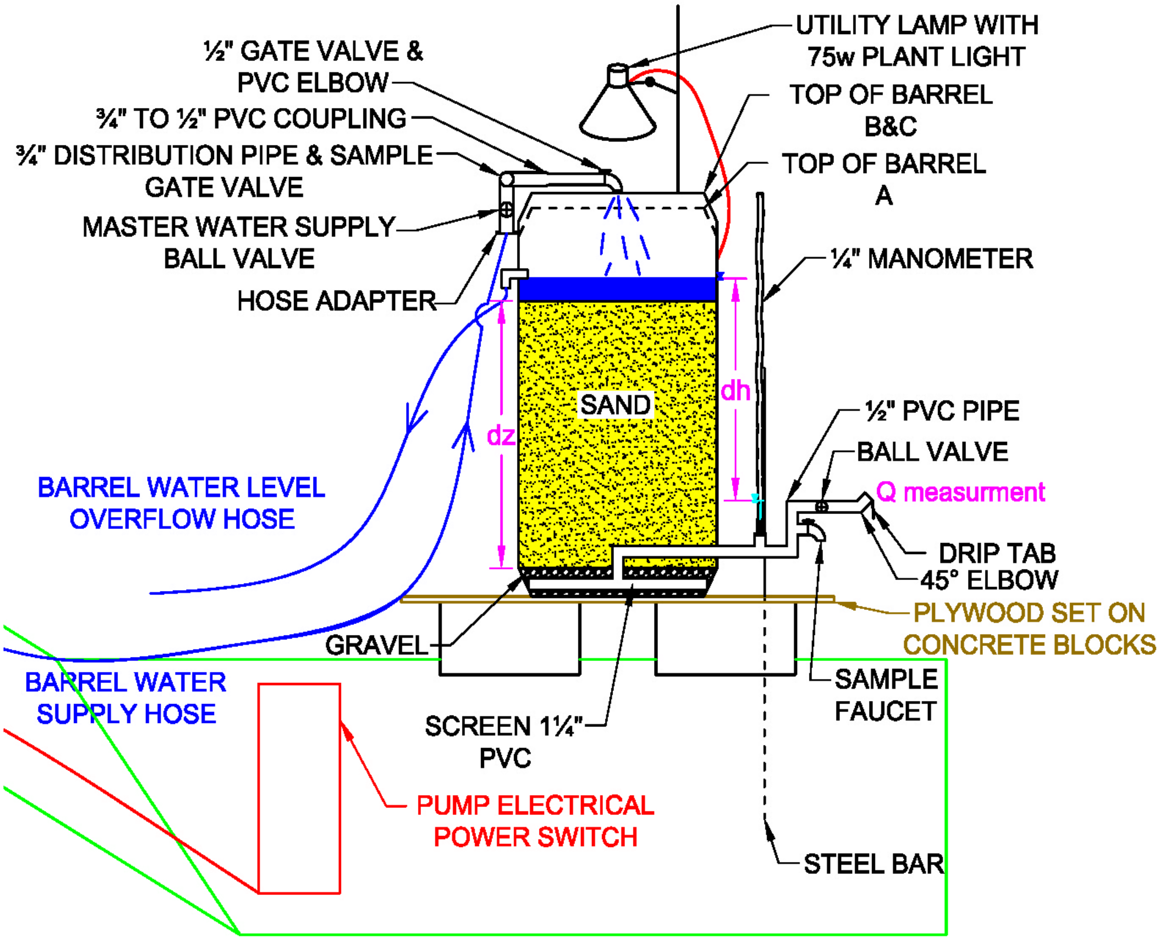


Figure J-3. Close-Up View of Barrel Test Set-Up.

SAMPLING PROCEDURE

Microorganisms

To sample for microorganisms, the sampler wore two sets of gloves and the sample port was first rinsed thoroughly with alcohol. Brass sample ports at the inflow and all three barrels allowed each sample port to be burned with a propane torch before sampling occurred. The burning of the sample port was to rid the port of any contamination from wind, rain, and other wildlife, such as spiders and bugs that in any way may contaminate the sample port. A small amount of water was passed through the sample port. The port was burned. More water was allowed to pass through the port to cool it back to its original temperature. SI staff used SemperGuard Nitrile PF industrial latex gloves to avoid contamination on the bottles. The first set of gloves was removed to prevent any microorganism contamination from the cleaning and burning of the sample port step. The bottles were filled without rinsing due to acids placed in the bottles by the lab.

Once all the bottles were filled, they were placed in a cooler filled with ice. The lab picked up all samples on the day of sampling due to specific hold times that different analyses required. The total/fecal Coliform count was performed from 100mL bottles containing a sodium thiosulfate tablet from the lab.

TP, NO_3^-, NO_2, $SO_4^=$, TSS, TOC, NH_3 and Color

To sample for the rest of the constituents, the sampler wore one set of gloves. No burning or rinsing with alcohol was required. A small amount of water was passed through the sample port. The bottles were filled without rinsing due to acids placed in some of the bottles by the lab as preservatives. The NO_3^-, NO_2, $SO_4^=$ and TSS were analyzed from a 1L bottle, while NH_3 and TP were analyzed from a 500 mL bottle (containing <2mL sulfuric acid) and TOC from a 250mL amber glass bottle (containing <2mL sulfuric acid). Color was analyzed from a 250ml bottle with no preservative. Once all the bottles were filled, they were placed in a cooler filled with ice. The lab picked up all samples on the day of sampling due to specific hold times that different analyses required.

FIELD PARAMETERS

In addition to collecting water samples for lab analysis, the hydrologic technician measured and recorded the water quality field parameters. Physical parameters included pH, specific electrical conductivity, temperature, iron, and turbidity. (Note: After the first two samples yielded no iron in any barrel and minimal iron–less than 0.2 mg/L; at the inflow, iron monitoring was dropped from the field sampling). SI used a YSI instrument, Model 63, to measure pH, specific electrical conductance, temperature and salinity. A CHEMets Kit was used to measure iron concentration, which can measure between 0-1 ppm and 1-10 ppm, and SI used a LaMotte 2020 Turbidity meter to measure the turbidity concentration. Flow and *dh* readings were also collected from each of the barrels. It was decided once the project began to take all the YSI parameters twice (morning and afternoon) every day when flow and *dh* measurements were taken.

RESULTS

For the first two "full suite" samplings (NO_3^-, NO_2, $SO_4^=$, TSS, TOC, TP and NH_3), the results are presented in Table J-1. Again, the main purpose of these samplings was to determine inflow water quality and nutrients that might be available to aid in the formation of the biofilm. As shown below, the water was low in nutrients and even gained sulfate, phosphorous, ammonia and nitrate slightly on occasion (which is speculated to simply be the washing out of what was in the sands prior to the test or even at times is such a small difference it is well within the error of the lab). Total Organic Carbon was consistently reduced in all barrels and nitrite was very low or non-detect. Of note is that there were never detected amounts of Total Suspended Solids in any of the barrels or Inflow.

Table J-1. Results of Two "Full Suite" Sampling Events (4-5-2004 & 4-19-2004).

Full Suite Sampling		TP (mg/L)	NO_2 (mg/L)	NO_3^- (mg/L)	NH_3 (mg/L)	$SO_4^=$ (mg/L)	TSS (mg/L)	TOC (mg/L)
Inflow	4/5/2004	0.09	0.02	ND	0.11	17	ND	6.3
Barrel A	4/5/2004	0.11	0.03	ND	0.17	18	ND	5.5
Barrel B	4/5/2004	0.12	0.03	0.05	0.16	18	ND	5.2
Barrel C	4/5/2004	0.12	0.03	0.05	0.11	18	ND	5.3
Inflow	4/19/2004	0.11	ND	ND	0.23	6.7	ND	7.9
Barrel A	4/19/2004	0.12	ND	ND	0.23	17	ND	5.3
Barrel B	4/19/2004	0.11	ND	0.37	0.25	18	ND	5.4
Barrel C	4/19/2004	0.12	ND	0.12	0.24	17	ND	6.1

The color results are consistently reduced between Inflow and all the Barrels, as illustrated in Figure J-4. The last sample date (5-24-04) was the only date not exhibiting this quality, but the Inflow color was so low (5, at the method detection limit) that speculation is that no reduction could be detected other than in Barrel A, which was non-detect. The secondary drinking water standard for color is 15 PCU, so no barrel was ever in exceedance.

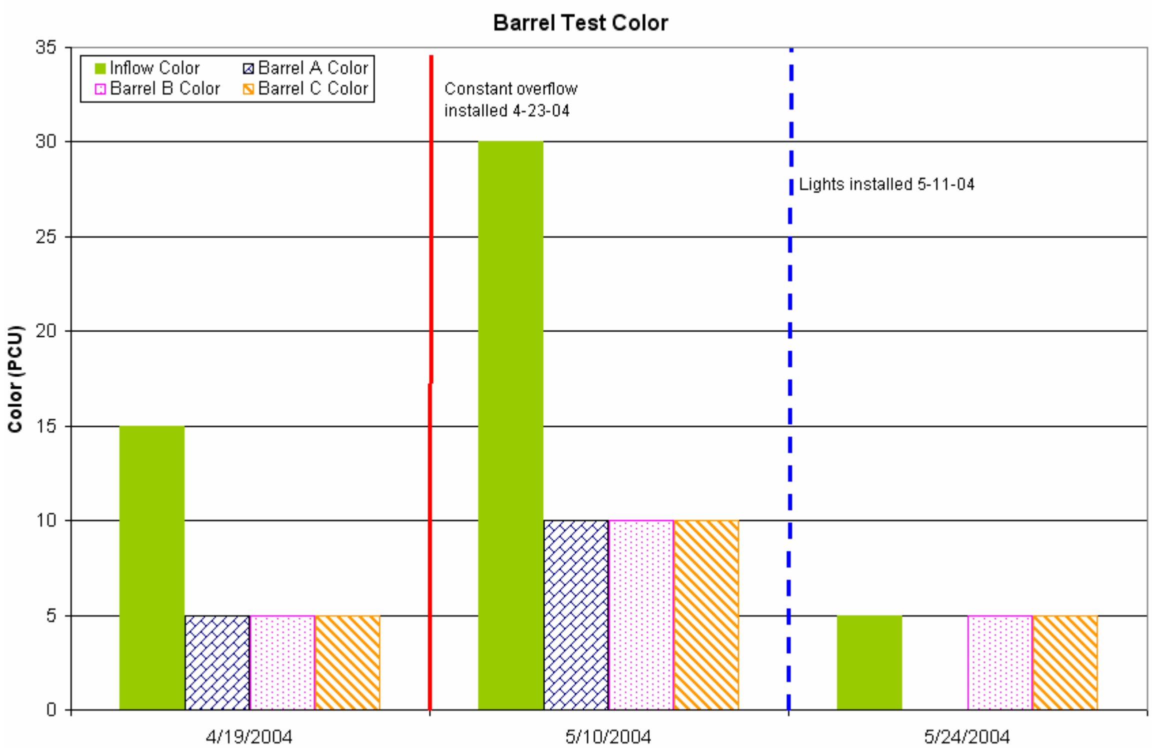


Figure J-4. Results of Color Sampling Events.

Hydraulic conductivity leveled out at between ~ 0.5 to 2.5 ft/day for all barrels once the lights were added (5-11-04) and an obvious biofilm developed, as shown below in Figure J-5.

The removal efficiency for Total Coliform was calculated by dividing the Inflow TC measurement by the individual Barrel TC measurements. These results are show in Figures J-6 through J-10. One recent result (5-20-2004) for Barrel B show a non-detect for Total Coliform (down to the 1 cfu detection level) with the qualification that there was confluent (overlapping) growth on the straight sample analysis plate, unable to be determined as Coliform or not. In the dilution plates of analyses that followed, there was no Total Coliform detected (dilutions were 10 ml of sample to 100 ml of water and 1 ml of sample to 100 ml of water). Two later sampling result (5-24-2004 & 6-30-2004) show Barrel A with a Total Coliform count of 3, which is below the DWS. The most recent (and final) sampling (5-27-2004) shows greatly increased TC in the Inflow and resulting lesser removal in the barrels. The results of the efficiency (Figure 7) agree with literature values that you can expect a 1 to 3 log removal from a mature biofilm, Barrels B & C generally around 2 log removal and Barrel A closer to 3 in most recent sample. Also, of note is the fact that while there have been various non-detects or 0 measurements for Fecal Coliform in different barrels throughout the study, Barrel A has been consistently non-detect or 1 for the last 3 readings (5-24-2004, 5-27-004 & 6-30-2004) despite wide variance in the Inflow quantity (see Figure J-11). Barrel C has also been reading 1 for Fecal Coliform two of the last 3 readings.

Pictures of the barrels follow in Figures J-12 through J-14.

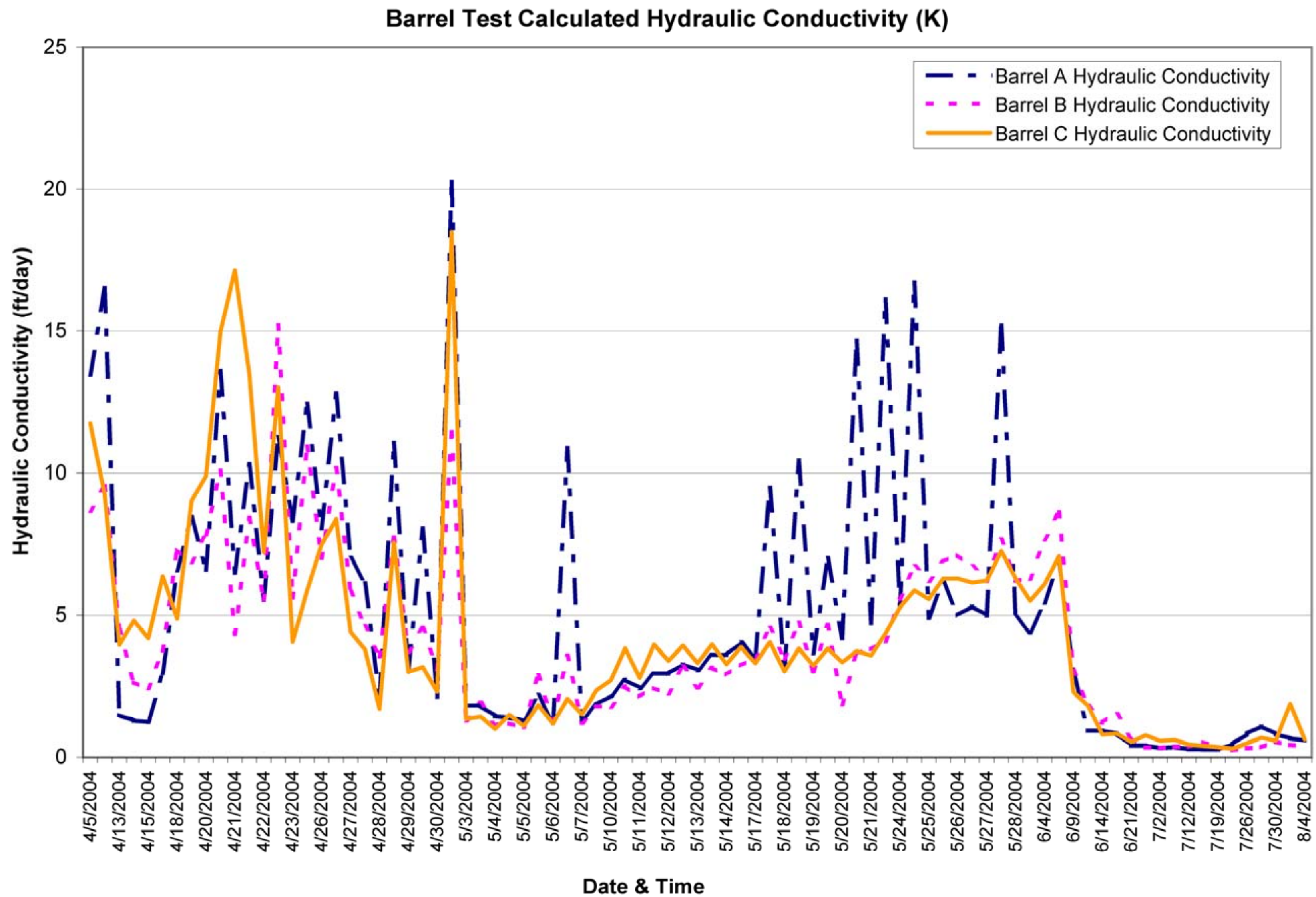


Figure J-5. Barrel Test Calculated Hydraulic Conductivity.

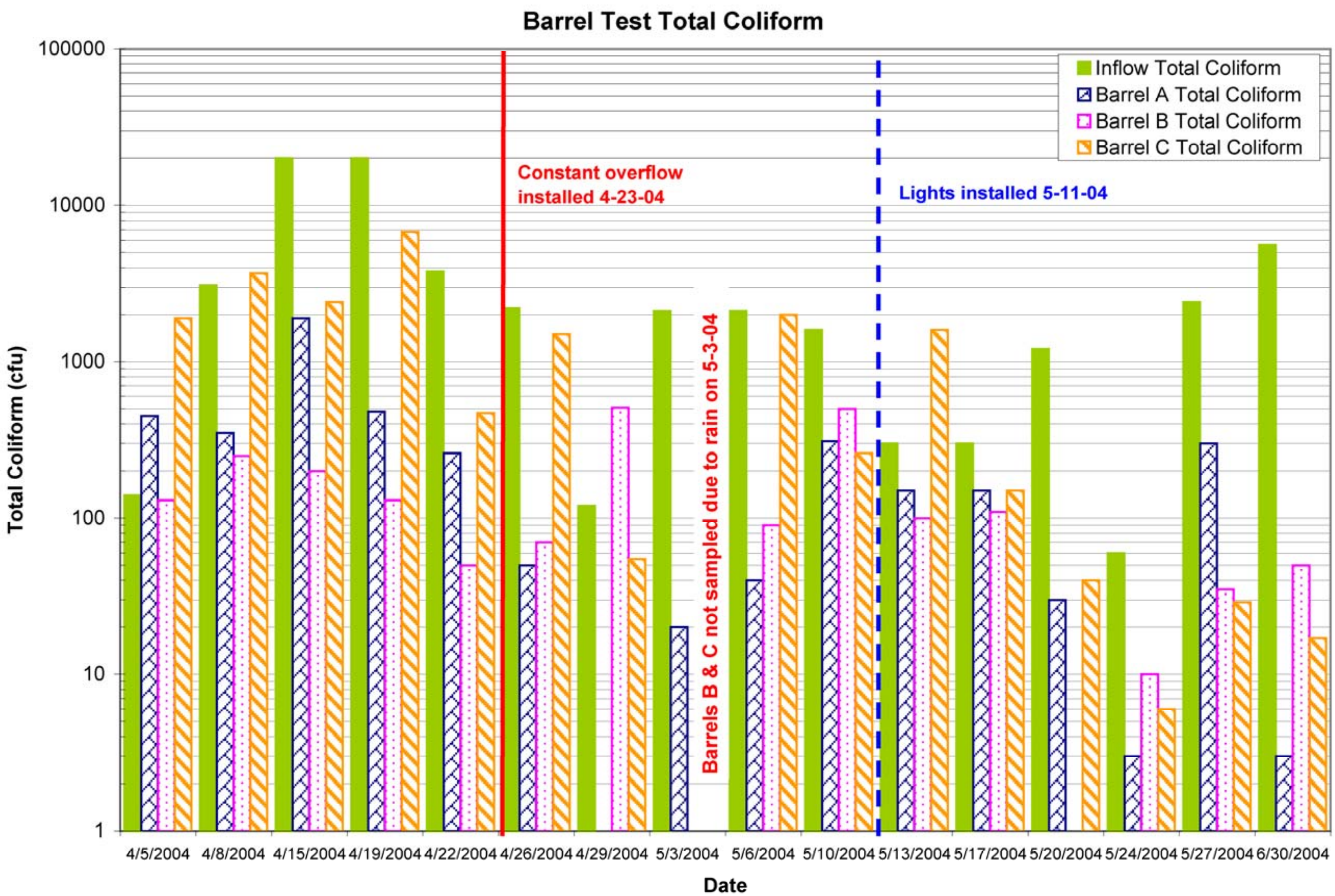


Figure J-6. Barrel Test Total Coliform Results.

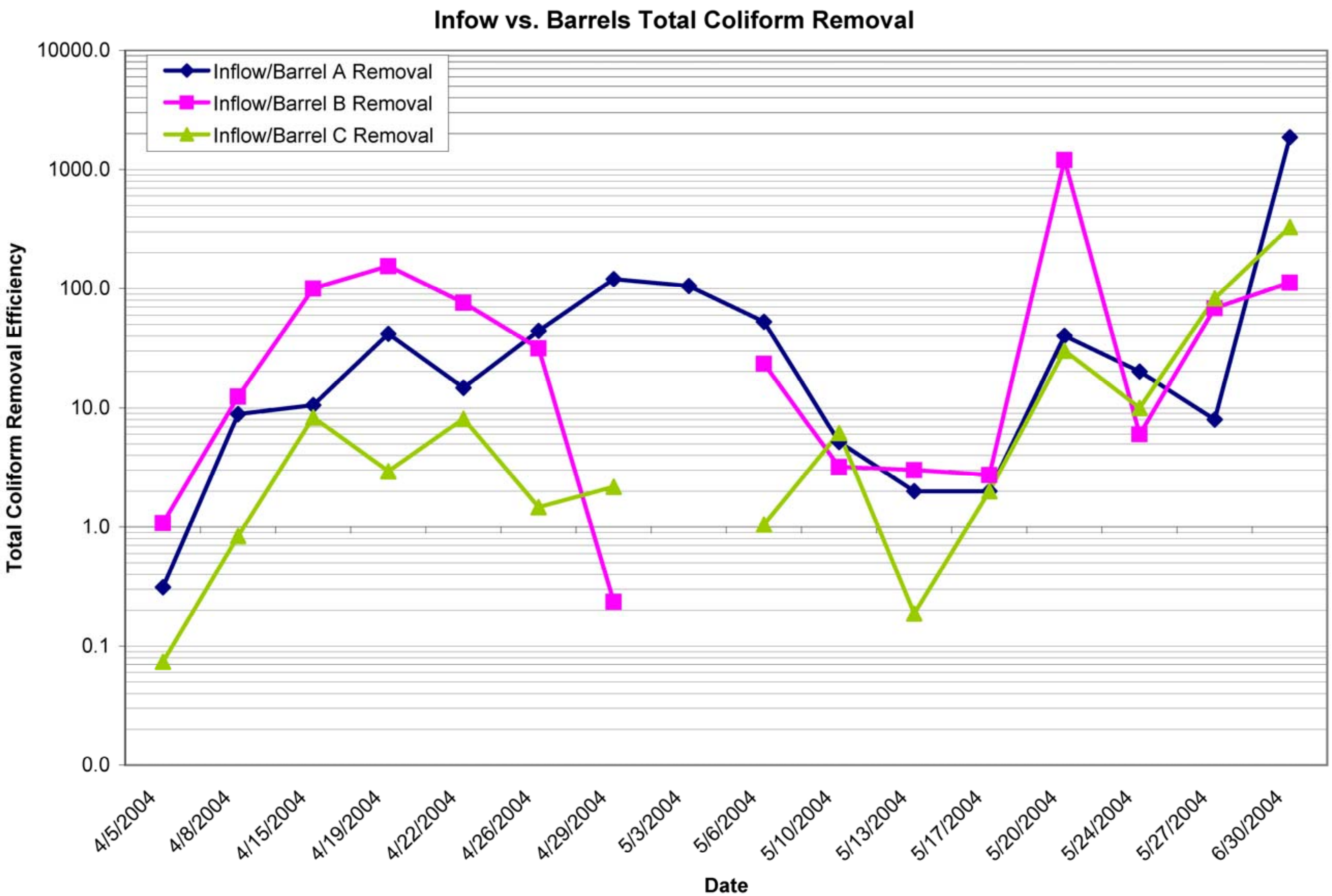


Figure J-7. Removal Efficiency of Inflow with All Barrels.

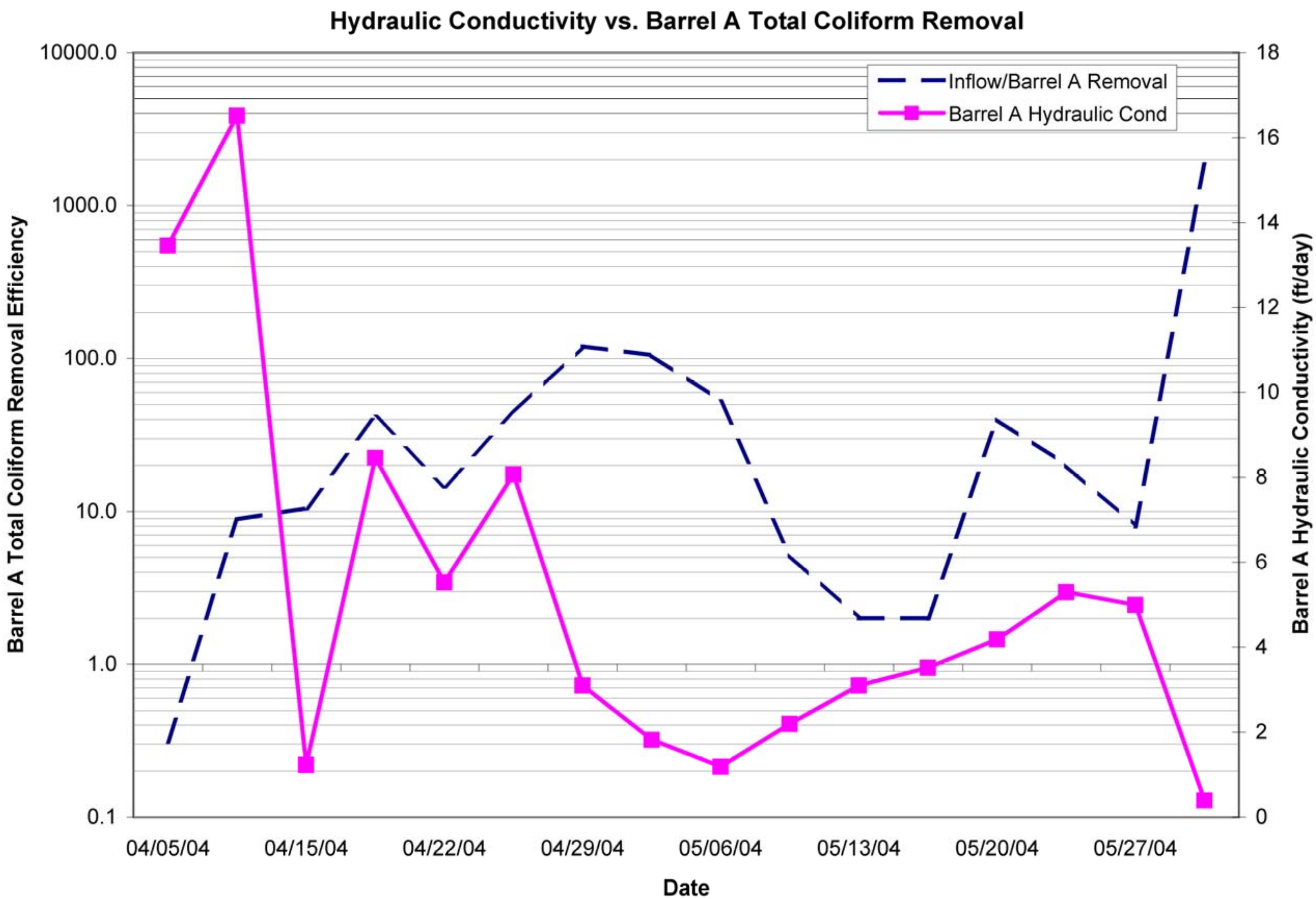


Figure J-8. Removal Efficiency of Barrel A with Hydraulic Conductivity.

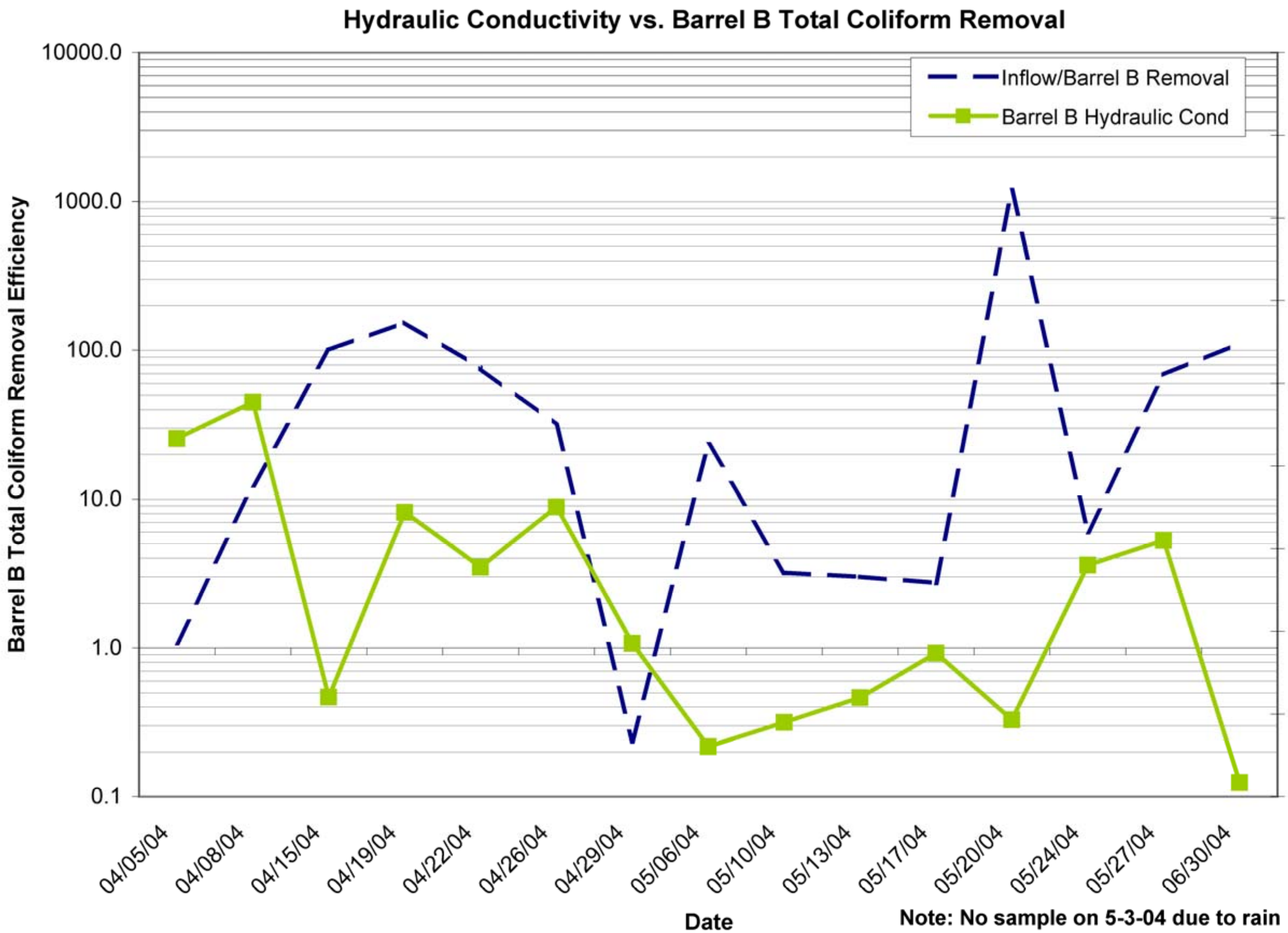


Figure J-9. Removal Efficiency of Barrel B with Hydraulic Conductivity.

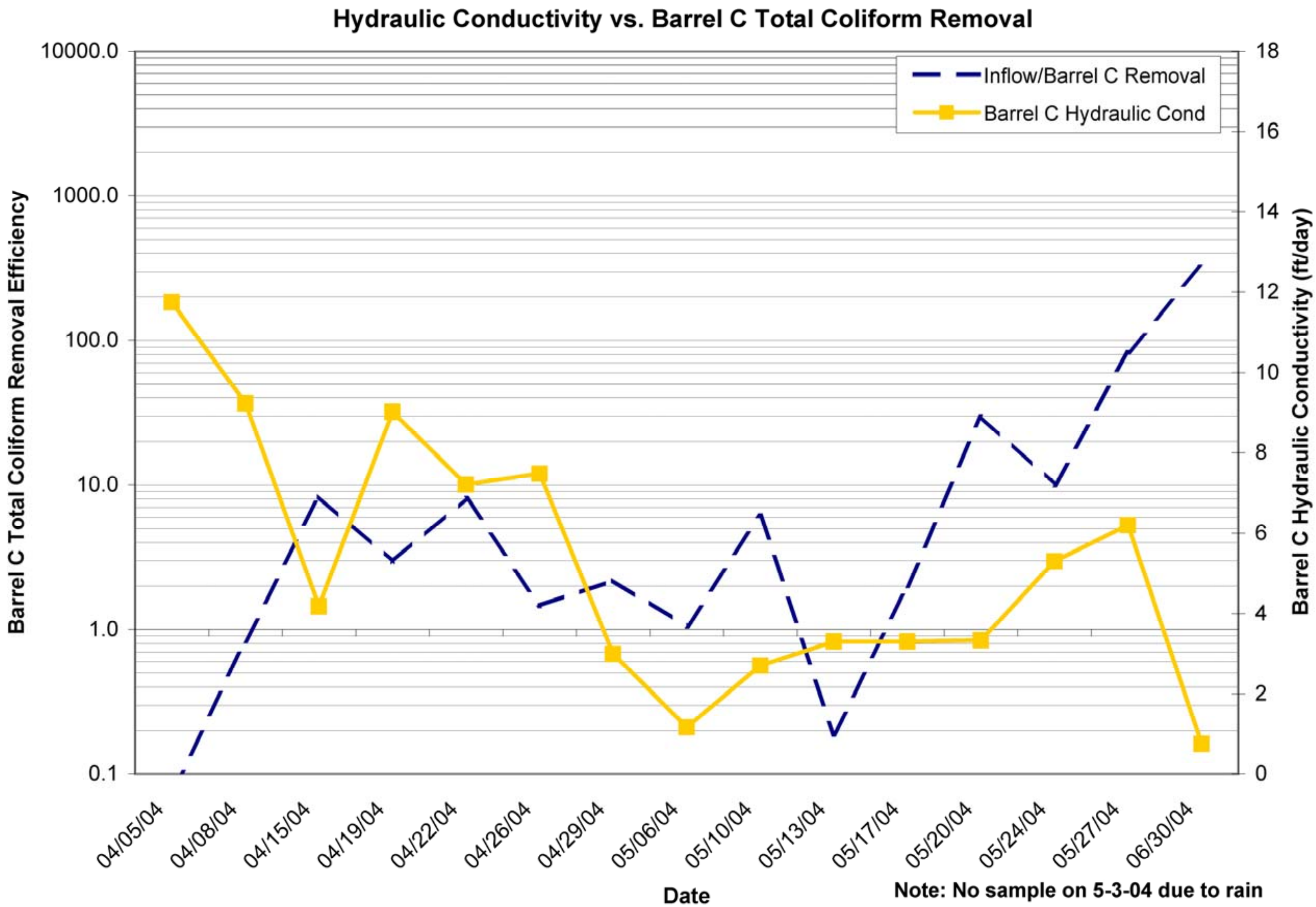


Figure J-10. Removal Efficiency of Barrel C with Hydraulic Conductivity.

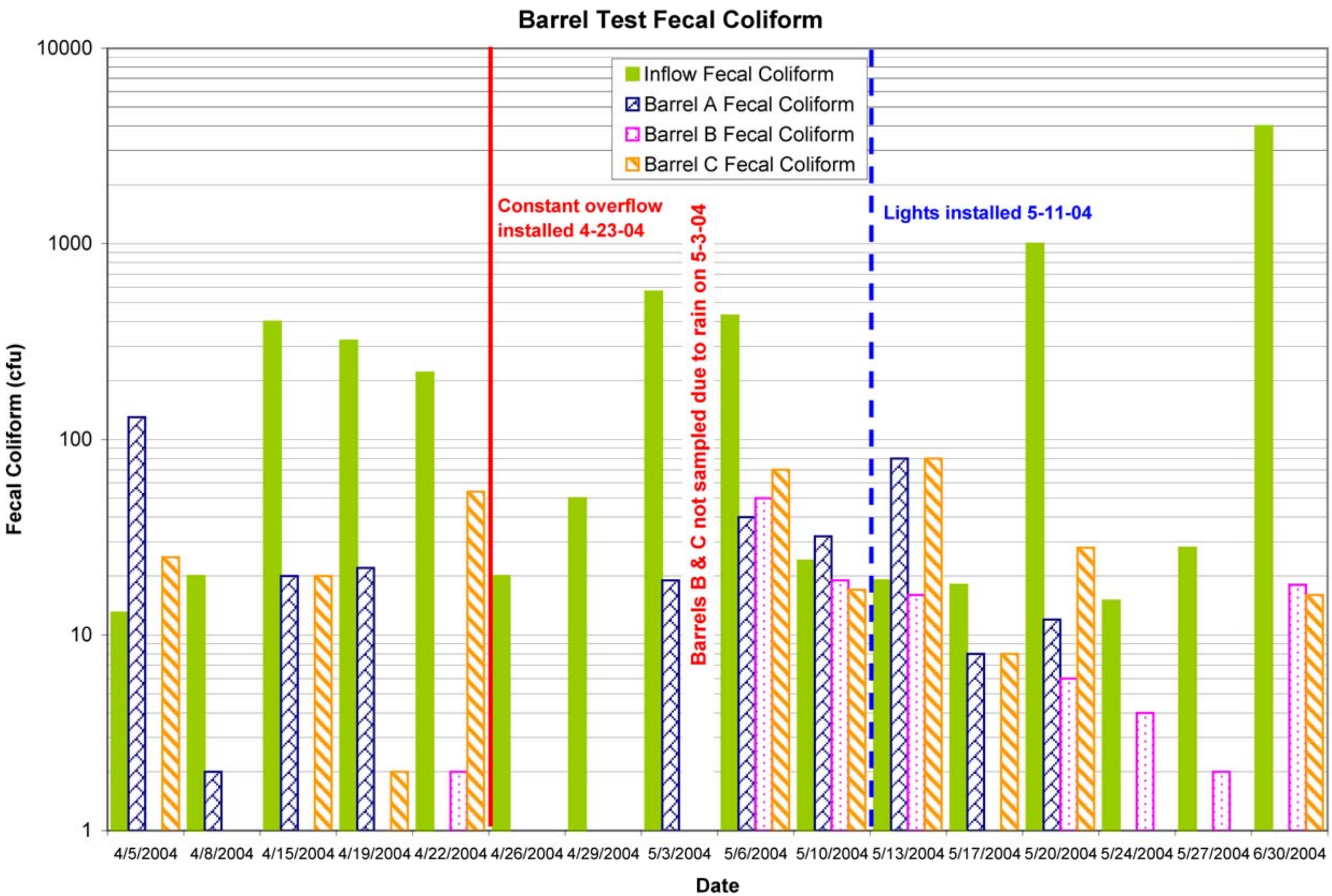


Figure J-11. Barrel Test Fecal Coliform Results.

Figure J-12. Front View of Barrels.

Figure J-13. Far Side View of Barrels Showing Reservoir and Electric Set-Up.

Figure J-14. Side View of Barrels.