A MODIFIED BARRIERED LANDSCAPE WATER RENOVATION SYSTEM FOR TREATING HUMAN WASTEWATER

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ABSTRACT

A MODIFIED BARRIERED LANDSCAPE WATER RENOVATION SYSTEM FOR TREATING HUMAN WASTEWATER

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A Modified Barriered Landscape Water Renovation System (BLWRS) was constructed for advanced treatment of wastewater at a freeway rest area. Water was evenly distributed on a sandy loam soil underlaid by coarse sand to gravel with a water table ranging from 1.2 to 2.1 m (4 to 7') deep. The water table acted as a natural barrier to vertical movement of applied water. The spray area was surrounded by an energy trench backfilled with a 1% corn meal mixture for stimulating denitrification. Ozonation removed any odors before wastewater application. The loading rate was 6.4 cm (2.5") per week with a 14 hour resting period between applications. Sampling and analysis of the ground water indicated that no increase in NH_3, NO_3^-, TKN, i-PO_4 had occurred. Soil and ground water samples showed that zones conducive to denitrification occurred in the rhizosphere, saturated zone, and energy trench. These zones greatly reduced any threat of NO_3^- contamination to the ground water table. This BLWRS also drastically reduced populations of fecal coliforms indicating minimal health hazards.

To My Parents

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INTRODUCTION

Renovation of wastewater in recent years has been the topic of many discussions and much research. Discharge of untreated or primary treated effluent has, in many cases, resulted in severe water pollution problems. This created losses in recreational areas and in industrial and domestic water supplies. Failure to treat wastes has resulted in eutrophication of our waterways and disruption of many ecosystems. Convential wastewater treatment plants can greatly reduce the organic load but the nutrients that cause eutrophication are not effectively removed. Recently land application of wastewater has received much attention as a solution to water system contamination.

Land application of wastewater can take on many forms: overland flow, evapotranspiration, slow infiltration, rapid infiltration, and special types of rapid infiltration such as a Modified Barriered Landscape Water Renovation System (BLWRS). The BLWRS uses the soil as a physical, chemical, and biological filter in the renovation process. Treatment of wastewater in a BLWRS consists of an aerobic and anaerobic zone. The aerobic zone removes BOD, N, and P and the anaerobic zone receives any excess nitrate produced, denitrifies it to N_2 gas which is then returned to the atmosphere. This system gives a uniform distribution of wastewater and aerobic conditions in the soil, is an inexpensive treatment system, needs relatively small amounts of land area, and has an added advantage in that it can be engineered to a particular waste and a particular soil.

This study evaluates a Modified Barriered Landscape Water Renovation System used in treating wastewater at the Coldwater rest area and information station on north-bound I-69, Branch County. This system was modified in that it used a liquid barrier, the natural water table, as compared to a typical BLWRS which uses an impermeable layer such as plastic or an impermeable soil horizon. The spray area was located on the highway median with a 1.2 to 2.1 m (4 to 7') deep water table. The median is 91.4 m (300') or more wide for 182.9 - 243.8 m, (600-800') with 70% Brady series and the remainder Gilford. Both of these series are sandy loam over coarse sand to gravel.

The objective of this study was to assess the potential of a Modified Barriered Landscape Water Renovation System for land treatment and disposal of the effluent as a polishing method to meet future water pollution control regulations.

LITERATURE REVIEW

Today there is a need for waste treatment so that the quality of ground and surface water supplies can be maintained. One of the most promising techniques for renovation of wastes has been the use of land treatment systems. In addition to renovation benefits, the economics and energy costs of applying sewage wastes to land, in many instances, are more favorable than the highly sophisticated physical, chemical, and biological processes developed for advanced sewage treatment (Jacobs, 1977). If we properly manage our soils, they can be effective as an advance treatment system that will remove vast amounts of N and P, greatly reduce biological oxygen demand (BOD), and enhance soil structure and fertility through the addition of organic matter, N, and P. Wastewater can supply needed elements to enhance plant growth; as has been found in Muskegon County, Michigan (EPA, 1976.) This project uses spray irrigation to successfully grow crops. There was intense management of the soil in order to utilize the effluent efficiently.

Proper management is the key to use of the soil as a biological, chemical, and physical filter. As a physical filter, the soil can receive large quantities of water while still efficiently remove suspended solids. Day, Stroehleim, and Tucker (1972) found that the infiltration rate was lower with wastewater application than with well water and that the wastewater contained higher concentrations of soluble salts, nitrates, phosphates, and the soil had a higher modulus of ruptures.

Another physical problem that arises especially with high applications of wastewater is the filling in of pore spaces at the surface thus clogging the pores. This problem can be rectified by temporarily halting the application of water or reducing the application rate. Clogging is the result of the deposition of a layer of sludge on the soil surface (DeVries, 1972). DeVries also found that there was formation of an organic mat under high rates of application at low temperatures. In 1973, Thomas also found that high rates of application causes organic matting on the surface resulting in pore clogging. Even the most severe filter failure could be rectified as was found by DeVries. He found that the previous filtering capacity could be regained after an eight day rest period.

The ability of a soil to remove chemicals from wastewater is determined by several chemical processes. Ion exchange is the most commonly recognized chemical process occurring in soils (Reed, et al., 1972). This process is related to characteristics of the clay fraction and organic matter in the soil. Reed, et al., 1972 also found that the high capacity of soils to retain anions cannot be accounted for by anion exchange or entirely by precipitation of insoluble phosphates. Rather, it is thought that phosphate ions react with the Al and Fe present at the surfaces of layer aluminum silicate minerals and with Fe and Al hydroxide phases of the soil. In 1968, Juo and Ellis found that adsorbed P slowly becomes a form which is difficult to remove from the soil probably due to incorporation as an impurity in the solid phases or crystallization of $FePO_4$.

The strong point for a land treatment system is its high potential for removal of N and P from wastewaters. When sewage effluent is applied in small amounts, N which is usually in the ammonium form may be adsorbed by negatively charged clay and organic colloids in the soil.

Flooding and drying should be scheduled so that the amount of NH_4^+ adsorbed during flooding is not more than can be nitrified during drying (Lance, et al., 1973). Otherwise, some adsorbed NH_4^+ will not be oxidized causing less NH_4^+ to be adsorbed during subsequent flooding and hence an increase in the NH_4^+ content of the renovated water. When this occurs, a sequence of short, frequent flooding periods or long drying periods should be used to nitrify the adsorbed NH_4^+ (Bouwer, et al., 1974).

Nitrogen can also be lost in the soil by volatilization of NH_3 and fixation of NH_3 by organic compounds in the soil. The pH values of wastewater is usually about

7.5 to 8.0 which volatilizes slight amounts of NH_3. At pH's higher than this and with adequate air-water contact, volatilization of NH_3 is significant (Lance, 1972). In 1961, Burge and Broadbent demonstrated the fixation of NH_3 by organic soils and showed a linear dependence on the amount of C available in the soil.

Denitrification is an important process whereby N applied with wastewater in excess of plant or crop requirements can be removed from the soil-water system (Lance, 1972). The species believed to account for most of the denitrifying activity are of the genera Pseudomonas, Achromobacter, Baccillus, and Micrococcus (Tiedje, 1978). In a laboratory study conducted on an intermittently flooded column, 83% of the N added was removed and presumed denitrified (Broadbent, 1973). Bouwer and Chaney (1974); and Meek et al., (1969) found that periodic wetting and drying, characteristic of land treatment systems, has enhanced denitrification.

There has been evidence that vegetation has a beneficial effect on denitrification (Bouwer, 1973; Broadbent, 1973; Wodendorp, et al., 1966). Plant roots consume O_2 and therefore create anaerobic pockets in the soil. One study found 15% to 20% of the NO_3 passing through the rhizosphere might be denitrified by this mechanism (Woldendorp, et al., 1966).

If the major part of N and P removal is to be by plants, care must be taken to provide the nutritional needs of the crops. At Pennsylvania State University a study was conducted to determine the effect of nutrient removal by crops with applied wastewater. It was found that 66.6 kg (148 lbs.) of N and 15.75 kg (35 lbs.) of P per acre were removed by a corn crop, while 183,6 kg (408 lbs.) of N and 25.2 kg (56 lbs.) of P per acre were removed by reed canary grass (Sopper and Kardos, 1973).

Phosphorus in wastewater is usually in the orthophosphate form. Murrmann and Koutz (1972) found that P originally present as organic P or polyphosphates was converted to orthophosphate during preliminary treatment. Very little applied P as compared to N is lost by leaching (Hook et al., 1973). At a depth of 61 cm (24") there was little or no increase in P levels even when the P applied exceeded plant uptake (Hook et al., 1973). Phosphorus is readily fixed in the soil. In calcareous soils, dicalcium phosphate and octacalicum phosphate was usaully formed whereas in acid conditions P was combined with Al and Fe to form Fe and Al phosphates (i.e.strengite and variscite, respectively) (Ellis, 1973).

Ellis and Erickson (1969) observed large variations in the fixation of P. Dune sand fixed 25.4 kg (77 lbs.) of P, while a loam soil fixed over 408 kg (900 lbs.) of P per acre foot. Also there seemed to be variation in the abilities of different horizons to fix P. The A horizon fixed less P than the B horizon which was presumably due to leaching of Fe and Al from the A to the B horizon. Once the soil reached its maximum absorptivity for P, a resting period of at least three months will restore the soils ability to fix P. This was most likely due to continued weathering of the soil along with the formation of more insoluble P. The number of times the recovery cycle can be completed is unknown but the adsorption capacity of a Mexico soil changed little after 82 years of phosphate fertilization (Ellis, 1973).

The biological oxygen demand (BOD) placed on receiving waters by effluent from treatment plants has been used for indicating the quality of treatment provided by the plant. This oxygen demand is the amount required to fulfill the respiratory needs of microorganisms decomposing the organic compounds. Miller (1973) estimated bacterial populations in the range of 135 to 4050 kg (300 to 9,000 lbs.) per acre. When wastewater was applied as in land treatment systems, this large population can greatly reduce the BOD. Reduction of BOD was accomplished under both aerobic and anaerobic conditions. Under aerobic conditions decomposition occurred rapidly while under anaerobic conditions decomposition proceeded at a slower rate. The end products of aerobic decomposition were CO_2, H_2O, NO_3 and SO_4 and anaerobic decomposition end products were H_2S, NH_4^+, CO_2, and H_2O.

MATERIALS AND METHODS

Description and Operation of BLWRS

The sewage treatment system at the Coldwater information center consists of two lagoon cells, a retention tank where ozonation takes place, and a Barriered Landscape Water Renovation System (BLWRS) for polishing treatment in the highway median. Figure 1 shows a plan of the system including an example of the spray coverage. The wastewater is pumped from the rest area building to one of the lagoon cells. The lagoon cell to be filled is determined by the opening of a connecting gate valve. Lagoon #1 is the larger of the two cells consisting of 2856 cu. meters (102,000 cu.ft.) and the second lagoon has an area of 1512 cu. meters (54,000 cu. ft.). Water can be removed from either cell into a 46,617 liter (12,300 gal) retention tank where two .45 kg (1 lb.)/hour ozonators are constantly treating the water that is to be sprayed for reducing odors and microbial populations.

From the retention tank a centrifugal pump supplies the water through a 10.2 cm (4") pipe which runs under the northbound lanes of I-69 over to the median where the BLWRS is located. The BLWRS is constructed on a sandy loam soil over a coarse gravelly sand which is at a depth of

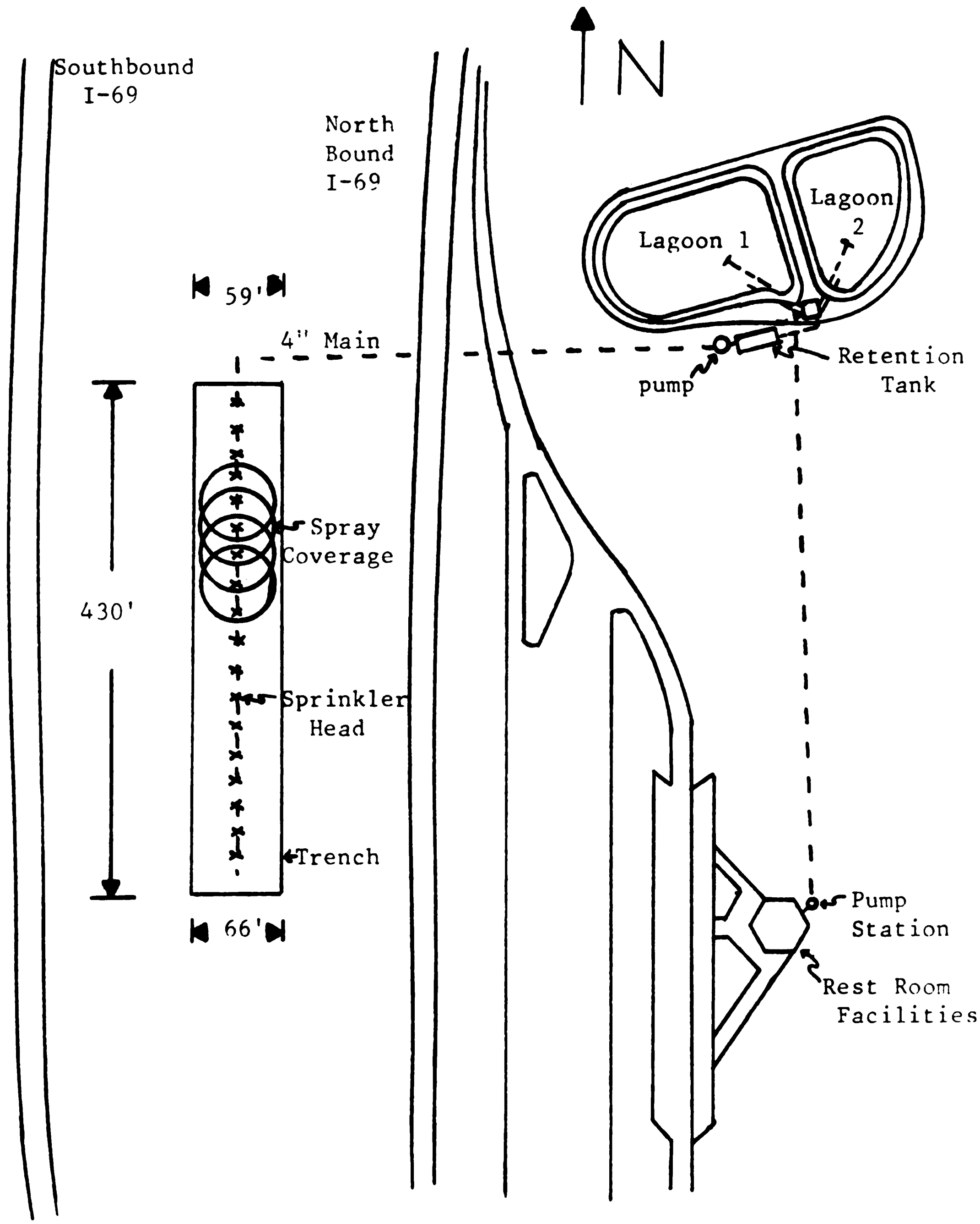

Figure 1. Overview of Lagoons, Barriered Landscape Water Renovation System and Spray Coverage.

approximately 1.5 m (5'). The water table acts as a natural barrier for any applied water that may have not been fully treated while leaching through the soil profile.

Any water that may reach this barrier is then moved horizontally through the system trench which is between 20-45 cm (8-18") in width and extends 15 cm (6") below the dry season (August 11) water table. The trench is back-filled with peat and 1% corn meal within 0.3 m (1 ft.) of the surface where the remainder is filled with the excavated soil. This trench completely surrounds the spray area. The organic material in the trench acts as an energy source for denitrifying bacteria so that any NO_3 in the ground water can be transformed to N_2, NO_2, or N_2O. In this way there is little or no degradation of the ground water.

The BLWRS consists of 19 sprinklers that spray on an area 131 m (430 ft.) long, 20 m (66 ft.) at the south end and 18 m (59 ft.) at the north end. The natural vegetative cover and soil surface was disturbed as little as possible in order to maintain infiltration and an environment conducive to denitrifiers. The water was sprayed automatically from 10:00 hours to 20:00 hours every week at a pressure of 10.5 psi. This pressure was used in order to minimize aerosols. The spray nozzle is a 160 GE 7/64 which is rated at 0.83 GPM at 10.7 m (35') radius. The amount of water sprayed totalled 3604 l. (951.03 gal)/ hour/19 sprinklers. This number was varified by field measurements.

Sampling Procedures

A system of 20 paired wells with well points were placed into the groundwater table to sample the top 15 cm (6") of water. The wells were placed in pairs, one well inside the trench and the other outside the trench to monitor any changes in the applied water as it is passed through the energy source barrier. Four other wells without well points were placed in the spray area and nine other wells also without well points surrounding the BLWRS. These thirteen wells were installed 45 cm (18") into the groundwater table to monitor any mixing that might occur between the ground water and the applied water. Figure 2 shows the placement of the wells. These wells were sampled two times per week for chemical analysis and twice a month for microbial contamination. The samples were taken before application started in the spring, while spraying was being conducted during June, July, and August, and also after the application of wastewater was discontinued.

To insure that a fresh sample of water was obtained, one liter of water was pumped out of the wells using the Guzzler "400" from the Dart Union Co., Providence, Rhode Island. The wells were then sampled by dropping a 50 milliliter centrifuge tube into the well. These tubes had previously been washed, wrapped, and sterilized in the

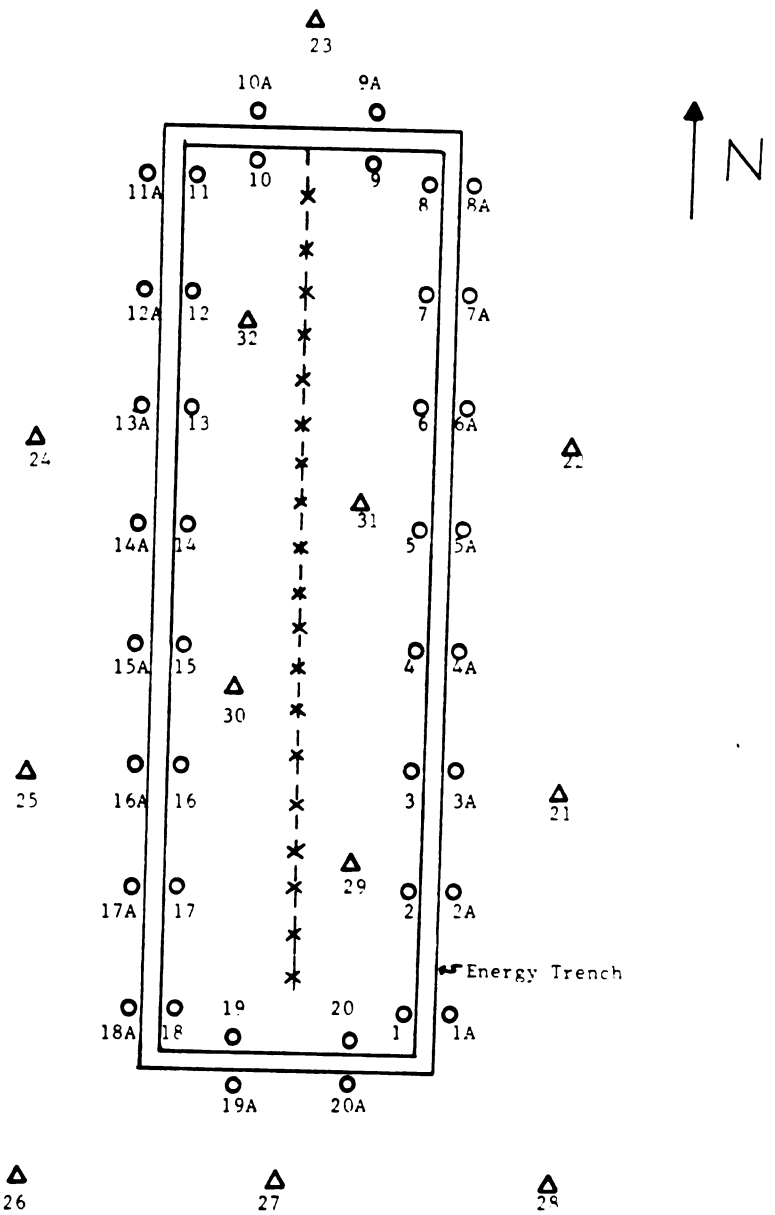

Figure 2. Barriered Landscape Water Renovation System at the Coldwater Information Center.
(O) Ground Water Sample taken at 15 cm (6").
(Δ) Ground Water Sample taken at 45 cm (18")
and Numerical Indication of Sample Number.

lab before use in the field. The sampling clip was also sterilized before each use by immersion in a 12% chlorox solution.

The lagoons and retention tank were sampled twice a week for chemical concentrations and bimonthly for microbial population estimates. These samples were taken by the grab technique. The retention tank had two sampling sites, the first sample was taken at the point of water entry and this was also where the first ozonator treated the tank water for reduction in odors and microbiological organisms. Sampling of the retention tank taken at site #2 was the point of discharge into the main pipe where the water was treated by the second ozonator. The samples taken at these four sites for chemical analysis were obtained with a polyethylene bottle whereas the microbial samples were taken with a sterile glass bottle containing sodium thiosulfate.

Soil samples were taken using a 7.6 cm (3") bucket auger to follow the N and P concentrations and their movement in the soil. Samples were taken prior to application of wastewater, two, four, and eight weeks after the onset of application. Composites of the spray area and the peripheral area (non-spray) were obtained at the 0-15 cm (0-6"), 15-30 cm (6-12"), and 30-45 cm (12-18") layers from at least 20 locations within each area.

Meteorological Data

A standard U.S. weather station was installed at the lagoon area to monitor the climate during this experiment. To measure precipitation, a rain gauge was installed and an evaporation pan (Class A Weather Bureau) was also installed to measure evaporation. For temperature and relative humidity measurements, a recording thermo-hydrograph was installed. Next to the evaporation pan an anemometer was installed which measured the amount of wind since the last sampling date. A printing totalizing integrator connected to a pyronometer was used to measure the radiant energy.

Storage of Samples

After each sample was taken, it was placed in a styrofoam cooler containing ice for transport until they all could be returned to the lab. BOD_5 analysis was performed immediately upon returning from the field as were the samples taken for microbial analysis. The samples taken for chemical analysis were transferred to clean 50 milliliter glass storage bottles and placed in a cooler at $4^{o}C$ until the chemical analysis could be performed which was usually within five days. The remainder of the samples were then acidified using 6 N hydrochloric acid and stored again at $4^{o}C$ until the total organic C content measurement could be performed.

Chemical Analyses

Unless otherwise indicated, the chemical analyses were performed as described in Methods for Chemical Analyses of Water and Wastes (1974).

BOD_5

The BOD five-day was analyzed as follows: A nutrient solution was made up by adding one milliliter per liter of the following four solutions to distilled water.

1. Ferric chloride

   0.25 grams of $FeCl_3 \cdot 6H_2O$ in one liter of distilled water.

2. Magnesium sulfate

   22.5 grams of $MgSO_4 \cdot 7H_2O$ in one liter of distilled water.

3. Calcium chloride

   27.5 grams of anhydrous $CaCl_2$ in one liter of distilled water.

4. Phosphate buffer

   a. 8.5 grams of KH_2PO_4.

   b. 21.75 grams of K_2HPO_4.

   c. 33.4 grams of Na_2HPO_4.

   d. 1.7 grams of NH_4Cl.

   e. dissolve in 500 milliliters of distilled water.

f. the combined working reagent should be be at a pH of 7.2 without further adjustment.

To the nutrient solution, composed of these four solutions, is added one ml per liter of water from the lagoon being used to apply water on the highway median and which acts as the seed to insure a population of microorganisms to oxidize the organic material. This solution was then aerated to saturation with oxygen before use. Fifteen and 30 milliliters of retention tank samples, or 50 milliliters of ground water samples were transferred to 300 milliliter bottles which were then brought up to volume with the nutrient solution. Dissolved oxygen measurements were performed after five days of incubation in the dark at 20°C. BOD_5 was determined in ppm of O_2 consumed by living organisms while utilizing the organic matter present in the sample.

Total Kjeldahl Nitrogen and Total Phosphorus in Wastewater

Reagent: Hydrogen peroxide-sulfuric digest solution (H_2O_2-H_2SO_4). Add 30% H_2O_2, 1 g of Se metal powder, and 14 g $LiSO_4 \cdot H_2O$. Then add 420 ml of concentrated H_2SO_4 while carefully cooling the mixture.

Procedure: Add 25 ml of ground water sample, lagoon sample, or retention tank sample into a 125 ml Erlenmeyer flask and add 5 ml of reagent. Heat for one half hour after the fumes disappear. Transfer quantitatively into a 250 ml volumetric flask and bring to volume with distilled water. Analysis for TKN used the idophenol blue colormetric method on the Technicon Auto Analyzer. For analyzing total P, the molybdophosphovanadate method was used on the Technicon Auto Analyzer.

Ammonia (NH_3) in Wastewater

Reagents:

1. Alkaline Phenol. Dissolve 200 grams of NaOH in distilled water. Cool and slowly add 276 ml of liquified phenol while cooling and constantly stirring. Add 0.5 ml of Brij-35 and dilute to one liter.
2. Sodium Hypochlorite. Any household bleach will suffice.
3. Potassium Sodium Tartrate. Dissolve 150 g of $KNaC_4H_4O_6 \cdot 4H_2O$ in distilled water, add 0.5 ml of Brij-35 and dilute to one liter.

Procedure: Analyze for NH_3 colorimetrically on the Technicon Auto Analyzer. A green colored compound was formed when the NH_4^+ ion reacted with the sodium phenoxide. The concentration of the green colored compound formed was then measured on the colorimeter.

Nitrite and Nitrate

Reagents: 1. Ammonium Chloride. Dissolve 10 g of NH_4Cl in distilled water, then add 0.5 ml liters of Brij-35 and dilute to one liter.

2. Color Reagent. Dissolve 20 g of sulfanilamide ($C_6H_8N_2O_2S$), 200 ml of concentrated H_3PO_4, one g of N-1-Napthylethylenediamine dihydro-chloride ($C_{12}H_{14}N_2 \cdot 2HCl$), and one ml of Brij-35 in two liters of distilled water.

Procedure: The concentration of NO_2^- and NO_3^- was determined by passing the sample through a Cd reduction column where the NO_3^- was reduced to NO_2^-. The NO_2^- then reacted with sulfanilamide to form a diazo compound. The concentration of this coumpound was then determined colormetrically on the Technicon Auto Analyzer. A sample for NO_2^- level was also measured and the difference between the reduced sample and the nitrite sample gave the nitrate concentration.

Inorganic Phosphorus (i-PO_4)

Reagent: The color reagent was made by adding 50 ml of 4.9 N H_2SO_4, 15 ml of Ammonium Molybdate $(NH_4)_6Mo_7O_{24} \cdot 4H_2O$, 30 ml of ascorbic acid, and 5 ml of antimony potassium tartrate $K(SbO)C_4H_4O_6 \cdot \frac{1}{2}H_2O$.

Procedure: The reagent reacted with the orthophosphate ion to form a blue antimony - phosphomolybdenum complex which was measured colorimetrically on the Technicon Auto Analyzer.

Soil pH

Ten grams of soil were placed in a 50 ml plastic beaker and 10 ml of distilled water added. This was stirred intermittently for 20 minutes and read directly with an Orion Research Digital Ionalyzer Model 801A which was standardized with standard buffer solutions of pH 4.01, 7.00, and 10.00.

Extractable Phosphorus in Soils

Reagent: Bray P

Add 15 ml of 1.0 N NH_4F and 25 ml of 0.5 N HCl to distilled water and dilute to 500 ml with distilled water.

Procedure: Five grams of soil were weighed into a 125 ml Erlenmeyer flask and then 20 ml of reagent were added. The soil with reagent added was then shaken for 5 minutes on a rotary shaker at 200 rpm, then filtered through Whatman #2 filter paper. Analysis for PO_4 was performed on the Technicon Auto Analyzer using the same procedure done on the wastewater.

Extractable Ammonia in Soils (NH_3)

Twenty grams of field wet soil were weighed into a 125 ml Erlenmeyer flask and 20 ml of 1.0N KCl were then added. This was then shaken for 30 minutes on a rotary shaker at 200 rpm, then filtered through Whatman #2 filter paper. Analysis was then performed on the Technicon Auto Analyzer following the same procedure utilized for the wastewater.

Extractable Nitrate in Soils (NO_3^-)

Reagent: Add 4.82 g of $CaSO_4$ to two liters of distilled water.

Procedure: Twenty grams of field wet soil were weighed into a 125 ml Erlenmeyer flask and then 20 ml of reagent were added. This was then shaken for 30 minutes on a rotary shaker at 200 rpm. The solution was then filtered through Whatman #2 filter paper and analyzed colorimetrically on the Technicon Auto

Analyzer following the wastewater procedure.

Total Kjeldahl Nitrogen (TKN) and
Total Phosphorus (t-P) in Soils

Reagent: Same reagent as was prepared for the wastewater tests.

Procedure: One gram of field wet soil was weighed into a 125 ml Erlenmeyer flask and 5 ml of reagent were then added. This was then heated for one half hour after the fumes disappeared. The solution was transferred quantitatively into a 250 ml volumetric flask and brought to volume with distilled water. Analysis was performed on the Technicon Auto Analyzer following the same procedure as was done on the wastewater analysis.

Moisture Content in Soils

A clean, dry Al boat was weighed, field wet soil was added and then reweighed, the soil was then dried for 48 hours in an oven at 104°C, then the boat and oven dry soil was reweighed. The difference between the wet and oven dry soil was determined and divided by the weight of the oven dry soil.

Microbial Analyses

The microbial analyses were performed as given in Standard Methods for the Examination of Water and Wastewater (1978).

Total Coliforms

The multiple tube dilution technique with lauryl tryptose broth was used for total coliform concentration. Dilutions of the samples were made and inoculated into the broth, then incubated for 48 hours at 35°C. The most probable number (MPN) method determined the concentration of total coliforms in each sample.

Fecal Coliforms

Samples of positive tubes from the total coliform test were transferred into EC medium and incubated for 24 hours at 44.5°C in a water bath. Fecal coliform concentrations were reported on the positive tubes using the most probable number (MPN) method.

Total Streptococci

Multiple tube dilution technique was also run on total streptococci using azide dextrose broth on properly diluted samples. The tubes were then incubated for 48 hours at 35°C after which the most probable number (MPN) method on the positive tubes determined the concentration of total streptococci.

Fecal Streptococci

Positive tubes from the total streptococci test were transferred into ethyl violet azide dextrose broth. These tubes were then placed in a water bath at $35^{\circ}C$ for 24 hours. After this time period, the most probable number (MPN) method was used to determine fecal streptococci concentration.

RESULTS AND DISCUSSION

Introduction

The Modified Barriered Landscape Water Renovation System at the Coldwater Information Center was operated from June 15 to August 10, 1979. For analyses and discussion, these data are divided into three distinct periods. The first period was during the application of wastewater from Lagoon 2, the smaller of the two lagoons, which contained stabilized waste. The second period of application was the disposal of wastewater from Lagoon 1 which contained partially stabilized waste. The final period was application of wastewater from Lagoon 2. The important difference of this period from the previous two was that Lagoon 2 contained fresh waste in an unstabilized condition and also a mixture of sludge from Lagoon 1. Sludge was introduced from Lagoon 1 since it had been pumped over to the smaller lagoon to sustain the system with an adequate amount of wastewater so spray application could continue for as long as possible. The data from each sampling is shown in Table A through G in the Appendix. Data for each of the three periods are reported in terms of the means and standard deviation in tables in this section. Some of the standard deviations are quite high. This variability can be expected when varying conditions in the field are considered.

System Conditions prior to Wastewater Application

Background samples for the wells were obtained on the 16th of April and the 7th and 11th of May. Some of the NO_3 - N levels were found to be in excess of 10 ppm which is the highest allowable standard for drinking water. The NO_3^- was found to be high in only the top 15 cm (6") of the ground water whereas the samples taken at the 45 cm (18") level were well below the EPA standards. Presented in Table 1 are the 18 well samples that were found to be high in NO_3^-. The other 34 wells had normal NO_3^-.

As the values in Table 1 show, as the season progressed the NO_3^- concentrations fluctuated in some of the wells whereas in most of the wells the NO_3^- concentrations decreased. The high NO_3^- was due to construction on the site which haphazardly deposited varying amounts of vegetation on the soil surface. As the vegetation decomposed NO_3^- increased in the soil. This NO_3^- was then flushed down to the water table due to the fall rains and snow melt in the early spring. Denitrification at this time was minimal and subsequently the NO_3^- accumulated in the ground water. The high NO_3^- levels also had some correlation to the growth of vegetation. As the season progressed and temperatures increased there was substantial new vegetative growth which was mainly perennial weeds.

Table 1. Sampling Wells of the Top 15 cm(6") of the Ground Water found High in Nitrate Concentration before the Onset of Spray Application.*

Wells	Sampling Dates			
	April 16	May 7	May 11	June 11
	ppm			
1	29.3	32.2	34.2	30.2
2	46.5	32.9	33.3	3.8
2A	53.9	46.3	63.2	29.4
3A	47.8	20.8	19.5	4.6
4	25.7	15.9	14.1	13.4
4A	21.0	7.0	4.6	1.6
5A	36.9	18.8	6.8	0.8
12	21.8	15.0	15.2	5.1
13	32.2	14.7	7.4	1.3
14	37.0	28.9	12.3	6.0
14A	31.0	18.8	7.8	0.7
15A	21.2	1.5	3.4	4.9
16	20.1	17.6	24.1	3.0
17	24.3	31.9	25.3	16.0
17A	17.8	35.4	39.2	43.4
18	45.1	43.9	37.9	25.6
19	26.8	27.6	32.2	30.8
20	19.3	39.2	48.3	31.0

*This represents 18 of 52 wells sampled; 34 of which were less than 15 ppm.

The NO_3^- concentration decrease in the ground water was probably due to less NO_3^- being leached through the soil profile by increased NO_3^- removal by the vegetation and the excess NO_3^- could have been removed from the soil solution by denitrification. As the temperatures increased, the oxygen concentration in the rhizosphere decreased and anaerobic microenvironments developed. With the anaerobic conditions, denitrifier populations utilized the NO_3^- as a terminal electron acceptor thereby transforming excess NO_3^- to nitrogen gas with eventual release into the atmosphere.

In Table 2 the concentrations of NH_3, NO_3^-, TKN, i-PO_4, and t-P are tabulated for the system prior to wastewater application. As can be seen in the early part of the season before application of wastewater, the concentrations of the nitrogen compounds were at their maximum. The first sampling was the highest for NH_3 and NO_3^- and was due to the low activity of bacteria since the soil temperature was below $10^{o}C$ ($50^{o}F$) until the first of June.

System Conditions During Wastewater Application

Hydrology

Due to the high rate of evaporation and low rainfall, this BLWRS evapotranspired more and leached less than usual for a BLWRS. The hydrologic data can be found in Table 3. With the dry weather conditions encountered during wastewater application the water table steadily dropped. During the approximately eight weeks of

Table 2. Mean and Standard Deviation of Nutrient Concentrations in Ground Water Samples before Application of Wastewater.

Date of Sampling	NH_3		NO_3		TKN		t-P		$i\text{-}PO_4$	
	$\bar{X}$	S	$\bar{X}$	S	$\bar{X}$	S	$\bar{X}$	S	$\bar{X}$	S
	ppm									
4/16	0.92	0.69	14.1	14.8	0.66	0.54	0.07	0.09	0.16*	0.05
5/07	0.23	0.37	11.0	13.1	1.06	2.80	0.02	0.01	0.01	0.01
5/11	0.22	0.40	11.3	14.4	0.43	0.52	0.05	0.14	0.01	0.02
6/11	0.34	0.31	6.9	10.8	0.43	0.46	0.10	0.00	0.02	0.01

*$i\text{-}PO_4$ is larger than t-P due to high clay content in sample. Test for $i\text{-}PO_4$ was run before digest, which removed clay fraction, was performed for t-P analysis.

Table 3. Hydraulic Data of the Barriered Landscape Water Renovation System.

Date	Effluent Applied	Rainfall	Evaporation*
	mm		
6/15-17	10.50	0.00	20.00
6/18-21	10.50	0.75	21.25
6/22-24	20.50	9.75	24.75
6/25-28	15.75	0.00	18.25
6/29-7/01	42.00	4.25	27.25
7/02-05	26.25	1.25	19.50
7/06-08	35.00	23.00	23.00
7/09-12	26.25	3.00	14.25
7/13-15	35.00	0.00	18.75
7/16-19	26.25	0.75	19.00
7/20-22	35.00	0.00	25.00
7/23-26	26.25	0.00	18.75
7/27-29	35.00	8.00	11.75
7/30-8/02	26.25	6.50	19.00
8/03-05	35.00	15.00	20.75
8/06-09	26.25	14.50	22.50
8/10-12	35.00	18.75	18.75
8/13-15	26.25	0.00	13.75
TOTAL	493.00	105.50	356.25
	(19.72")	(4.11")	(13.89")

*Data from a Class A pan.

application 493 mm (19.72") of wastewater was applied and 105.5 mm (4.11") of rain fell. Evaporation was estimated from a Class A pan and found to be 356.25 mm (13.89"). This resulted in a relative water distribution of 82% applied effluent, 18% rainfall, and 60% evaporation. Thus, the water available for drainage was calculated to be 242.25 mm (9.45") which was 40% of the wastewater + rainfall or half as much as the wastewater applied. Since the drainage was half as much as the effluent applied this could have caused the concentration of pollutants in the wastewater to almost double. These values are tabulated in Table 4. Wastewater application was conducted automatically between 1000 hours and 2000 hours which resulted in 61.25 mm (2.4") of effluent applied per week. With a rest period of 14 hours there was no ponding or organic mat formed on the soil surface indicating that the system was never hydraulically overloaded.

Three times during the application of wastewater, accurate measurements of the water table level were taken. These measurements were taken in order to determine if the applied water had any effect on varying the height of the water table and also to determine the direction of water table flow. A surveyors level was used in determining the water levels. The retention tank located across the highway was used as a benchmark which was set at 100 feet and all elevations are relative to this. Figures 3, 4, 5

Table 4. Hydraulic Distribution During Operation of the Barriered Landscape Water Renovation System at the Coldwater Information Center.

	Amount mm	Percent of Total
Effluent Applied	439.00	82
Rainfall	105.50	18
Evaporation	356.25	60
Water Available for drainage	242.25	40

present the water table elevations at three times during the operation of the BLWRS. According to the levels found in figures 3, 4, and 5, the water table for the most part moved in both a north and southwesterly direction.

<u>Nitrogen</u>

Nitrogen in this system can be traced from the lagoons to the retention tank to the amount that was held in the soil and finally to the concentrations found in the ground water. The values in Table 5 are the averages found for TKN, NH_3, NO_2^- - N, and NO_3^- - N (NO_3^-) in the lagoons and retention tank. The table was divided into three sections, each section designates which lagoon was being used for wastewater application on the BLWRS.

The levels of TKN and NH_3 increased appreciably during the last application period of 7/16 to 8/10. This was caused on July 20 and 23 when Lagoon 1 was being pumped over to Lagoon 2 so that water could be supplied for application into August. Water from Lagoon 1 was being pumped from the bottom of the lagoon and caused considerable mixing in Lagoon 2 of the untreated and primary treated wastewater which was then transferred into the retention tank.

As Table 5 indicates the starting values for NH_3 were the highest of all the forms of nitrogen. While the wastewater was being applied there was a great possibility of nitrification of the NH_3. This can be seen in the

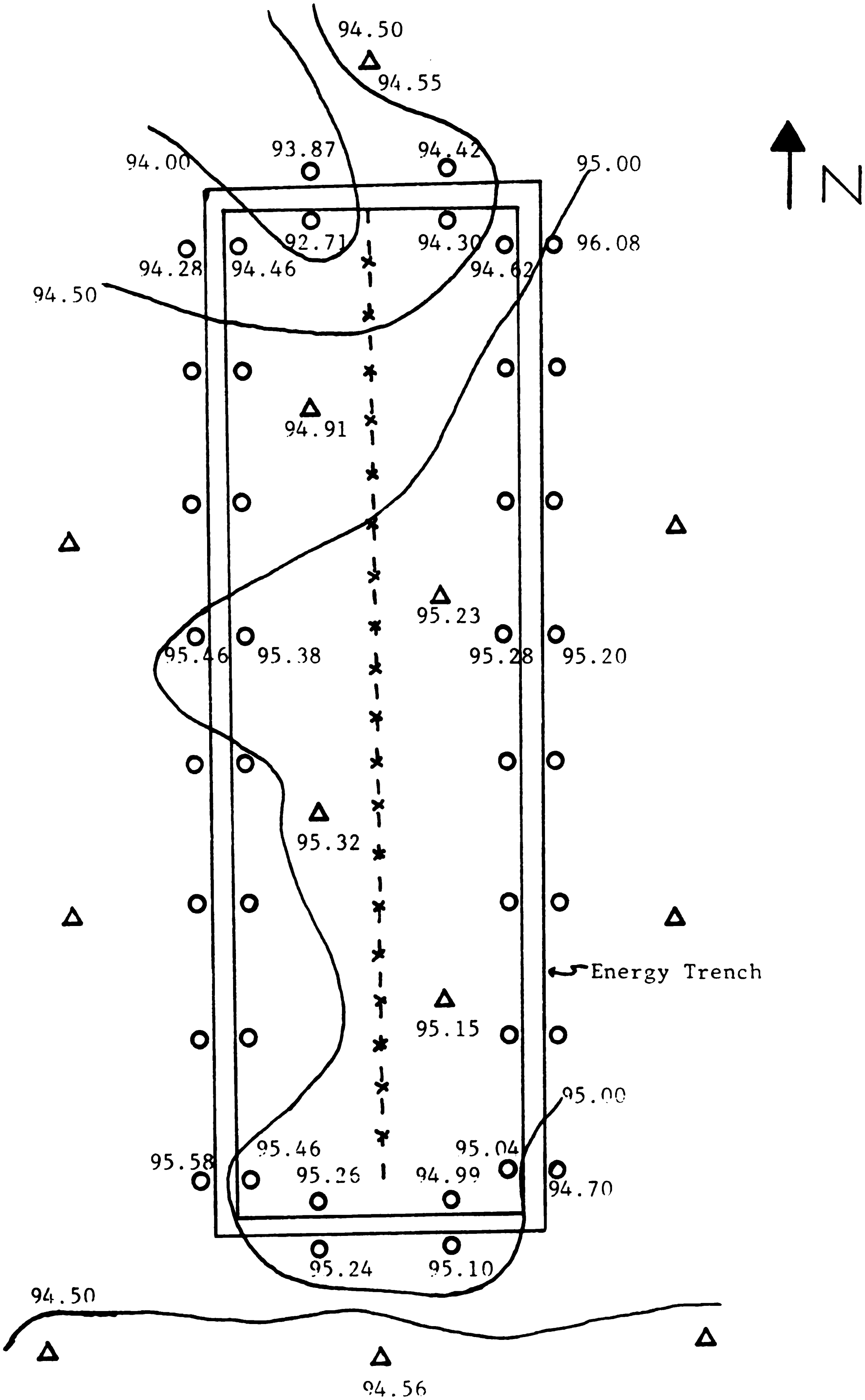

Figure 3. Ground Water Table Elevations at each Sampling Well on 1 July 1979.

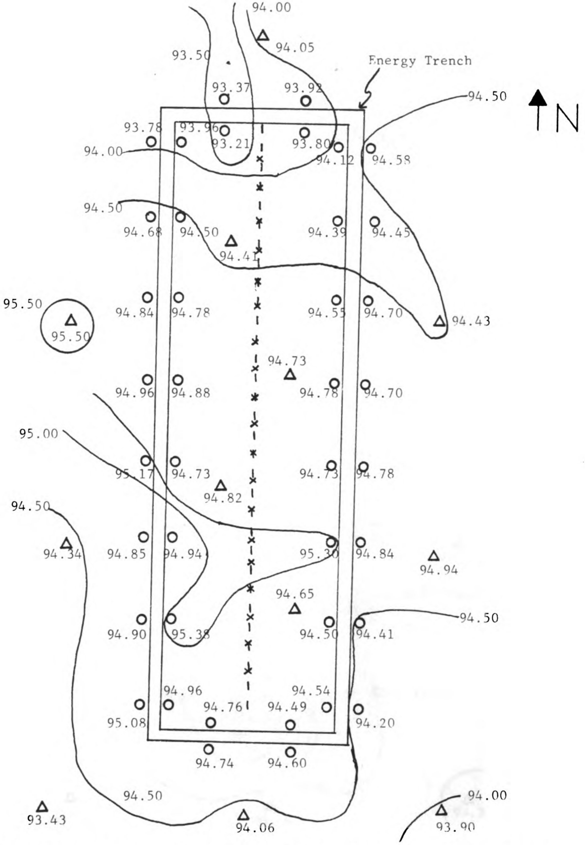

Figure 4. Ground Water Table Elevations at each Sampling Well on 6 August 1979.

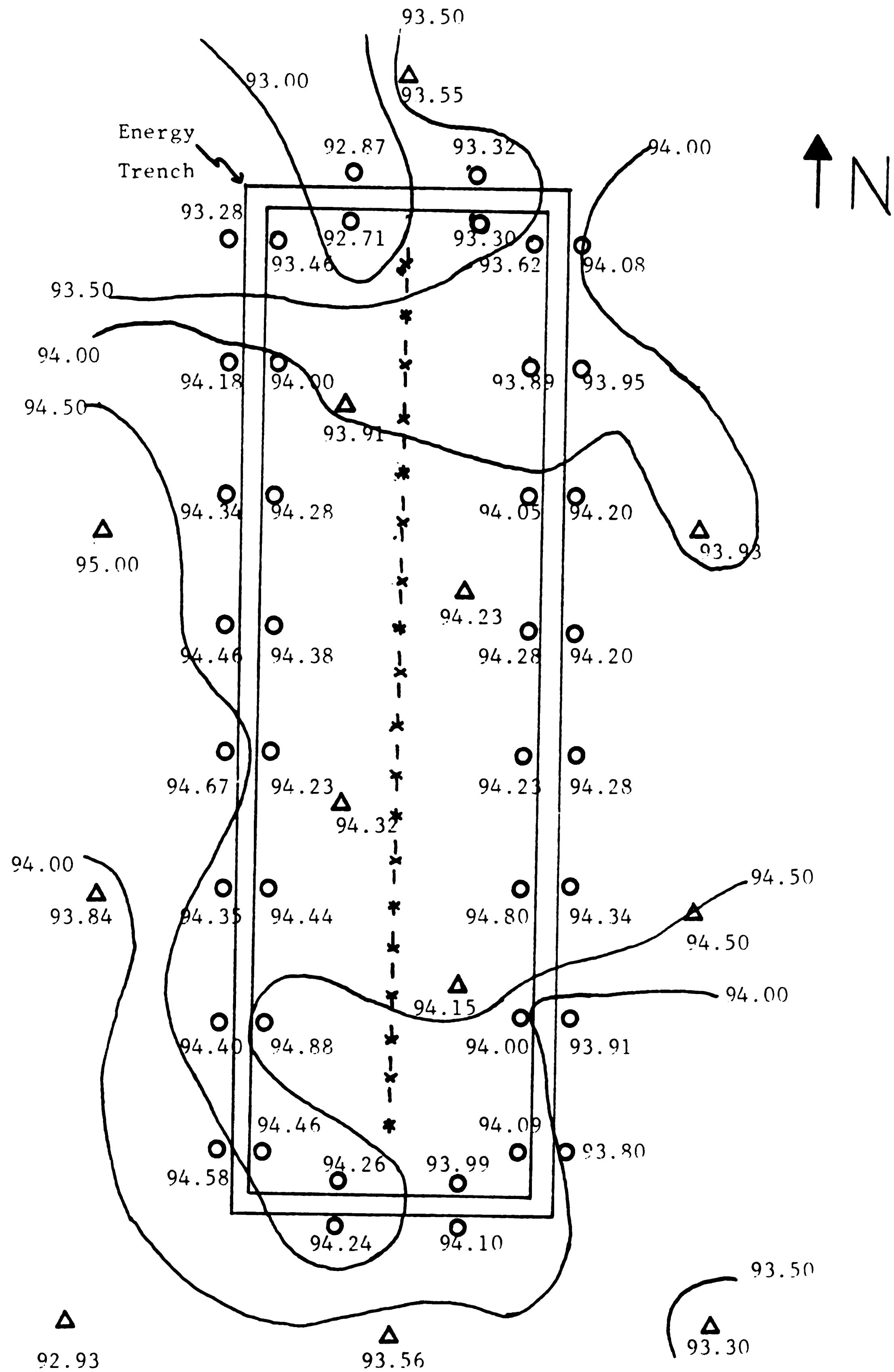

Figure 5. Ground Water Table Elevations at each Sampling Well on 13 August 1979.

Table 5. Mean and Standard Deviation of Concentrations of Nitrogen Components in the Lagoons and Retention Tank Wastewater.

Period of Sampling	TKN		NH_3		NO_2^-		NO_3^-		Total N (TKN + NO_2^- + NO_3^-)
	$\bar{X}$	S	$\bar{X}$	S	$\bar{X}$	S	$\bar{X}$	S	$\bar{X}$
	ppm								
6/15-7/03*									
Lagoon 1	15.3	7.6	6.1	1.4	0.02	0.01	0.28	0.22	15.6
Lagoon 2	15.2	5.6	8.6	5.8	0.13	0.11	0.17	0.08	15.5
Tank 1	11.6	4.6	6.8	4.4	0.61	0.20	1.88	1.25	14.8
Tank 2	11.0	4.2	7.3	3.6	0.65	0.20	2.13	1.33	14.6
7/04-7/16**									
Lagoon 1	15.8	5.1	7.6	1.4	0.01	<0.01	0.20	0.00	16.0
Lagoon 2	22.3	3.0	14.2	2.6	0.02	0.01	0.20	0.00	22.5
Tank 1	12.7	2.8	9.2	2.7	0.17	0.02	0.68	0.05	13.6
Tank 2	12.8	2.5	8.9	2.3	0.18	0.02	1.10	0.08	14.0
7/17-8/10***									
Lagoon 1	40.6	17.9	25.8	9.9	0.04	0.03	0.58	0.31	41.3
Lagoon 2	35.0	13.7	24.8	4.6	0.01	<0.01	0.13	0.05	35.7
Tank 1	24.6	6.2	22.2	5.8	0.14	0.14	1.95	3.11	26.7
Tank 2	24.8	5.9	20.8	4.3	0.14	0.14	2.15	3.10	27.1

*Spray application water being drawn from Lagoon 2.
**Spray application water being drawn from Lagoon 1.
***Spray application water being drawn from Lagoon 2 after Lagoon 1 had been pumped into Lagoon 2 during 7/20 and 7/23.

difference of NH_3 values between Table 5 and Table 6.

After the wastewater was applied on the BLWRS, the levels of TKN, NH_3, and NO_3^- could be followed by soil sampling which occurred on 6/22, 7/09, and 8/13. The TKN values in Table 6 show that the levels of free ammonia and organic N varied in the upper 15 cm (6") of the soil profile. This variation was due to the organic matter in the soil. The 15-45 cm (6-18") depth decreased in TKN indicating that less organic matter was in this depth than in the soil surface. Also, much of the free NH_3 was nitrified to NO_3^-. In the process of nitrification, NH_3 was oxidized to NO_2^- and was not particularly stable in the soil. Nitrite is rapidly converted to NO_3^- by Nitrosomonas bacteria and therefore very difficult to follow in the soil. Consequently samples were not analyzed for NO_2^- in the soil. Evidence that nitrification occurred could be accounted for since the upper soil profile increased in NO_3^- concentration.

Nitrate levels tabulated in Table 6 indicate that approximately half of all NO_3^- found in the soil was either being utilized by plants or denitrified in anaerobic pockets in the rhizosphere. The NO_3^- not utilized or denitrified in the upper 15 cm (6") was leached through the soil profile without additional reduction. Indication of this can be found in the following 30 cm (12") of soil. Also, the levels of NO_3^- did not decrease, as would have been expected, through dilution in the soil solution due

Table 6. Concentrations of Nitrogen Components in the Upper Soil Profile of the Spray Area during Wastewater Application.

Date of Sampling	Depth of Sampling cm	(inches)	TKN	NH_3	NO_3^-	NO_3^- in Soil Solution
			ppm			
6/22	0-15	(0-6)	1096	0.86	2.9	20.9
	15-30	(6-12)	608	0.90	1.6	12.8
	30-45	(12-18)	543	1.13	1.4	13.3
7/09	0-15	(0-6)	904	1.43	4.6	25.6
	15-30	(6-12)	706	1.11	1.9	12.5
	30-45	(12-18)	622	0.95	1.7	11.3
8/07	0-15	(0-6)	1240	5.86	6.1	26.4
	15-30	(6-12)	752	3.08	3.2	18.2
	30-45	(12-18)	647	2.55	2.8	17.4

to evapotranspiration.

Ammonia in the water table did not change appreciably during the operation of the BLWRS, Table 7. Levels of NH_3 ranged from a high of 0.24 ppm to a low of 0.13 ppm. This concentration of NH_3 in the water table was 10-20% of the concentration of NH_3 applied to the soil. Ammonia in the wastewater applied to the soil ranged from 4.07 ppm on June 22 to a high of 34.46 ppm on August 6. Considering the levels of NH_3 in the applied water and the concentrations found in the water table it could be ascertained that microbial environments nitrified the NH_3 to NO_3^- in the upper soil profile. Any NO_3^- not utilized by plants was leached, then mostly reduced to N_2 in aerobic environments.

Throughout the treatment process, the NO_3^- levels in the sampling wells varied, Table 7. The shallower paired wells contained higher concentrations than did the deeper wells . This was due to NO_3^- leaching through the soil profile and becoming concentrated in the upper 15 cm (6") of the water table. Here the NO_3^- came in contact with an anaerobic environment in the mounded water table which was an ideal environment for denitrification. As this occurred, the water moved towards the energy source trench where additional denitrification took place. Table 8 shows that there is about 1 ppm reduction in NO_3^- from the wells, before the energy trench, to the wells on the outside of the trench.

Table 7. Mean and Standard Deviation of Concentrations of Nitrogen Compounds in Ground Water Sampling Wells and Soil Temperatures.

Date of Sampling	TKN		NH_3		NO_3^- Shallow Paired Wells		NO_3^- Deep Wells (Spray Area)		Soil Temperature	
	$\bar{X}$	S	$\bar{X}$	S	$\bar{X}$	S	$\bar{X}$	S	^oC	^oF
	ppm									
6/15	0.48	0.48	0.16	0.28	8.4	13.2	1.4	1.3	13.3	56
6/18	0.36	0.39	0.22	0.32	6.9	10.2	1.9	2.0		
6/22	0.41	0.38	0.15	0.32	7.6	12.1	5.7	10.0		
6/25	0.33	0.36	0.15	0.32	6.8	10.0	2.6	3.7	16.7	62
7/01	0.40	0.41	0.18	0.31	4.6	6.1	1.9	1.9		
7/06	0.38	0.35	0.13	0.25	4.5	6.1	2.4	2.2		
7/09	0.37	0.35	0.15	0.26	4.4	5.8	2.5	2.0	20.6	69
7/13	0.95	1.12	0.15	0.26	3.3	3.7	3.0	2.9		
7/16	0.96	0.99	0.24	0.60	3.3	3.2	3.5	3.5		
7/20	0.63	0.53	0.22	0.59	2.2	3.2	3.1	3.1	25.6	78
7/23	0.40	0.45	0.13	0.22	3.4	3.4	3.5	2.9		
7/26	1.03	0.90	0.14	0.25	3.7	3.3	3.5	2.9		
7/30	0.78	0.82	0.14	0.24	3.6	3.2	3.9	3.7	28.3	83
8/03	0.25	0.28	0.14	0.24	4.0	3.8	5.2	5.5		
8/06	0.21	0.28	0.17	0.28	4.3	4.0	6.5	6.3		
8/10	0.23	0.25	0.19	0.36	4.8	5.1	5.5	5.8	32.2	90
8/13	0.32	0.40	0.17	0.29	5.9	6.1	7.3	8.4		

Table 8. Mean and Standard Deviation of the Nitrate-Nitrogen Concentration in Ground Water Samples from the Shallow Paired Wells on the Inside of the Energy Trench to the Shallow Wells on the Outside of the Energy Trench.

Date of Sampling	Inside Shallow Wells		Outside Shallow Wells	
	$\bar{X}$	S	$\bar{X}$	S
	ppm			
6/15	7.7	10.2	6.8	12.4
6/18	7.8	9.8	6.0	10.8
6/22	8.4	11.3	6.7	13.1
6/25	9.6	13.1	4.3	4.6
7/01	4.9	7.0	4.5	5.4
7/06	5.0	6.8	4.2	5.5
7/09	4.7	6.6	4.0	5.0
7/13	3.4	3.8	3.1	3.7
7/16	3.0	2.9	3.1	3.1
7/20	2.7	3.7	1.8	2.5
7/23	3.3	3.7	3.0	3.1
7/26	4.0	3.7	3.6	3.0
7/30	3.8	3.6	3.3	2.9
8/03	4.3	4.4	3.6	3.1
8/06	4.6	4.7	3.9	3.4
8/10	5.1	5.5	4.6	4.7
8/13	5.4	6.4	5.8	5.9
AVERAGE	5.2		4.3	

The deeper wells in the spray area had low NO_3^- concentrations until July 30 when the NO_3^- levels began increasing, Table 7. Each sampling after that contained an increase in NO_3^-. Investigation of the situation proved that at this time of the season the sample was being pulled from the top 20 to 23 cm (7.8 to 9") depth. At this depth vertical movement of applied water was halted and an increase of NO_3^- is expected, thus indicating that the BLWRS did not malfunction.

The conclusion that the system was functioning properly affirmed the fact that the deep wells outside the BLWRS did not increase in NO_3^- but remained at a fairly steady level. Table 9 compares the NO_3^- levels between the seven deep wells outside the BLWRS to the deep wells on the spray area. These values confirm that the BLWRS did not malfunction but that samples were taken in the mounded water zone before denitrification occurred.

The efficiency of this BLWRS for removing any threat of contamination of our waters from N forms can be seen in Table 10. Efficiency for TKN never dropped below 94%, reduction in NH_3 was above 97% for the entire application period, and Total N efficiency of this system had increased from 75% to over 92%.

Table 9. Mean and Standard Deviation Comparing the Nitrate-Nitrogen Concentrations in the Deep Wells Outside the BLWRS to the Deep Wells on the Spray Area.

Date of Sampling	Deep Wells Outside the BLWRS		Deep Wells in the Spray Area	
	$\bar{X}$	S	$\bar{X}$	S
	ppm			
7/30	2.7	3.1	5.9	4.2
8/03	3.2	3.7	8.7	7.0
8/06	3.4	3.8	11.8	6.5
8/10	1.9	2.4	11.8	4.0
8/13	2.0	2.5	16.6	6.3

Table 10. Treatment Efficiency of the Barriered Landscape Water Renovation System in Reducing Concentrations of Nitrogen Components from Lagoon Treated Waste.

Period of Samplings	TKN	NH_3	Total N ($TKN + NO_3^-$)
	%		
6/15-7/03	96.4	97.6	75.1
7/04-7/16	94.8	98.1	83.8
7/17-8/10	98.0	99.2	92.2

Phosphorus

Table 11 tabulates the concentration of phosphorus contained in the lagoons and in the retention tank before wastewater was applied. The first two periods were at the same concentration but the third period resulted in an increase in P, which can be attributed to Lagoon 1 being pumped into Lagoon 2 to supply more wastewater for application. The lagoon had been pumped from the bottom causing considerable mixing of the water with some sludge creating increased levels of phosphorus. The total amount of P applied was 13.4 kg/ha (12#/acre) which is small compared to demand of vegetation.

Soil analysis for t-P and extractable P can be found in Table 12. Values for t-P are quite variable throughout the entire period of spray application. The values obtained in the t-P test show that this soil, a sandy loam, was possibly low in organic matter. Also, the amount of P applied was low thereby adding very little to the soil. Values for extractable P (Bray-P) indicate that the small amount of P applied from the wastewater had been taken up by the vegetation.

Results of the Bray - P test indicate the amount of P readily available for plant uptake. Phosphorus in water which infiltrates the soil is readily adsorbed in the upper surface. The difference between the 0-15 cm (0-6") layer and the 15-45 cm (6-18") layer show this to be so. The

Table 11. Mean and Standard Deviations of Concentration of Phosphorus Components in the Lagoons and Retention Tank Wastewater.

Period of Sampling	t-P $\bar{X}$	t-P S	$i\text{-}PO_4$ $\bar{X}$	$i\text{-}PO_4$ S
	ppm			
6/15-7/03*				
Lagoon 1	2.70	0.74	1.53	0.40
Lagoon 2	2.93	1.19	1.95	1.17
Tank 1	3.00	0.47	2.38	0.47
Tank 2	2.97	0.43	2.43	0.41
7/04-7/16**				
Lagoon 1	2.85	0.94	1.58	0.60
Lagoon 2	4.65	0.37	3.54	0.11
Tank 1	2.53	0.30	2.04	0.26
Tank 2	2.48	0.33	2.06	0.26
7/17-8/10***				
Lagoon 1	6.11+	1.30+	3.97	1.01
Lagoon 2	6.35	0.19	5.27	0.27
Tank 1	5.75	0.36	5.09	0.26
Tank 2	5.70	0.37	5.11	0.29

*Spray application water being drawn from Lagoon #2.
**Spray application water being drawn from Lagoon #1.
***Spray application water being drawn from Lagoon #2 after Lagoon #1 had been pumped into Lagoon #2 during 7/20 and 7/23.
+These values do not include the sampling while the lagoons were mixed due to sludge contamination.

Table 12. Concentration of Phosphorus Components in the Upper Soil Profile of the Spray Area during Wastewater Application.

Date of Sampling	Depth of Sampling cm	(inches)	t-P	Bray-P
	ppm			
6/22	0-15	(0-6)	266	6.7
	15-30	(6-12)	211	4.1
	30-45	(12-18)	193	3.9
7/09	0-15	(0-6)	265	9.1
	15-30	(6-12)	260	4.7
	30-45	(12-18)	268	5.1
8/07	0-15	(0-6)	290	5.4
	15-30	(6-12)	250	3.6
	30-45	(12-18)	192	3.2

15-45 cm (6-18") layer presents information that the soil at this depth remained in equilibrium while that at the 0-15 cm (0-6") layer adsorbed and/or fixed most of the P that was contained in the applied water.

Results of the t-P and i-PO_4 in the ground water samples also showed that the applied P did not leach to the ground water. These values are tabulated in Table 13. The mean value for t-P never reached above 0.3 ppm and the i-PO_4 never obtained values higher than 0.03 ppm. The tabulated results verify the fact that the P was taken up by the vegetation and that contamination of the ground water would not be the result of P infiltration.

The calculated treatment efficiency of this BLWRS was determined for P components and on the average were 96.7 and 99.6% for t-P and i-PO_4, respectively. The efficiency would be 100% if the samples were corrected for background P. The reduction percentages were determined from the time that the wastewater left the retention tank to where it came in contact with the shallow paired wells. The values indicate that the hazard of eutrophication was eliminated from any phosphorus source. Treatment efficiencies are tabulated for each sampling period in Table 14.

Carbon

In this study analysis of carbon took on two forms: Biological Oxygen Demand (BOD) and Total Organic Carbon

Table 13. Mean and Standard Deviation of Phosphorus Concentration in Ground Water Sampling Wells.

Date of Sampling	t-P $\bar{X}$	t-P S	i-PO_4 $\bar{X}$	i-PO_4 S
	ppm			
6/15	0.10*	0.02	0.01	< 0.01
6/18	0.10*	0.02	0.01	< 0.01
6/22	0.10*	0.00	0.01	0.01
6/25	0.10*	0.00	0.01	0.00
7/01	0.10*	0.00	0.02	0.03
7/06	0.10*	0.02	0.03	0.04
7/09	0.10*	0.02	0.01	0.00
7/13	0.10*	0.02	0.01	< 0.01
7/16	0.30	0.28	0.01	0.00
7/20	0.01	0.01		
7/23	0.01	0.01		
7/26	0.02	0.02	0.01	< 0.01
7/30	0.02	0.04	0.01	< 0.01
8/03	0.01	< 0.01	0.01	0.01
8/06	0.01	< 0.01	0.01	< 0.01
8/10	0.01	0.01	0.01	< 0.01
8/13	0.01	0.01	0.01	< 0.01

*Values were below detectable range of 0.1 ppm.

Table 14. Calculated Treatment Efficiency of the Barriered Landscape Water Renovation System for Concentrations of Phosphorus Components.

Period of Sampling	t-P	i-PO_4
	%	
6/15-7/03	96.5	99.5
7/04-7/16	94.0	99.3
7/17-8/10	99.7	99.9

(TOC). Values for BOD in the lagoons and the retention tank are shown in Table 15. Only a small percentage of BOD was reduced from the lagoons to the retention tank. But when comparing the wastewater used for spray application to the values found in the shallow paired wells there was a more impressive reduction.

The mean and standard deviation comparing the shallow paired wells and the deep wells for BOD are tabulated in Table 16. The values for the paired wells are slightly higher than for the deep wells. These higher values are understandable in that there is probably a higher content of easily oxidized carbon materials in the upper profile of the water table than in the 45 cm (18") depth. The percent efficiency of this BLWRS for BOD on June 29 and July 26 samplings are 67.5% and 55.3%, respectively, Table 17.

Results of the analyses for TOC can be found in Table A in the Appendix; lagoon and retention tank concentrations are presented in Table 18. The values obtained for TOC are interpreted in the same manner as the BOD data since TOC is actually a potential for BOD and the oxygen demand would be approximately the same. In comparing the shallow wells to the deep wells, Table 19, there was only a difference of 4.6 ppm which is not deemed significant since all the results were variable. Since TOC did not increase in the ground water the conclusion is

Table 15. Biological Oxygen Demand of the Lagoons and Retention Tank Wastewater at the Coldwater Information Center.

Sampling Site	Date of Sampling 6/29	7/26
	ppm	
Lagoon 1	15.0	59.0
Lagoon 2	24.0	23.0
Tank 1	20.0	17.0
Tank 2	20.0	17.0

Table 16. Mean and Standard Deviation of the Biological Oxygen Demand in the Well Water below the Barriered Landscape Water Renovation System at the Coldwater Information Center.

Date of Sampling	Shallow Paired Wells		Deep Wells	
	$\bar{X}$	S	$\bar{X}$	S
	ppm			
6/29	6.5	4.0	3.2	1.4
7/26	7.6	4.7	4.4	2.0

Table 17. Treatment Efficiency of the Barriered Landscape Water Renovation System of Biological Oxygen Demand from the Retention Tank to the Ground Water.

Date of Sampling	BOD %
6/29	67.5
7/26	55.3

Table 18. Concentration of Lagoon and Retention Tank Wastewater for Total Organic Carbon at the Coldwater Information Center.

Sampling Site	Date of Sampling 4/16	5/07	6/11	7/01	8/03
	ppm				
Lagoon 1	45	26	50	39	157
Lagoon 2	46	84	57	45	80
Tank 1		41	23	34	36
Tank 2		43	15	35	36

Table 19. Mean and Standard Deviation of Concentration of Total Organic Carbon in the Shallow Paired Wells and the Deep Wells.

Date of Sampling	Shallow Paired Wells		Deep Wells	
	$\overline{X}$	S	$\overline{X}$	S
	ppm			
4/16	22.2	13.2	10.6	2.1
5/07	16.7	7.8	9.9	2.5
6/11	11.3	6.3	9.2	4.1
7/01	11.3	6.9	9.9	3.7
8/03	11.8	4.2	10.9	5.4
AVERAGE	14.7		10.1	

that the system was removing TOC. Also, the inside wells were compared to the outside wells, Table 20. The energy trench apparently did not add to the C content of the water table since the average of the inside wells and the outside wells were the same.

Treatment efficiency was also calculated for TOC on the July 01 and August 03 samplings. The results were 67.7% for the July sampling and 67.2% for the August 03 sampling. Values in Table 21 were not corrected for background TOC. These results show that the ELWRS also greatly reduced the TOC content of the wastewater.

Table 20. Mean and Standard Deviation Comparing the Concentration of Total Organic Carbon between the Shallow Paired Wells Inside the Energy Trench and the Shallow Paired Wells Outside the Energy Trench Surrounding the Barriered Landscape Water Renovation System.

Date of Sampling	Inside Wells $\bar{X}$	Inside Wells S	Outside Wells $\bar{X}$	Outside Wells S
	ppm			
6/11	11.4	6.4	11.7	6.0
7/01	10.8	4.1	12.3	8.6
8/03	12.7	5.2	10.9	2.9
TOTAL	34.9		34.9	

Table 21. Treatment Efficiency of the Barriered Landscape Water Renovation System of Total Organic Carbon from the Retention Tank to the Ground Water.

Date of Sampling	TOC %
7/01	67.7
8/03	67.2

Microbiology

Ozonation was used primarily for odor control but had some effect upon populations of miccroorganisms in the retention tank.

The analysis for total coliform, fecal coliform, total streptococci and fecal streptococci (Tables F, G, H) gave variable results as to the germicidal effectiveness of ozonation in this situation. Comparison of the indexes from the lagoons to those of the retention tank show some increases and some decreases, but are mostly in the same order of magnitude for each organism. Because of the heavy particulate matter, temperature of the water, and other interfering factors, the ozonation cannot be considered a reliable means of reducing these bacterial populations.

Microbiological samples were obtained before the onset of wastewater application to find any indication of contamination in the wells. The first sampling on April 18 found some of the wells fairly high in total coliforms but substantially low in MPN of fecal coliforms. This established a base line of residual soil organisms against which subsequent samples would provide data of the changes in microbiological populations in the ground water after wastewater was applied. Following the first sampling for microbes, a second sample was taken on May 15. Results of this sampling showed that fecal coliform counts had been reduced. This was most likely due to flushing out of the wells a number of times since the first sampling.

After application had proceeded, two additional samples were taken. Populations of fecal coliforms remained at low numbers except for two wells on the July 6 sampling which was probably a result of sampling technique. Numbers of total coliforms were high on some of the wells as can be seen in Table E in the Appendix but was the result of soil microbes initially found in the soil giving no indication that contamination had resulted from spray application.

The data in Table F in the Appendix and Table 22 tabulating the average of fecal coliforms in the samples indicate that on July 20 the fecal coliforms had drastically increased. On July 13 the shallow paired wells had been redug deeper as a result of a drop in the water table. Apparently, contamination resulted not from the wastewater but from disturbance and possible contamination of the wells. A final microbial sample was taken on August 3 and all but four shallow wells had returned to counts below 200 organisms per 100 milliliters. This indicates that the BLWRS operational set up was still reducing fecal coliforms in the wastewater and the four wells found high were most likely a result of sampling technique. Data collected for the entire schedule of water application provided information that this type of land application for the period applied does not indicate wastewater contamination of the ground water and that health hazards are minimized.

Table 22. Average MPN of Fecal Coliforms at the Barriered Landscape Water Renovation System.

Date of Sampling	Shallow Paired Wells	Deep Wells
	MPN/100 ml	
4/18	41.9	0
5/15	20.2	0
6/18	17.3	2.2
7/06	5.5	1.5
7/20	9,148.4*	0.3
8/03	69.1	1.6

*Wells reset before this sampling.

CONCLUSION

An experiment at the Coldwater rest area and travel information center using a Modified Barriered Landscape Water Renovation System (BLWRS) achieved advanced treatment of human wastewater. The ground water aquifer was monitored continuously while applying wastewater and there was no indication that contamination, either chemical or biological, had occurred. The system performed equally well under conditions of applying either stabilized or unstabilized wastewater.

A little more than half (60%) of the wastewater applied was evapotranspired, leaving only 40% of the wastewater available for drainage. This is not representative of a typical BLWRS, but was caused by an unusually dry summer season. At no time during the treatment process was there surface ponding or soil pore clogging indicating that the BLWRS was never hydraulically overloaded.

Chemical and biological analyses of all the sampling parameters show that this system was an effective treatment system. Nitrification occurred in the upper soil profile and all indications were that denitrification was accomplished in the rhizosphere, saturated zones in the soil, and in the energy trench. Any threat of NO_3^-

contamination was removed and the efficiency was greater than 92% for all nitrogen sources. Phosphorus was fixed and/or adsorbed in the upper 15 cm (6") of the soil. Stabilized waste was effectively reduced by 96.7% for t-P and i-PO_4 reduced 99.6%. Both BOD and TOC were removed by this system. The energy trench did not increase the carbon content of the ground water.

The wastewater was ozonated before application to the soil and gave variable results in reducing total streptococcci, fecal streptococci, total coliform, and fecal coliform. Microbial contamination in land treatment systems is of great concern to local public health officials and hopefully this study will help alleviate this concern. The ozonation also removed all odors from the wastewater.

Consideration of soil characteristics along with a good management program is necessary for eradicating eutrophication of our surface waterways and any threat of contamination to the ground water. This study showed that suitable land treatment could be a very effective method of wastewater treatment.

REFERENCES

REFERENCES

Alexander, Martin. 1965. Nitrification. pp. 307-343. W. E. Bartholomew and F. E. Clark (ed.) Soil nitrogen. Agron. No. 10. Amer. Soc. of Agron. Madison, Wisconsin.

Bendixen, T. W., R. D. Hill, F. T. Dubyne, and G. G. Robeck. 1969. Cannery Waste Treatment by Spray Irrigation-Runoff. J. Water Pollut. Contr. Fed. 41:385-391.

Bouwer, Herman. 1973. Renovation secondary effluent by ground water recharge with infiltration basins. pp. 164-175. In W. E. Sopper and L. T. Kardos (ed.) Recycling treated municipal wastewater and sludge through forest and cropland. Pennsylvania State University Press, University Park, Penn.

Bouwer, H., and R. L. Chaney. 1974. Land Treatment of Wastewater. 26:133-173.

Broadbent, F. E. 1973. Factors Affecting Nitrification-Denitrification in Soils. In: Recycling Treated Municipal Wastewater and Sludge Through Forest and Cropland. Sopper, W. E., and L. T. Kardos, (ed.).

Burge, W. E., and F. E. Broadbent. 1961. Fixation of Ammonia by Organic Soils. Soil Sci. Soc. Am. Proc. 25:199-204.

Day, A. D., J. L. Stroehlein, and T. C. Tucker. 1972. Effects of Treatment Plant Effluent on Soil Properties. J. Water Pollut. Contr. Fed. 44(3):372-375.

DeVries, J. 1972. Soil Filtration of Wastewater Effluent and the Mechanism of Pore Clogging. J. Water Pollut. Contr. Fed. 44:565-573.

Ellis, B. G., and A. E. Erickson. 1969. Movement and Transformations of Various Phosphorus Compounds in Soils. Report to Michigan Water Resource Commission.

Ellis, B. G. 1973. The Soil as a Chemical Filter. In: Recycling Treated Municipal Wastewater and Sludge Through Forest and Cropland. Sopper, W. E., and L. T. Kardos (ed.). University Park, The Pennsylvania State University Press. pp.46-70.

Erickson, A. E., B. G. Ellis, J. M. Tiedje, A. R. Wolcott, C. M. Hanson, F. R. Peabody, E. C. Miller, and J. W. Thomas. 1974. Soil modification for denitrification and phosphate reduction of feedlot waste. Environmental Protection Technology Series, EPA-660/2-74 057, U. S. E. P. A.

Erickson, A. E., J. M. Tiedje, B. G. Ellis and C. M. Hanson. 1971. A Barriered Landscape Water Renovation System for removing phosphate and nitrogen from liquid feedlot waste. Procl. Int. symposium on Livestock Wastes, Amer. Soc. of Agric. Eng.

Erickson, A. E., J. M. Tiedje, B. G. Ellis, and C. M. Hanson. 1972. Initial Observations of Several Medium-sized Barriered Landscape Water Renovation Systems for Animal Waste. Proceedings of the 1972 Cornell Agr. Waste Management Conf. pp. 405-410.

Focht, D. D. and H. Joseph. 1973. An improved method for the enumeration of denitrifying bacteria. Soil Sci. of Amer. Proc. 37:698-699.

Geldreich, E. E., H. F. Clark, and C. B. Huff. 1964. A Study of Pollution Indicators in a Waste Stabilization Pond. J. Water Pollut. Contr. Fed. 36(11):1372-1379.

Hook, J. E., L. T. Kardos, and W. E. Sopper. 1973. Effect of Land Disposal of Wastewater on Soil Phosphorus Relations. In: Recycling Treated Municipal Wastewater and Sludge Through Forest and Cropland. Sopper, W. E. and L. T. Kardos, (ed.) University Park, The Pennsylvania State University Press. pp. 200-219.

Jacobs, L. W. (editor). 1977. Utilizing Municipal Sewage Wastewaters and Sludges on Land for Agricultural Production. North Central Regional Extension Publication No. 52.

Juo, A. S. R., and B. G. Ellis. 1968. Particle Size Distribution of Aluminum, Iron, and Calcium Phosphates in Soil Profiles. Soil Sci. 106:374-380.

Lance, J. C. 1972. Nitrogen Removal by Soil Mechanisms. J. Water Pollut. Contr. Fed. 44:1352-1361.

Law, J. P., R. E. Thomas, and L. H. Myers. 1970. Cannery Wastewater Treatment by High Rate Spray on Grassland. J. Water Pollut. Contr. Fed. 42:1621-1631.

Lindsay, W. L., and E. C. Moreno. 1960. Phosphate Phase Equilibria in Soils. Soil Sci. Soc. Amer. Proc. 24:177-182.

Luley, H. G. 1963. Spray Irrigation of Vegetable and Food Processing Wastes. J. Water Pollut. Contr. Fed. 35:1252-1261.

Meek, B. D., L. B. Grass and A. J. MacKenzie. 1969. Applied Nitrogen Losses in Relation to Oxygen Status of Soils. Soil Sci. Soc. of Amer. Proc. 33:575-578.

Miller, R. H. 1973. The Soil as a Biological Filter. In: Recycling Treated Municipal Wastewater and Sludge Through Forest and Cropland. Sopper, W. E., and L. T. Kardos, (ed.). University Park, The Pennsylvania State University Press. pp. 71-94.

Murrmann, R. P., and F. R. Koutz. 1972. Role of Soil Chemical Processes in Reclamation of Wastewater Applied to Land. Chapt. 4 in Wastewater Management By Disposal on the Land. Corps. of Engineers. U. S. Army. Cold Regions Research and Engineering Laboratory. Hanover, N. H.

Office of Technology Transfer, Environmental Protection Agency. 1974. Methods for Chemical Analysis of Water and Wastes, EPA - 625/6-74/003.

Office of Research and Development, Environmental Protection Agency. 1976. Wastewater: Is Muskegon County's Solution Your Solution?

Office of Research and Development, Environmental Protection Agency. 1978. Microbial Methods for Monitoring the Environment, EPA - 600/8-78-017.

Parkinson, J. A., and S. E. Allen. 1975. A Wet Oxidation Procedure Suitable for the Determination of Nitrogen and Mineral Nutrients in Biological Material. Comm. Soil Science and Plant Analysis. 6(1):1-11.

Reed, S. C. (co-ord.). 1972. Wastewater Management by Disposal on the Land. U. S. Army Cold Regions Res. Eng. Lab. Spec. Rep. 171, Hanover, N. H.

Sopper, W. E., and L. T. Kardos. 1973. Vegetation Responses to Irrigation with Treated Municipal Effluent. In: Recycling Treated Municipal Wastewater and Sludge through Forest and Cropland. Sopper, W. E., and L. T. Kardos, (ed.). University Park, the Pennsylvania State University Press. pp. 271-294.

Thomas, R. E. 1973. The Soil as a Physical Filter. In: Recycling Treated Municipal Wastewater and Sludge Through Forest and Cropland. Sopper, W. E., and L. T. Kardos, (ed.). University Park, the Pennsylvania State University Press. pp. 38-45.

Thomas, R. E., B. Bledsoe, and K. Jackson. 1976. Overland Flow Treatment of Raw Wastewater with Enhanced Phosphorus Removal. Robert S. Kerr Environmental Research Laboratory. EPA Series No. 600/2-76-131. p. 36.

Tiedje, J. M. 1978. Denitrification in Soil. In: Microbiology - 1978. Schlessinger, D., (ed.) American Society for Microbiology. pp. 362-366.

Woldendorp, J. W., K. Dilz and G. J. Kolenbrander. 1966. The fate of fertilizer nitrogen on permanent grassland soils. Proc. Gen. Mtg. Europ. Grassland Fed. 1965:53-76.

APPENDIX

Table A. Nutrient Concentrations of Ground Water Monitoring Wells on the Barriered Landscape Water Renovation System Spray Area at the Coldwater Rest Area.

Date 4/16

Sampling Site	NH_3	NO_2	NO_3	i-PO_4	t-P	TKN	TOC
	ppm						
1	0.45	0.054	29.3	0.12	0.07		
1A	0.65	0.041	9.3	0.17	0.04		
2	0.29	0.054	46.5	0.22	0.03		
2A	0.56	0.039	53.9	0.09	0.02		
3	0.46	0.033	12.3	0.18	0.08		
3A	1.15	0.034	47.8	0.16	0.05		
4	1.15	0.049	25.7	0.14	0.03		
4A	1.17	0.060	21.0	0.14	0.03		
5	0.87	0.038	6.3	0.20	0.02		
5A	0.25	0.033	36.9	0.16	0.05		
6	1.53	0.068	14.6	0.25	0.03	0.5	43
6A	1.15	0.038	5.0	0.32	0.42	0.7	
7	0.54	0.043	1.2	0.18	0.11	1.5	
7A	0.94	0.025	0.6	0.17	0.06	1.1	13
8							
8A							
9	2.61	0.034	0.8	0.11	0.03	3.0	27
9A	0.87	0.026	2.9	0.18	0.05	0.9	19
10	3.33	0.029	0.7	0.12	0.14		
10A	3.04	0.032	0.9	0.22	0.12		
11	0.58	0.031	7.5	0.15	0.43	0.5	
11A	0.75	0.044	10.0	0.23	0.06	0.9	
12	0.36	0.030	21.8	0.13	0.07	0.4	
12A	1.14	0.022	7.2	0.13	0.09	0.9	
13	0.28	0.026	32.2	0.05	0.03	0.4	
13A	1.29	0.032	2.7	0.15	0.01	0.3	
14	0.27	0.049	37.0	0.18	0.03	0.6	
14A	0.25	0.038	31.0	0.11	0.03	1.1	29
15	0.59	0.037	15.1	0.12	0.03	0.7	11
15A	1.66	0.043	21.2	0.18	0.01	0.5	
16	0.59	0.041	20.1	0.12	0.01	0.2	
16A	0.76	0.059	0.5	0.18	0.01	0.3	
17	0.79	0.040	24.3	0.15	0.10	0.3	40
17A	1.02	0.043	17.8	0.11	0.10	0.3	
18	0.49	0.039	45.1	0.12	0.02	0.7	
18A	0.24	0.037	11.3	0.15	<0.01	0.7	
19	0.39	0.038	26.8	0.11	0.06	0.3	10
19A	0.94	0.038	9.1	0.09	0.03	0.5	
20	1.31	0.029	19.3	0.09	0.01	0.1	8
20A	0.56	0.034	3.0	0.14	0.02	1.0	
21	0.92	0.026	0.7	0.20	0.02	0.5	9
22	1.61	0.026	2.3	0.20	0.03	0.1	10
23	0.29	0.033	2.0	0.12	0.01	0.4	15
24	0.31	0.028	1.6	0.22	<0.01	0.7	11
25	2.12	0.035	3.4	0.27	<0.01	0.1	11
26	1.00	0.037	3.2	0.23	0.13	0.5	
27	1.10	0.025	2.4	0.16	0.05	0.3	
28	0.60	0.031	0.6	0.08	0.19	0.6	
29	1.39	0.027	1.6	0.15	0.03	0.3	10
30	0.41	0.025	2.3	0.19	0.02	0.6	8
31	0.44	0.027	5.1	0.23	0.21	0.7	9
32	0.53	0.028	1.2	0.20	0.04	1.9	12
Lagoon 1	0.33	0.062	0.6	0.90	2.08	6.8	45
Lagoon 2	36.5	0.226	0.9	4.87	5.57	47.3	46
Tank 1							
Tank 2							

Table A. (Continued)

Date 5/07

Sampling Site	NH_3	NO_2	NO_3	$i\text{-}PO_4$	t-P	TKN	TOC
	ppm						
1	0.11	0.008	32.2	0.005	0.02	2.8	13
1A	0.33	0.020	3.2	0.044	<0.01	0.8	20
2	1.34	0.033	32.9	0.066	0.01	0.5	
2A	0.15	0.016	46.3	0.019	0.01	20.1	10
3	0.20	0.022	2.0	0.031	0.08	1.6	
3A	0.13	0.012	20.8	0.018	0.06	0.9	
4	0.22	0.028	15.9	0.028	0.02	0.4	30
4A	0.22	0.009	7.0	0.012	<0.01	1.2	14
5	0.27	0.009	9.1	0.012	<0.01	0.5	
5A	0.28	0.019	18.8	0.008	<0.01	0.3	15
6	0.13	0.014	1.8	0.017	<0.01	0.3	17
6A	0.19	0.019	14.2	0.017	<0.01	0.5	11
7							
7A	0.18	0.024	1.1	0.017	<0.01	0.6	
8	0.26	0.253	0.4	0.037		3.2	
8A	0.12	0.006	0.1	0.006	<0.01	0.3	19
9	2.18	0.005	0.1	0.006	<0.01	2.6	
9A	0.23	0.014	0.1	0.014	<0.01	0.7	18
10	0.91	0.010	0.1	0.006	0.02	1.7	23
10A	1.06	0.006	0.1	<0.001	0.02	1.8	20
11	0.11	0.012	4.5	0.013	0.02	0.5	11
11A	0.09	0.007	5.7	0.009	<0.01	0.8	14
12	0.01	0.004	15.0	0.006	0.02	0.3	16
12A	0.01	0.003	5.4	0.005	<0.01	0.2	
13	0.13	0.009	14.7	0.008	<0.01	0.4	36
13A	0.14	0.014	0.3	0.015	0.01	<0.1	15
14	0.11	0.096	28.9	0.010	0.01	0.8	
14A	0.16	0.161	18.8	0.013	0.05	2.6	38
15	0.20	0.023	8.1	0.026	0.05	0.7	10
15A	0.19	0.019	1.5	0.021	0.04	0.1	9
16	0.26	0.022	17.6	0.032	0.01	0.3	12
16A	0.15	0.015	0.2	0.012	<0.01	0.3	
17	0.17	0.036	31.9	0.017	0.03	2.0	28
17A	0.15	0.019	35.4	0.015	0.03	<0.1	10
18	0.21	0.022	43.9	0.020	0.03	0.2	
18A	0.21	0.023	17.3	0.024	0.03	0.2	12
19	0.26	0.026	27.6	0.029	<0.01	0.1	13
19A	0.20	0.022	10.4	0.020	<0.01	<0.1	12
20	0.06	0.006	39.2	0.007	<0.01	<0.1	10
20A	0.02	0.003	10.3	0.004	<0.01	<0.1	11
21	0.04	0.003	0.4	0.004	0.03	<0.1	12
22	0.01	0.002	2.0	0.006	0.01	<0.1	7
23	0.01	0.002	0.2	0.005	0.04	<0.1	11
24	0.03	<0.002	0.1	0.002	<0.01	0.2	
25	0.01	<0.002	1.2	0.002	<0.01	0.5	7
26	0.02	0.004	1.3	0.006	<0.01	<0.1	9
27	0.05	0.010	0.6	0.014	0.08	<0.1	
28	0.05	0.010	0.1	0.012	0.02	0.1	14
29	0.07	0.011	1.7	0.017	0.02	<0.1	12
30	0.07	0.007	2.8	0.005	<0.01	<0.1	7
31	0.02	<0.002	8.1	0.003	0.01	1.5	11
32	0.07	0.006	2.0	0.008	0.01	0.1	9
Lagoon 1	12.7	0.022	0.1	2.99	3.45	14.9	26
Lagoon 2	4.6	1.59	2.7	1.30	3.32	20.8	84
Tank 1	17.8	0.037	0.1	3.06	3.65	23.0	41
Tank 2	19.6	0.035	0.1	3.09	3.35	26.0	48

Table A. (Continued)

Date 5/11							
Sampling Site	NH_3	NO_2	NO_3	i-PO_4	t-P	TKN	TOC
	ppm						
1	0.05	0.001	34.2	<0.01	<0.01	<0.1	
1A	0.13	0.003	1.3	<0.01	<0.01	0.2	
2	0.10	0.010	33.3	<0.01	<0.01	0.2	
2A	0.42	0.001	63.2	<0.01	<0.01	0.1	
3	0.06	0.003	2.1	<0.01	<0.01	<0.1	
3A	0.10	<0.001	19.5	<0.01	<0.01	<0.1	
4	0.11	0.019	14.1	<0.01	<0.01	<0.1	
4A	0.33	0.017	4.6	<0.01	<0.01	0.6	
5	0.23	0.012	6.8	<0.01	0.05	0.3	
5A	0.45	0.005	9.7	<0.01	<0.01	0.8	
6	0.08	0.001	2.0	<0.01	0.04	0.1	
6A	0.10	0.002	12.1	<0.01	<0.01	0.3	
7							
7A	0.08	0.003	1.3	<0.01	<0.01	0.1	
8	0.36	0.061	0.2	<0.01	<0.01	0.8	
8A	0.22	0.001	<0.1	<0.01	<0.01	0.1	
9	2.51	0.003	<0.1	<0.01	<0.01	2.9	
9A	0.25	0.003	<0.1	<0.01	<0.01	0.4	
10	1.20	0.004	<0.1	<0.01	0.03	1.8	
10A	1.10	0.002	<0.1	<0.01	0.03	1.5	
11	0.39	<0.001	4.5	<0.01	0.02	0.5	
11A	0.15	0.006	13.6	<0.01	0.07	0.4	
12	0.11	0.001	15.2	<0.01	0.01	0.6	
12A	0.09	<0.001	4.4	<0.01	0.01	0.3	
13	0.05	0.002	7.4	<0.01	0.01	0.1	
13A	0.06	0.004	0.6	<0.01	0.01	0.2	
14	0.15	0.048	12.3	<0.01	0.09	1.0	
14A	0.21	0.126	7.8	0.01	0.06	1.3	
15	0.07	0.003	9.9	0.01	0.04	0.2	
15A	0.07	0.002	3.4	0.01	0.03	<0.1	
16	0.07	0.003	24.1	0.02	0.03	0.4	
16A	0.08	0.001	0.6	<0.01	0.07	0.6	
17	0.08	<0.001	25.3	<0.01	0.01	<0.1	
17A	0.07	0.002	39.2	<0.01	<0.01	0.3	
18	0.05	0.004	37.9	<0.01	<0.01	0.4	
18A	0.07	0.001	21.1	<0.01	0.02	0.3	
19	0.11	0.002	32.3	<0.01	0.11	0.3	
19A	0.05	<0.001	13.0	<0.01	<0.01	<0.1	
20	0.14	0.008	48.3	0.01	<0.01	0.2	
20A	0.05	<0.001	14.2	<0.01	<0.01	0.1	
21	0.04	<0.001	1.0	<0.01	<0.01	<0.1	
22	0.05	<0.001	1.3	<0.01	0.03	0.1	
23	0.05	<0.001	0.3	<0.01	0.08	0.2	
24	0.05	<0.001	0.1	<0.01	0.03	0.1	
25	0.05	<0.001	1.0	<0.01	0.01	0.2	
26	0.05	<0.001	1.4	<0.01	0.01	0.1	
27	0.05	<0.001	0.7	<0.01	0.04	0.5	
28	0.05	<0.001	0.1	0.01	0.05	0.5	
29	0.05	<0.001	2.1	0.02	0.05	0.3	
30	0.05	<0.001	2.9	0.01	0.16	<0.1	
31	0.71	<0.001	10.7	0.17	0.02	1.2	
32	0.09	0.001	2.4	0.01	<0.01	0.3	
Lagoon 1	13.8	0.008	0.1	3.00	3.15	18.8	
Lagoon 2	2.05	1.32	0.2	0.91	2.37	13.3	
Tank 1							
Tank 2							

Table A. (Continued)

Date 6/11

Sampling Site	NH_3	NO_2	NO_3	i-PO_4	t-P	TKN	TOC
	ppm						
1	0.21	0.023	30.1	0.02	<0.1	0.2	6
1A	0.39	0.050	23.2	0.02	<0.1	1.0	18
2	0.18	0.027	3.8	0.03	<0.1	0.3	5
2A	0.20	0.032	29.4	0.02	<0.1	0.2	10
3	0.09	0.028	1.2	0.02	<0.1	0.3	11
3A	0.17	0.045	4.6	0.02	<0.1	0.1	8
4	0.17	0.078	13.4	0.01	<0.1	0.3	7
4A	0.42	0.041	1.6	0.01	<0.1	0.9	24
5	0.26	0.059	0.8	0.01	<0.1	1.0	9
5A	0.83	0.042	0.8	0.01	<0.1	2.1	13
6	0.24	0.052	1.1	0.03	<0.1	0.5	9
6A	0.30	0.121	2.3	0.03	<0.1	0.2	14
7	0.30	0.074	0.7	0.03	<0.1	0.1	8
7A	0.16	0.075	0.6	0.02	<0.1	0.2	10
8	0.46	0.095	0.9	0.02	<0.1	0.8	11
8A	0.45	0.076	0.7	0.01	<0.1	0.7	7
9	1.58	0.063	0.6	0.02	<0.1	2.1	34
9A	0.29	0.062	0.6	0.01	<0.1	0.7	11
10	0.97	0.056	0.6	0.01	<0.1	1.5	21
10A	0.50	0.038	0.6	<0.01	<0.1	1.0	13
11	0.26	0.035	0.7	0.01	<0.1	0.2	11
11A	0.37	0.041	1.4	0.01	<0.1	0.4	12
12	0.13	0.077	5.1	0.01	<0.1	0.2	10
12A	0.71	0.073	0.9	0.01	<0.1	0.7	12
13	0.12	0.082	1.3	0.01	<0.1	0.1	12
13A	0.16	0.072	0.7	0.01	<0.1	0.3	29
14	0.18	0.094	6.0	0.01	<0.1	0.6	14
14A	0.29	0.054	0.7	0.01	<0.1	0.6	10
15	0.07	0.097	2.1	0.01	<0.1	<0.1	10
15A	0.08	0.080	4.9	0.01	<0.1	0.3	7
16	0.06	0.062	3.0	0.01	<0.1	<0.1	10
16A	0.06	0.064	0.7	0.01	<0.1	0.1	6
17	0.02	0.045	16.0	0.01	<0.1	<0.1	14
17A	0.05	0.047	43.4	0.01	<0.1	<0.1	6
18	0.04	0.053	25.6	0.01	<0.1	<0.1	7
18A	0.04	0.046	30.7	0.01	0.1	<0.1	6
19	0.07	0.035	30.8	<0.01	<0.1	0.1	11
19A	0.03	0.030	10.4	<0.01	<0.1	<0.1	8
20	0.06	0.050	31.0	<0.01	<0.1	<0.1	8
20A	0.04	0.033	5.1	<0.01	<0.1	0.1	10
21	0.13	0.045	2.2	0.01	<0.1	0.2	7
22	0.67	0.002	3.2	0.01	<0.1	0.2	10
23	0.56	0.002	0.3	0.01	<0.1	0.2	8
24	0.80	0.003	0.2	0.07	<0.1	0.2	9
25	0.29	0.002	1.4	0.01	<0.1	0.2	21
26	0.59	0.028	0.9	0.01	<0.1	0.3	7
27	0.57	0.026	0.7	0.01	<0.1	0.1	7
28	0.72	0.011	0.3	0.01	<0.1	0.7	
29	0.35	0.031	3.8	0.05	<0.1	0.4	10
30	0.61	0.003	2.0	0.02	<0.1	0.2	7
31	0.71	0.003	2.7	0.01	<0.1	<0.1	6
32	0.64	0.003	3.0	0.01	<0.1	0.2	9
Lagoon 1	8.73	0.006	0.8	2.20	3.1	13.5	50
Lagoon 2	10.4	0.064	0.3	2.35	3.8	15.5	57
Tank 1	0.62	0.081	20.4	2.59	2.7	4.3	23
Tank 2	0.73	0.068	19.6	2.63	2.6	3.8	15

Table A. (Continued)

Date 6/15							
Sampling Site	NH_3	NO_2	NO_3	$i\text{-}PO_4$	t-P	TKN	TOC
	ppm						
1	0.01	0.001	27.3	<0.01	<0.1	<0.1	
1A	0.26	0.016	22.2	<0.01	<0.1	0.9	
2	0.07	0.009	2.7	<0.01	<0.1	0.8	
2A	0.03	0.002	24.5	<0.01	<0.1	0.2	
3	0.02	0.001	2.0	<0.01	<0.1	0.3	
3A	<0.01	0.007	2.2	<0.01	0.2	0.3	
4	0.16	0.042	14.3	<0.01	<0.1	0.3	
4A	0.37	0.021	2.2	<0.01	<0.1	1.0	
5	0.24	0.020	0.6	<0.01	<0.1	0.8	
5A	0.84	0.002	0.1	<0.01	<0.1	1.2	
6	0.02	0.001	0.7	<0.01	<0.1	0.3	
6A	0.15	0.058	1.9	<0.01	<0.1	0.4	
7	0.03	0.007	0.3	<0.01	<0.1	0.3	
7A	0.02	0.001	<0.1	<0.01	<0.1	0.4	
8	0.28	0.006	<0.1	<0.01	<0.1	0.6	
8A	0.27	0.002	<0.1	<0.01	<0.1	0.8	
9	1.64	0.003	<0.1	<0.01	<0.1	2.4	
9A	0.15	0.001	<0.1	<0.01	<0.1	0.7	
10	0.95	0.003	<0.1	<0.01	<0.1	1.5	
10A	0.51	0.001	<0.1	<0.01	<0.1	0.7	
11	0.04	0.001	0.2	<0.01	<0.1	0.1	
11A	0.35	0.003	0.1	<0.01	<0.1	0.6	
12	0.03	0.001	5.6	<0.01	<0.1	0.1	
12A	0.51	0.013	1.5	<0.01	<0.1	0.7	
13	0.03	0.008	0.3	<0.01	<0.1	0.1	
13A	0.34	0.013	<0.1	<0.01	<0.1	0.7	
14	0.18	0.021	5.0	<0.01	<0.1	0.7	
14A	0.25	0.004	0.1	<0.01	<0.1	0.9	
15	<0.01	0.018	3.4	<0.01	<0.1	<0.1	
15A	<0.01	0.002	1.9	<0.01	<0.1	<0.1	
16	0.01	0.001	5.1	<0.01	<0.1	0.1	
16A	0.01	0.001	<0.1	<0.01	<0.1	0.2	
17	<0.01	0.002	13.9	<0.01	<0.1	<0.1	
17A	<0.01	0.003	47.6	<0.01	<0.1	<0.1	
18	<0.01	0.001	13.6	<0.01	<0.1	0.1	
18A	<0.01	0.002	20.2	0.03	<0.1	<0.1	
19	0.06	0.003	29.3	0.01	<0.1	<0.1	
19A	<0.01	0.006	7.4	<0.01	<0.1	0.1	
20	0.01	0.013	29.7	<0.01	<0.1	<0.1	
20A	<0.01	0.008	2.6	<0.01	<0.1	0.1	
21	<0.01	0.021	1.6	<0.01	<0.1	0.1	
22	<0.01	0.001	2.6	<0.01	<0.1	0.5	
23	<0.01	0.002	0.1	0.02	<0.1	0.2	
24	0.03	0.002	<0.1	<0.01	<0.1	0.4	
25	0.01	0.002	0.9	<0.01	<0.1	0.2	
26	0.02	0.057	0.6	<0.01	<0.1	0.2	
27	<0.01	0.008	0.5	<0.01	<0.1	0.1	
28	0.10	0.020	<0.1	<0.01	<0.1	0.7	
29	0.06	0.004	4.0	0.02	<0.1	0.3	
30	0.01	0.003	1.5	<0.01	<0.1	0.5	
31	0.07	0.003	2.4	0.01	<0.1	0.4	
32	0.01	0.004	2.9	<0.01	<0.1	0.2	
Lagoon 1	6.31	0.005	0.5	1.99	2.5	9.6	
Lagoon 2	3.21	0.289	0.2	0.99	2.2	10.5	
Tank 1	6.85	1.83	0.9	2.21	3.2	11.9	
Tank 2	6.85	1.97	0.9	2.30	2.9	10.8	

Table A. (Continued)

Date 6/18							
Sampling Site	NH_3	NO_2	NO_3	i-PO_4	t-P	TKN	TOC
	ppm						
1	0.12	0.013	26.0	0.02	<0.1	<0.1	
1A	0.21	0.048	16.1	0.02	<0.1	0.1	
2	0.20	0.029	4.3	0.03	<0.1	0.2	
2A	0.08	0.007	18.1	0.01	<0.1	<0.1	
3	0.08	0.010	4.0	0.01	<0.1	0.1	
3A	0.11	0.011	1.6	0.02	<0.1	0.2	
4	0.21	0.052	15.8	0.01	<0.1	<0.1	
4A	0.32	0.020	6.7	0.01	<0.1	0.5	
5	0.43	0.014	0.5	<0.01	<0.1	0.7	
5A	1.20	0.009	<0.1	<0.01	<0.1	1.4	
6	0.04	0.005	2.7	<0.01	<0.1	<0.1	
6A	0.12	0.059	3.0	<0.01	<0.1	0.2	
7	0.13	0.025	0.3	0.01	<0.1	0.2	
7A	0.09	0.008	<0.1	0.01	<0.1	0.2	
8	0.34	0.020	<0.1	0.02	0.1	0.5	
8A	0.30	0.007	<0.1	0.01	0.1	1.3	
9	1.42	0.007	<0.1	0.01	<0.1	1.9	
9A	0.25	0.007	<0.1	0.01	<0.1	0.6	
10	1.13	0.011	<0.1	0.01	<0.1	1.5	
10A	0.60	0.006	<0.1	0.01	<0.1	0.7	
11	0.06	0.004	0.4	0.01	<0.1	0.1	
11A	0.35	0.011	0.1	0.01	<0.1	0.5	
12	0.07	0.010	6.7	0.01	<0.1	<0.1	
12A	0.53	0.016	2.3	0.01	<0.1	0.5	
13	0.10	0.011	0.1	0.01	<0.1	0.1	
13A	0.29	0.015	0.2	0.01	<0.1	0.5	
14	0.13	0.013	1.5	0.01	0.1	0.5	
14A	0.30	0.007	<0.1	0.01	0.1	0.5	
15	0.05	0.014	5.2	0.01	<0.1	<0.1	
15A	0.01	0.005	2.8	0.01	<0.1	<0.1	
16	0.04	0.010	3.6	0.01	<0.1	0.1	
16A	0.13	0.016	<0.1	0.02	0.1	0.2	
17	0.02	0.009	13.7	0.01	<0.1	0.1	
17A	0.01	0.006	44.7	0.01	<0.1	0.1	
18	0.04	0.009	13.6	0.01	<0.1	<0.1	
18A	0.06	0.011	14.2	0.01	0.3	<0.1	
19	0.04	0.021	28.9	0.01	<0.1	0.1	
19A	0.02	0.030	7.6	0.01	<0.1	0.3	
20	0.03	0.025	27.9	0.01	<0.1	0.1	
20A	0.03	0.014	2.4	0.01	<0.1	0.5	
21	<0.01	0.009	1.5	0.01	<0.1	0.2	
22	<0.01	0.006	2.7	0.01	<0.1	0.5	
23	<0.01	0.002	0.2	0.01	<0.1	0.3	
24	0.04	0.003	<0.1	0.01	<0.1	0.4	
25	0.02	0.005	1.1	0.01	<0.1	0.3	
26	0.05	0.064	0.7	0.01	<0.1	0.4	
27	0.03	0.009	0.5	0.01	<0.1	0.1	
28	0.16	0.010	<0.1	0.01	<0.1	0.6	
29	0.06	0.006	4.4	0.01	<0.1	0.2	
30	0.06	0.008	1.4	0.01	<0.1	0.3	
31	0.08	0.004	6.7	0.01	<0.1	<0.1	
32	0.06	0.004	2.9	0.01	<0.1	0.2	
Lagoon 1	4.83	0.022	0.1	1.59	2.1	9.2	
Lagoon 2	3.56	0.141	0.1	1.16	1.9	9.7	
Tank 1	1.97	3.80	3.6	2.22	2.7	5.4	
Tank 2	2.32	3.90	3.9	2.27	2.8	5.2	

Table A. (Continued)

Date 6/22

Sampling Site	NH_3	NO_2	NO_3	i-PO_4	t-P	TKN	TOC
	ppm						
1	0.04	0.002	22.4	<0.01	0.1	0.7	
1A	0.06	0.027	16.1	<0.01	<0.1	<0.1	
2	0.05	0.007	5.6	<0.01	<0.1	0.4	
2A	0.04	0.004	20.9	<0.01	<0.1	0.1	
3	0.03	0.002	4.0	<0.01	<0.1	0.1	
3A	0.02	0.002	2.9	<0.01	0.1	0.4	
4	0.08	0.033	17.5	<0.01	<0.1	0.2	
4A	0.31	0.013	3.8	<0.01	<0.1	0.6	
5	0.20	0.016	0.2	<0.01	<0.1	0.5	
5A	1.34	0.003	0.1	<0.01	<0.1	1.4	
6	0.02	0.001	1.4	<0.01	<0.1	0.4	
6A	0.02	0.046	5.1	<0.01	<0.1	0.2	
7	0.04	0.006	0.2	0.01	<0.1	0.1	
7A	0.02	0.004	0.1	<0.01	<0.1	0.2	
8	0.12	0.014	0.1	<0.01	<0.1	0.3	
8A	0.21	0.005	0.1	<0.01	<0.1	0.5	
9	1.68	0.008	0.1	0.01	<0.1	1.8	
9A	0.20	0.004	0.1	0.01	<0.1	0.6	
10	1.00	0.004	0.1	<0.01	<0.1	1.2	
10A	0.53	0.001	0.1	<0.01	<0.1	0.8	
11	0.02	0.001	0.6	<0.01	<0.1	1.5	
11A	0.42	0.003	0.1	0.01	<0.1	0.9	
12	0.05	0.010	6.6	0.01	<0.1	0.2	
12A	0.21	0.014	5.1	<0.01	<0.1	0.5	
13	0.06	0.001	0.3	0.10	<0.1	0.2	
13A	0.16	0.033	0.4	0.01	<0.1	0.4	
14	0.10	0.010	2.1	0.01	0.1	0.8	
14A	0.27	0.001	0.1	<0.01	<0.1	0.6	
15	0.02	0.002	4.7	<0.01	<0.1	0.4	
15A	<0.01	0.034	2.7	0.01	0.1	0.2	
16	0.06	0.004	6.6	<0.01	0.1	0.9	
16A	0.06	0.004	0.2	<0.01	<0.1	0.3	
17	0.05	0.005	9.6	<0.01	<0.1	0.2	
17A	0.06	0.001	56.9	<0.01	<0.1	0.1	
18	0.05	0.005	14.6	<0.01	<0.1	0.1	
18A	0.04	0.005	12.2	<0.01	<0.1	0.3	
19	0.04	0.007	41.1	<0.01	<0.1	<0.1	
19A	0.03	0.014	5.7	<0.01	<0.1	0.2	
20	0.03	0.010	29.6	<0.01	<0.1	0.2	
20A	0.02	0.020	4.4	<0.01	0.1	0.2	
21	0.02	0.007	1.6	<0.01	<0.1	<0.1	
22	<0.01	0.001	3.8	<0.01	0.1	0.2	
23	<0.01	0.001	0.4	<0.01	<0.1	0.1	
24	0.03	0.005	0.3	<0.01	<0.1	0.3	
25	0.01	0.009	1.1	<0.01	<0.1	0.1	
26	<0.01	0.027	0.8	<0.01	0.1	0.2	
27	<0.01	0.004	0.6	<0.01	<0.1	0.1	
28	0.02	0.005	<0.1	<0.01	0.1	0.4	
29	<0.01	0.016	4.6	0.02	<0.1	0.4	
30	<0.01	0.027	1.5	0.02	<0.1	0.3	
31	0.04	0.046	11.5	0.05	0.1	<0.1	
32	0.04	0.095	3.0	0.02	0.1	0.2	
Lagoon 1	4.07	0.041	0.3	1.37	2.7	16.6	
Lagoon 2	5.70	0.215	0.3	1.28	2.5	13.9	
Tank 1	5.89	0.594	2.7	1.97	2.6	9.8	
Tank 2	5.56	0.625	2.9	2.03	2.6	9.5	

Table A. (Continued)

Date 6/25

Sampling Site	NH_3	NO_2	NO_3	i-PO_4	t-P	TKN	TOC
	ppm						
1	0.06	0.015	14.8	<0.01	<0.1	<0.1	
1A	0.12	0.030	13.4	<0.01	<0.1	<0.1	
2	0.08	0.019	5.7	0.01	0.1	0.2	
2A	0.04	0.014	14.8	<0.01	<0.1	<0.1	
3	0.03	0.013	5.5	<0.01	<0.1	<0.1	
3A	0.02	0.017	4.2	<0.01	<0.1	<0.1	
4	0.12	0.033	20.8	<0.01	<0.1	<0.1	
4A	0.21	0.025	5.4	<0.01	<0.1	0.7	
5	0.21	0.017	0.2	<0.01	<0.1	0.4	
5A	1.40	0.015	0.1	<0.01	<0.1	1.4	
6	0.01	0.022	2.3	<0.01	<0.1	<0.1	
6A	0.06	0.049	4.3	<0.01	<0.1	0.2	
7	0.10	0.023	0.3	<0.01	<0.1	0.2	
7A	0.04	0.023	0.3	<0.01	<0.1	0.3	
8	0.15	0.021	<0.1	<0.01	<0.1	0.3	
8A	0.22	0.015	<0.1	<0.01	<0.1	0.4	
9	1.55	0.014	<0.1	<0.01	<0.1	1.6	
9A	0.20	0.017	<0.1	<0.01	<0.1	0.5	
10	1.00	0.015	<0.1	<0.01	<0.1	1.4	
10A	0.51	0.013	<0.1	<0.01	<0.1	0.8	
11	0.03	0.008	0.4	<0.01	<0.1	0.2	
11A	0.51	0.013	0.1	<0.01	<0.1	0.9	
12	0.05	0.009	6.7	<0.01	<0.1	0.3	
12A	0.17	0.024	5.7	<0.01	<0.1	0.3	
13	0.03	0.009	0.2	<0.01	<0.1	0.3	
13A	0.06	0.026	0.3	<0.01	<0.1	0.3	
14	0.14	0.015	1.7	<0.01	<0.1	0.8	
14A	0.26	0.011	0.1	<0.01	<0.1	1.0	
15	0.03	0.011	3.9	<0.01	<0.1	0.1	
15A	0.03	0.014	5.4	<0.01	<0.1	0.1	
16							
16A	0.08	0.012	0.1	<0.01			
17	<0.01	0.008	43.5	<0.01	<0.1	<0.1	
17A	<0.01	0.010	8.1	<0.01	<0.1	0.1	
18	<0.01	0.008	14.8	<0.01	<0.1	<0.1	
18A	<0.01	0.012	8.9	<0.01	<0.1	<0.1	
19	0.03	0.014	35.6	<0.01	<0.1	0.1	
19A	0.01	0.018	7.0	<0.01	<0.1	0.1	
20	0.01	0.019	26.4	<0.01	<0.1	<0.1	
20A	0.01	0.022	4.0	<0.01	<0.1	<0.1	
21	<0.01	0.007	2.0	<0.01	<0.1	0.2	
22	<0.01	0.011	4.2	<0.01	<0.1	0.4	
23	<0.01	0.009	0.3	<0.01	<0.1	0.1	
24	0.03	0.008	0.2	<0.01	<0.1	0.2	
25	0.04	0.011	1.1	<0.01	<0.1	0.3	
26	<0.01	0.029	0.8	<0.01	<0.1	0.1	
27	<0.01	0.011	0.8	<0.01	<0.1	0.2	
28	0.04	0.009	0.1	<0.01	<0.1	0.3	
29	0.01	0.014	3.9	0.01	<0.1	0.2	
30	0.03	0.017	1.5	0.01	0.1	<0.1	
31	0.01	0.008	13.6	<0.01	0.1	0.2	
32	0.01	0.006	3.0	<0.01	0.1	0.3	
Lagoon 1	8.05	0.017	0.6	1.92	2.7	14.1	
Lagoon 2	9.58	0.071	0.2	1.93	2.6	14.9	
Tank 1	6.83	0.890	2.6	2.30	2.5	9.6	
Tank 2	6.66	0.901	3.1	2.35	2.5	9.7	

Table A. (Continued)

Date 6/29*

Sampling Site	NH_3	NO_2	NO_3	$i-PO_4$	t-P	TKN	TOC
	ppm						
1							
1A							
2							
2A							
3							
3A							
4							
4A							
5							
5A							
6							
6A							
7							
7A							
8							
8A							
9	1.54	0.003	<0.1	<0.01	<0.1	1.6	
9A	0.23	0.003	<0.1	<0.01	0.1	0.3	
10	1.02	0.005	<0.1	<0.01	<0.1	1.0	
10A	0.53	0.001	<0.1	<0.01	0.1	0.7	
11	0.08	0.001	0.1	<0.01	<0.1	0.2	
11A	0.56	0.006	<0.1	<0.01	<0.1	0.7	
12	0.08	0.002	3.9	<0.01	0.1	0.3	
12A	0.11	0.022	5.6	<0.01	<0.1	0.1	
13	0.07	0.003	0.2	<0.01	<0.1	0.1	
13A	0.08	0.022	0.1	<0.01	0.1	0.2	
14	0.17	0.008	2.2	<0.01	0.1	0.4	
14A	0.40	<0.001	<0.1	<0.01	<0.1	0.6	
15							
15A							
16							
16A							
17							
17A							
18							
18A							
19							
19A							
20							
20A							
21							
22							
23	0.04	<0.001	<0.1	<0.01	<0.1	0.2	
24							
25							
26							
27							
28							
29							
30							
31							
32							
Lagoon 1	6.21	0.005	<0.1	0.90	4.1	29.7	
Lagoon 2	11.1	0.040	<0.1	2.16	3.2	16.7	
Tank 1	9.64	0.604	1.0	2.30	3.3	14.1	
Tank 2	9.50	0.652	1.2	2.38	2.7	13.2	

* Inclement weather limited sampling.

Table A. (Continued)

Date 7/01

Sampling Site	NH_3	NO_2	NO_3	i-PO_4	t-P	TKN	TOC
	ppm						
1	0.04	0.004	4.4	<0.01	0.1	0.1	14
1A	0.04	0.009	7.7	<0.01	<0.1	0.1	11
2	0.26	0.024	5.7	0.03	0.1	1.0	7
2A	0.03	<0.001	8.0	<0.01	<0.1	<0.1	11
3	0.04	<0.001	3.7	<0.01	<0.1	0.1	9
3A	0.04	<0.001	4.8	<0.01	<0.1	<0.1	11
4	0.08	0.007	22.8	<0.01	<0.1	<0.1	10
4A	0.41	0.010	7.3	<0.01	<0.1	0.3	46
5	0.34	0.012	0.2	<0.01	<0.1	0.6	19
5A	1.38	<0.001	<0.1	<0.01	<0.1	1.4	14
6	0.04	<0.001	2.2	<0.01	<0.1	0.1	5
6A	0.04	0.009	4.4	<0.01	<0.1	0.3	6
7	0.04	0.003	0.4	<0.01	<0.1	0.3	14
7A	0.05	0.009	0.7	<0.01	<0.1	0.2	11
8	0.18	0.010	0.4	<0.01	<0.1	0.4	13
8A	0.33	0.002	<0.1	<0.01	<0.1	0.6	11
9	1.49	0.012	<0.1	<0.01	<0.1	1.6	13
9A	0.21	0.001	<0.1	<0.01	<0.1	0.5	8
10	0.80	0.005	<0.1	<0.01	<0.1	1.0	13
10A	0.42	0.005	<0.1	<0.01	<0.1	0.7	7
11	0.04	0.001	<0.1	<0.01	<0.1	0.1	10
11A	0.40	0.007	<0.1	<0.01	<0.1	1.9	10
12	0.06	0.002	2.6	<0.01	<0.1	0.2	10
12A	0.12	0.017	4.0	<0.01	<0.1	0.3	10
13	0.04	0.001	0.1	<0.01	<0.1	0.1	13
13A	0.20	0.003	<0.1	<0.01	<0.1	0.9	13
14	0.17	0.005	0.9	<0.01	<0.1	0.5	12
14A	0.47	<0.001	<0.1	<0.01	<0.1	0.7	16
15	0.06	0.002	4.1	<0.01	0.1	<0.1	7
15A	0.03	0.003	1.6	<0.01	0.1	0.4	9
16	<0.01	<0.001	1.6	<0.01	0.1	<0.1	
16A							
17	0.03	0.002	3.4	0.01	0.1	0.2	7
17A	<0.01	<0.001	9.7	0.01	0.1	0.2	8
18	<0.01	<0.001	7.8	0.01	0.1	0.3	5
18A	<0.01	<0.001	13.7	0.02	0.1	0.1	14
19	<0.01	<0.001	23.3	0.01	<0.1	0.1	18
19A	0.03	0.002	19.7	0.01	0.1	0.1	11
20	0.01	0.002	10.1	<0.01	<0.1	0.1	6
20A	<0.02	<0.005	4.0	<0.01	0.1	0.1	6
21	<0.01	<0.001	2.0	<0.01	<0.1	0.1	21
22	0.01	<0.001	5.5	<0.01	<0.1	0.1	9
23	0.01	<0.001	<0.1	<0.01	<0.1	0.4	9
24	0.06	<0.001	<0.1	<0.01	<0.1	0.3	11
25	0.02	<0.001	1.0	<0.01	0.1	0.6	8
26	0.04	0.002	0.4	<0.01	0.1	0.2	8
27	<0.01	<0.001	1.0	<0.01	<0.1	<0.1	6
28	0.11	0.001	<0.1	<0.01	<0.1	0.4	9
29	0.08	0.015	3.8	0.04	<0.1	0.2	10
30	0.13	0.014	1.6	0.06	0.1	0.6	10
31	0.17	0.016	4.7	0.11	0.1	0.3	9
32	0.53	0.245	2.3	0.23	0.1	0.9	9
Lagoon 1	6.98	0.006	<0.1	1.38	2.1	12.3	39
Lagoon 2	18.6	0.010	<0.1	4.15	5.2	25.3	45
Tank 1	13.8	0.367	0.5	3.30	3.7	18.8	34
Tank 2	13.0	0.406	0.8	3.23	3.7	17.7	35

Table A. (Continued)

Date 7/06							
Sampling Site	NH_3	NO_2	NO_3	i-PO_4	t-P	TKN	TOC
	ppm						
1	0.04	0.004	2.9	0.01	<0.1	<0.1	
1A	0.04	0.009	9.7	0.01	0.1	0.1	
2	0.03	0.006	6.1	0.01	<0.1	0.1	
2A	0.02	0.001	15.4	0.01	<0.1	<0.1	
3	0.01	<0.001	9.3	0.01	<0.1	<0.1	
3A	0.02	0.001	3.7	0.01	<0.1	<0.1	
4	0.03	0.026	23.0	0.01	<0.1	0.1	
4A	0.43	0.022	4.0	<0.01	<0.1	0.3	
5	0.24	0.027	0.4	<0.01	<0.1	0.3	
5A	1.14	<0.001	<0.1	<0.01	<0.1	1.2	
6	0.02	0.001	4.4	0.01	<0.1	<0.1	
6A	0.03	0.026	2.9	<0.01	<0.1	0.2	
7	0.02	0.005	0.6	<0.01	<0.1	0.1	
7A	0.03	0.011	0.9	<0.01	<0.1	0.1	
8	0.06	0.002	<0.1	<0.01	<0.1	0.2	
8A	0.26	0.001	<0.1	<0.01	<0.1	0.4	
9	1.16	0.003	<0.1	<0.01	<0.1	1.2	
9A	0.17	0.001	<0.1	<0.01	<0.1	0.2	
10	0.47	0.004	<0.1	0.01	<0.1	0.6	
10A	0.36	0.001	0.1	0.01	0.1	0.4	
11	0.01	<0.001	0.2	<0.01	0.1	<0.1	
11A	0.50	0.013	0.3	<0.01	0.1	0.6	
12	0.01	<0.001	1.6	<0.01	<0.1	<0.1	
12A	0.17	0.023	2.4	<0.01	<0.1	0.2	
13	0.02	0.002	0.9	<0.01	<0.1	<0.1	
13A	0.17	0.011	0.2	<0.01	<0.1	0.1	
14	0.10	0.007	1.0	<0.01	<0.1	0.2	
14A	0.41	0.001	0.1	<0.01	<0.1	0.6	
15	0.01	0.009	4.2	<0.01	<0.1	0.1	
15A	0.01	<0.001	3.0	<0.01	0.1	0.2	
16							
16A	0.01	0.004	0.1	<0.01	0.1	0.2	
17	0.01	0.018	1.9	<0.01	<0.1	<0.1	
17A	<0.01	0.002	5.1	<0.01	<0.1	<0.1	
18	<0.01	0.002	6.6	<0.01	<0.1	0.2	
18A	<0.01	0.003	10.0	<0.01	<0.1	0.9	
19	<0.01	0.003	21.5	<0.01	<0.1	0.1	
19A	0.01	0.010	18.8	<0.01	<0.1	0.2	
20	<0.01	0.009	10.4	<0.01	<0.1	0.6	
20A	<0.01	0.029	3.5	<0.01	<0.1	<0.1	
21	<0.01	0.003	2.1	0.01	<0.1	0.1	
22	<0.01	0.002	5.8	<0.01	0.1	0.2	
23	<0.01	0.003	0.3	<0.01	<0.1	0.5	
24	<0.01	0.001	0.2	<0.01	<0.1	0.3	
25	<0.01	0.001	1.2	<0.01	<0.1	0.4	
26	0.05	0.010	0.7	<0.01	<0.1	0.4	
27	<0.01	0.002	1.7	<0.01	<0.1	0.1	
28	0.10	0.008	0.2	<0.01	<0.1	0.2	
29	0.02	0.019	5.2	<0.01	<0.1	0.1	
30	0.01	0.015	4.9	<0.01	<0.1	0.1	
31	0.06	0.029	3.9	0.09	0.1	0.2	
32	0.35	0.161	2.3	0.16	0.2	0.8	
Lagoon 1	7.37	0.008	0.2	1.31	2.6	13.8	
Lagoon 2	17.4	0.034	0.2	3.48	4.2	22.7	
Tank 1	13.3	0.155	0.7	2.14	2.6	16.8	
Tank 2	12.4	0.162	1.1	2.18	2.5	16.5	

Table A. (Continued)

Date 7/09

Sampling Site	NH_3	NO_2	NO_3	i-PO_4	t-P	TKN	TOC
	ppm						
1	0.04	0.003	2.3	<0.01	0.1	<0.1	
1A	0.06	0.006	8.4	<0.01	<0.1	<0.1	
2	0.08	0.011	6.2	0.01	<0.1	<0.1	
2A	0.04	0.003	15.0	<0.01	<0.1	<0.1	
3	0.04	0.004	11.9	<0.01	<0.1	<0.1	
3A	0.03	0.004	3.7	<0.01	<0.1	<0.1	
4	0.03	0.002	26.2	<0.01	<0.1	<0.1	
4A	0.32	0.020	12.4	<0.01	<0.1	0.1	
5	0.25	0.010	0.3	<0.01	<0.1	0.2	
5A	1.20	0.002	0.1	<0.01	<0.1	1.0	
6	0.05	0.003	7.0	<0.01	<0.1	<0.1	
6A	0.04	0.006	2.8	<0.01	<0.1	<0.1	
7	0.02	0.005	0.7	<0.01	<0.1	0.1	
7A	0.06	0.009	1.5	<0.01	<0.1	0.1	
8	0.09	0.003	<0.1	<0.01	<0.1	0.3	
8A	0.24	0.003	<0.1	<0.01	<0.1	0.3	
9	1.00	0.004	<0.1	<0.01	<0.1	1.1	
9A	0.20	0.003	<0.1	0.01	<0.1	0.3	
10	0.55	0.005	<0.1	<0.01	<0.1	0.8	
10A	0.44	0.004	<0.1	<0.01	0.1	0.7	
11	0.04	0.004	0.1	<0.01	0.1	<0.1	
11A	0.32	0.005	0.3	<0.01	0.1	0.3	
12	0.05	0.004	2.9	<0.01	0.1	<0.1	
12A	0.14	0.016	2.7	<0.01	<0.1	<0.1	
13	0.01	0.005	1.8	<0.01	<0.1	<0.1	
13A	0.09	0.007	0.6	<0.01	<0.1	<0.1	
14	0.13	0.005	0.5	<0.01	<0.1	0.2	
14A	0.43	0.006	0.1	<0.01	<0.1	0.4	
15	0.01	0.038	2.9	<0.01	<0.1	<0.1	
15A	0.01	0.003	2.9	<0.01	<0.1	<0.1	
16	0.01	0.003	0.8	<0.01			
16A	0.03	0.002	0.2	<0.01	<0.1	0.1	
17	0.01	0.005	2.5	<0.01	<0.1	<0.1	
17A	0.01	0.003	3.3	<0.01	<0.1	<0.1	
18	0.09	0.004	6.6	<0.01	<0.1	<0.1	
18A	<0.01	0.002	6.5	<0.01	<0.1	<0.1	
19	<0.01	0.003	15.7	<0.01	<0.1	0.2	
19A	<0.01	0.003	15.3	<0.01	<0.1	<0.1	
20	0.02	0.005	5.7	<0.01	<0.1	0.5	
20A	0.02	0.025	3.2	0.01	<0.1	0.1	
21	0.02	0.005	3.6	0.01	<0.1	<0.1	
22	0.02	0.002	3.6	0.01	<0.1	0.2	
23	<0.01	0.004	0.3	0.01	<0.1	0.2	
24	0.07	0.001	0.2	<0.01	<0.1	0.2	
25	0.01	0.003	1.0	<0.01	<0.1	0.2	
26	0.02	0.005	0.5	0.01	<0.1	0.3	
27	0.01	0.003	3.5	0.01	<0.1	0.1	
28	0.15	0.006	0.1	0.01	<0.1	0.4	
29	0.04	0.009	4.0	0.01	<0.1	0.2	
30	0.04	0.003	4.8	0.01	<0.1	0.4	
31	0.04	0.001	5.8	0.01	<0.1	0.2	
32	0.02	0.002	2.3	<0.01	0.2	0.4	
Lagoon 1	5.93	0.009	0.2	1.04	2.0	11.7	
Lagoon 2	15.2	0.016	0.2	3.70	5.0	26.0	
Tank 1	7.78	0.151	0.6	1.73	2.2	11.5	
Tank 2	7.85	0.163	1.0	1.75	2.1	11.5	

Table A. (Continued)

Date 7/13

Sampling Site	NH_3	NO_2	NO_3	i-PO_4	t-P	TKN	TOC
	ppm						
1	<0.01	0.281	2.0	<0.01	<0.1	3.2	
1A	<0.01	0.013	8.4	<0.01	<0.1	0.5	
2	0.01	0.035	2.6	<0.01	<0.1	1.7	
2A	0.01	0.235	12.8	<0.01	<0.1	0.9	
3	<0.01	0.007	12.0	<0.01	<0.1	0.3	
3A	<0.01	0.468	3.4	<0.01	<0.1	0.3	
4	0.01	0.002	6.1	<0.01	<0.1	0.9	
4A	0.77	0.047	5.0	<0.01	<0.1	0.8	
5	0.39	0.008	0.1	<0.01	<0.1	1.3	
5A	1.56	0.002	0.1	<0.01	<0.1	4.0	
6	0.08	0.001	9.5	<0.01	<0.1	0.6	
6A	0.04	0.046	3.0	<0.01	<0.1	0.3	
7	0.04	0.007	0.5	<0.01	<0.1	1.6	
7A	0.08	0.008	1.1	<0.01	<0.1	0.3	
8	0.27	0.005	0.1	<0.01	<0.1	1.8	
8A	0.41	0.005	0.1	<0.01	<0.1	0.8	
9	0.47	0.004	<0.1	<0.01	<0.1	3.4	
9A	0.19	0.005	<0.1	<0.01	<0.1	1.2	
10	0.32	0.015	0.2	<0.01	<0.1	2.1	
10A	0.39	0.004	0.1	<0.01	0.2	6.0	
11	0.06	0.006	0.9	<0.01	<0.1	0.7	
11A	0.15	0.008	0.6	<0.01	<0.1	0.9	
12	0.04	0.004	1.2	<0.01	<0.1	1.0	
12A	0.30	0.068	2.4	<0.01	<0.1	1.4	
13	0.06	0.006	2.1	<0.01	<0.1	0.6	
13A	0.25	0.014	0.2	<0.01	<0.1	0.9	
14	0.27	0.008	0.3	<0.01	<0.1	1.1	
14A	0.34	0.005	0.1	<0.01	<0.1	1.4	
15	0.05	0.002	2.0	<0.01	<0.1	0.3	
15A	<0.01	0.005	1.1	<0.01	<0.1	0.3	
16							
16A							
17	<0.01	0.002	2.9	<0.01	<0.1	0.7	
17A	0.02	0.002	1.6	<0.01	<0.1	0.7	
18	0.01	0.006	8.5	<0.01	<0.1	0.6	
18A	0.02	0.037	3.8	<0.01	<0.1	0.6	
19	0.02	0.001	9.5	<0.01	<0.1	<0.1	
19A	0.02	0.001	10.3	<0.01	<0.1	<0.1	
20	0.08	0.002	4.0	<0.01	<0.1	<0.1	
20A	0.04	0.040	5.0	<0.01	<0.1	<0.1	
21	0.02	<0.001	4.5	<0.01	<0.1	<0.1	
22	0.04	0.001	2.4	<0.01	<0.1	0.2	
23	0.04	0.001	0.1	<0.01	<0.1	<0.1	
24	0.10	<0.001	<0.1	<0.01	<0.1	<0.1	
25	0.04	<0.001	1.5	<0.01	<0.1	<0.1	
26	0.05	<0.001	0.4	<0.01	<0.1	0.5	
27	0.11	<0.001	8.0	<0.01	<0.1	<0.1	
28	0.37	0.024	0.1	0.02	<0.1	0.3	
29	<0.01	0.002	2.0	0.01	<0.1	0.5	
30	<0.01	0.001	5.7	0.01	<0.1	0.5	
31	0.04	0.012	7.8	<0.01	<0.1	0.3	
32	0.01	0.004	2.9	<0.01	<0.1	<0.1	
Lagoon 1	7.84	0.008	0.2	1.52	2.6	14.4	
Lagoon 2	12.5	0.012	0.2	3.44	4.9	21.7	
Tank 1	7.58	0.177	0.7	1.96	2.4	10.7	
Tank 2	7.44	0.190	1.2	1.97	2.4	11.1	

Table A. (Continued)

Date 7/16

Sampling Site	NH_3	NO_2	NO_3	i-PO_4	t-P	TKN	TOC
	ppm						
1	0.10	0.017	1.9	0.01	0.1	2.4	
1A	0.03	0.005	6.6	0.01	0.1	1.1	
2	0.11	0.006	4.6	0.01	<0.1	0.9	
2A	0.11	0.067	8.3	<0.01	0.1	0.6	
3	0.02	0.005	11.3	<0.01	<0.1	0.1	
3A	0.02	0.058	5.9	<0.01	0.1	0.4	
4	<0.01	0.008	6.7	<0.01	<0.1	0.2	
4A	0.54	0.025	6.7	<0.01	<0.1	1.1	
5	0.54	0.006	0.1	<0.01	0.1	1.5	
5A	1.27	0.003	0.1	<0.01	0.1	1.9	
6	<0.01	0.002	8.6	0.01	<0.1	<0.1	
6A	<0.01	0.008	4.4	<0.01	<0.1	0.2	
7	<0.01	0.006	0.2	<0.01	<0.1	0.3	
7A	0.06	0.009	0.6	<0.01	<0.1	<0.1	
8	0.11	0.003	0.1	<0.01	<0.1	2.1	
8A	0.43	0.001	0.1	<0.01	<0.1	1.0	
9	0.39	0.006	0.1	<0.01	<0.1	1.3	
9A	0.94	0.003	0.1	0.01	<0.1	1.5	
10	0.24	0.011	0.5	0.01	<0.1	0.8	
10A	0.42	0.003	0.1	<0.01	<0.1	3.7	
11	0.02	0.004	0.5	<0.01	<0.1	0.2	
11A	0.02	0.002	0.6	<0.01	0.3	1.0	
12	0.08	0.002	5.9	<0.01	0.7	<0.1	
12A	0.11	0.011	4.5	<0.01	0.3	1.2	
13	0.04	0.002	1.3	<0.01	0.1	0.1	
13A	0.21	0.006	0.2	<0.01	0.8	1.4	
14	0.35	0.010	0.2	<0.01	0.5	1.5	
14A	0.70	0.003	<0.1	<0.01	0.1	0.8	
15	0.06	0.002	2.8	<0.01	0.2	0.2	
15A	0.02	0.002	1.1	<0.01	0.2	<0.1	
16							
16A							
17	0.02	0.002	4.2	<0.01	1.3	4.6	
17A	0.02	0.002	1.2	<0.01	0.8	1.8	
18	0.03	0.006	7.5	<0.01	0.6	<0.1	
18A	0.02	0.009	3.5	<0.01	0.4	<0.1	
19	0.02	0.004	6.6	<0.01	0.1	<0.1	
19A	0.03	0.005	8.7	<0.01	0.1	<0.1	
20	0.02	0.062	4.1	<0.01	0.7	0.3	
20A	0.02	0.004	5.1	<0.01	0.6	2.4	
21	0.02	0.002	5.4	<0.01	0.4	1.2	
22	0.02	0.001	1.7	<0.01	0.6	0.2	
23	0.02	<0.001	0.2	0.01	0.4	1.0	
24	0.04	0.001	0.1	<0.01	0.3	0.8	
25	0.08	0.001	2.5	<0.01	2.3	2.9	
26	0.04	0.001	0.6	<0.01	0.5	0.9	
27	0.04	0.004	9.3	<0.01	0.1	<0.1	
28	0.04	0.002	0.2	<0.01			
29	0.25	0.002	1.8	0.01	0.1	1.5	
30	0.06	0.002	8.1	0.01	0.1	<0.1	
31	0.05	0.002	8.4	0.01	0.7	0.9	
32	0.05	0.002	3.6	<0.01	0.9	0.2	
Lagoon 1	9.26	0.010	0.2	2.43	4.2	23.2	
Lagoon 2	11.7	0.013	0.2	3.55	4.5	18.8	
Tank 1	8.15	0.197	0.7	2.33	2.9	11.8	
Tank 2	7.97	0.198	1.1	2.35	2.9	11.9	

Table A. (Continued)

Date 7/20 Sampling Site	NH_3	NO_2	NO_3	$i-PO_4$	t-P	TKN	TOC
	ppm						
1	0.02	0.013	1.8		<0.01	0.7	
1A	0.02	0.008	3.6		<0.01	1.1	
2	0.02	<0.001	5.7		<0.01	0.4	
2A	0.09	0.017	6.3		<0.01	0.5	
3	0.03	0.002	12.3		<0.01	0.4	
3A	0.01	0.081	6.6		<0.01	0.2	
4	0.03	0.004	8.4		<0.01	0.4	
4A	0.26	0.017	7.0		<0.01	0.6	
5	0.53	0.006	<0.1		<0.01	1.4	
5A	1.17	0.001	<0.1		0.03	2.5	
6	0.02	0.010	8.2		<0.01	0.3	
6A	0.03	0.028	3.7		<0.01	0.2	
7	0.02	0.003	0.2		<0.01	0.3	
7A	0.05	0.005	0.1		<0.01	0.4	
8	0.25	0.001	<0.1		0.04	1.3	
8A	0.31	0.003	<0.1		<0.01	1.7	
9	0.32	0.006	<0.1		<0.01	1.2	
9A	0.58	<0.001	<0.1		<0.01	1.3	
10	0.11	0.017	0.3		<0.01	1.7	
10A	0.30	<0.001	<0.1		<0.01	1.7	
11	0.03	0.001	0.5		<0.01	<0.1	
11A	0.04	0.002	0.4		<0.01	0.2	
12	0.02	0.001	6.2		<0.01	0.4	
12A	0.32	0.020	3.1		<0.01	1.5	
13	0.02	0.003	1.9		<0.01	0.2	
13A	0.19	0.016	0.3		<0.01	0.4	
14	0.30	0.003	0.1		<0.01	0.6	
14A	0.64	0.001	<0.1		<0.01	1.0	
15	0.02	<0.001	4.1		<0.01	<0.1	
15A	0.02	0.001	1.5		<0.01	<0.1	
16							
16A							
17	<0.01	0.001	<0.1		<0.01	0.2	
17A	<0.01	<0.001	<0.1		<0.01	0.7	
18	<0.01	0.002	<0.1		<0.01	0.4	
18A	<0.01	<0.001	<0.1		<0.01	0.4	
19	<0.01	0.001	<0.1		<0.01	0.4	
19A	<0.01	0.007	<0.1		<0.01	0.4	
20	<0.01	0.001	<0.1		<0.01	0.2	
20A	<0.01	0.009	<0.1		<0.01	0.4	
21	<0.01	<0.001	<0.1		<0.01	0.4	
22	0.04	0.001	1.2		<0.01	0.7	
23	0.06	0.002	0.1		0.03	0.4	
24	0.08	0.001	<0.1		<0.01	0.4	
25	0.06	0.001	1.8		<0.01	0.4	
26	0.05	<0.001	1.1		<0.01	0.2	
27	0.04	<0.001	8.5		<0.01	0.2	
28							
29	0.05	0.001	3.0		<0.01	0.3	
30	0.30	0.002	7.0		<0.01	1.0	
31	0.06	<0.001	7.1		<0.01	0.4	
32	0.04	0.002	3.6		0.03	0.4	
Lagoon 1	10.7	0.010	0.1		4.70	23.6	
Lagoon 2	19.4	0.014	0.1		6.57	26.7	
Tank 1	17.0	0.218	0.7		5.18	21.5	
Tank 2	16.8	0.224	0.9		5.15	21.2	

Table A. (Continued)

Date 7/23

Sampling Site	NH_3	NO_2	NO_3	i-PO_4	t-P	TKN	TOC
	ppm						
1	0.04	0.003	1.5		0.01	0.1	
1A	0.03	0.002	5.0		<0.01	0.2	
2	0.02	0.001	4.8		<0.01	<0.1	
2A	0.10	0.010	6.6		0.01	0.3	
3	0.04	0.002	12.9		0.01	<0.1	
3A	0.04	0.055	7.4		0.01	0.4	
4	0.02	0.003	7.5		0.01	0.1	
4A	0.21	0.034	7.9		<0.01	0.5	
5	0.39	0.004	0.1		<0.01	1.0	
5A	1.37	0.002	<0.1		<0.01	2.0	
6	0.02	<0.001	9.2		<0.01	0.1	
6A	0.07	0.010	4.7		<0.01	0.3	
7	0.01	0.002	0.1		<0.01	0.2	
7A	0.09	0.001	<0.1		<0.01	0.3	
8	0.32	0.002	<0.1		<0.01	1.0	
8A	0.29	0.001	<0.1		<0.01	1.0	
9	0.45	0.005	<0.1		0.08	1.2	
9A	0.20	0.001	<0.1		0.04	1.0	
10	0.13	0.012	0.2		0.02	0.6	
10A	0.26	0.001	<0.1		0.02	1.9	
11	0.04	<0.001	0.4		<0.01	<0.1	
11A	0.04	0.003	0.4		<0.01	<0.1	
12	0.03	<0.001	4.6		<0.01	<0.1	
12A	0.36	0.013	2.5		<0.01	0.6	
13	0.03	<0.001	3.8		<0.01	0.1	
13A	0.09	0.003	2.1		<0.01	0.2	
14	0.28	<0.001	<0.1		<0.01	0.6	
14A	0.62	<0.001	<0.1		<0.01	1.0	
15	0.04	0.002	5.2		<0.01	0.1	
15A	0.03	0.001	0.7		<0.01	0.4	
16							
16A							
17	0.01	0.001	7.6		<0.01	<0.1	
17A	0.02	0.001	0.9		<0.01	<0.1	
18	0.03	0.001	6.4		<0.01	<0.1	
18A	0.02	0.001	4.5		<0.01	<0.1	
19	0.02	0.001	4.9		<0.01	<0.1	
19A	0.02	0.013	8.6		<0.01	<0.1	
20	0.05	0.006	2.9		<0.01	<0.1	
20A	0.01	0.003	4.5		<0.01	<0.1	
21	0.01	0.001	5.9		<0.01	<0.1	
22	0.02	<0.001	1.0		<0.01	0.5	
23	0.01	0.002	0.1		<0.01	0.3	
24	0.07	0.001	<0.1		<0.01	0.4	
25	0.06	0.002	1.8		<0.01	0.5	
26	0.03	0.002	1.5		<0.01	0.3	
27	0.01	0.001	7.8		<0.01	0.1	
28							
29	0.02	0.001	3.1		<0.01	0.2	
30	0.03	0.006	7.0		<0.01	<0.2	
31	0.01	0.001	6.9		<0.01	0.3	
32	0.03	0.028	3.5		<0.01	0.1	
Lagoon 1	19.6	0.036	0.7		93.3	7.26	
Lagoon 2	27.3	0.012	0.1		6.17	34.8	
Tank 1	22.0	0.407	1.6		5.85	28.7	
Tank 2	22.0	0.412	1.9		5.80	28.3	

Table A. (Continued)

Date 7/26

Sampling Site	NH_3	NO_2	NO_3	$i\text{-}PO_4$	t-P	TKN	TOC
	ppm						
1	<0.01	0.012	2.1	<0.001	0.04	0.2	
1A	<0.01	0.008	4.1	0.003	0.01	0.3	
2	<0.01	<0.001	7.0	<0.001	0.01	<0.1	
2A	0.03	0.013	6.7	<0.001	0.01	0.1	
3	<0.01	0.001	11.2	<0.001	0.02	<0.1	
3A	<0.01	0.028	8.0	<0.001	0.02	0.2	
4	<0.01	0.006	7.7	<0.001	0.02	0.3	
4A	0.12	0.123	7.7	<0.001	0.02	0.6	
5	0.54	0.007	<0.1	<0.001	0.02	1.1	
5A	1.27	0.002	<0.1	<0.001	0.01	2.1	
6	0.02	<0.001	9.8	0.004	<0.01	<0.1	
6A	0.03	0.013	6.2	0.004	0.01	<0.1	
7	0.02	0.003	0.3	0.002	0.01	<0.1	
7A	0.04	0.009	0.2	0.002	0.01	<0.1	
8	0.30	0.002	<0.1	0.002	0.01	0.6	
8A	0.30	0.001	<0.1	0.006	0.02	0.6	
9	0.46	0.019	<0.1	0.005	0.02	1.0	
9A	0.10	0.003	<0.1	0.002	0.10	0.4	
10	0.13	0.015	0.3	0.007	0.05	0.4	
10A	0.26	0.004	<0.1	0.005	0.02	1.2	
11	0.01	0.002	0.3	0.005	0.02	0.3	
11A	0.02	0.003	0.3	0.010	0.02	0.4	
12	0.02	0.002	6.0	0.006	0.02	0.4	
12A	0.30	0.050	3.0	0.005	0.02	1.0	
13	0.01	0.005	4.1	0.004	0.02	0.5	
13A	0.12	0.019	3.2	0.004	0.02	0.8	
14	0.36	0.012	0.1	0.004	0.03	1.4	
14A	0.57	0.003	<0.1	0.004	0.02	2.1	
15	0.04	0.003	4.1	0.004	0.02	1.4	
15A	0.02	0.001	1.3	0.004	0.02	0.8	
16							
16A							
17	0.01	0.001	9.3	0.005	0.03	2.5	
17A	<0.01	0.001	4.2	0.005	<0.01	0.5	
18	<0.01	<0.001	5.6	0.007	<0.01	0.8	
18A	<0.01	0.001	5.0	0.007	<0.01	0.5	
19	<0.01	<0.001	4.1	0.006	0.01	1.5	
19A	<0.01	0.001	7.5	0.005	0.08	4.2	
20	<0.01	0.002	3.7	0.008	0.03	0.4	
20A	<0.01	0.003	4.1	0.007	<0.01	0.9	
21	<0.01	0.001	5.8	0.005	0.01	0.5	
22	<0.01	0.001	1.0	0.005	0.01	1.4	
23	0.01	0.001	0.1	0.008	0.02	2.8	
24	0.13	0.002	<0.1	0.004	0.01	1.7	
25	0.02	0.001	1.5	0.007	0.01	1.8	
26	0.01	0.001	1.6	0.004	0.02	1.7	
27	0.01	0.001	6.9	0.003	0.02	1.7	
28							
29	0.03	0.006	2.7	0.003	0.02	2.7	
30	0.06	0.001	7.9	0.013	0.02	1.5	
31	0.10	0.003	7.1	0.038	0.04	2.6	
32	0.04	0.009	3.4	0.006	0.02	1.9	
Lagoon 1	17.4	0.027	0.9	2.67	51.7	42.5	
Lagoon 2	24.7	0.013	0.1	4.91	6.14	31.3	
Tank 1	26.7	0.166	0.6	4.92	6.16	32.7	
Tank 2	26.5	0.160	0.7	4.89	6.07	32.4	

Table A. (Continued)

Date 7/30

Sampling Site	NH_3	NO_2	NO_3	i-PO_4	t-P	TKN	TOC
	ppm						
1	0.18	0.014	2.0	0.023	0.02	1.4	
1A	0.10	0.003	4.3	0.009	0.04	1.7	
2	0.07	0.003	8.5	0.007	0.01	1.0	
2A	0.16	0.018	6.4	0.007	0.26	3.1	
3	0.04	0.003	8.5	0.010	0.04	1.9	
3A	0.05	0.022	9.0	0.006	0.01	1.9	
4	0.05	0.003	7.7	0.005	0.01	1.3	
4A	0.18	0.061	7.1	0.003	<0.01	2.0	
5	0.67	0.004	<0.1	<0.001	0.01	2.3	
5A	1.34	0.003	<0.1	0.004	0.01	4.0	
6	<0.01	0.002	7.9	0.003	<0.01	<0.1	
6A	<0.01	0.004	6.3	0.004	0.01	0.2	
7	<0.01	0.011	0.7	0.003	0.01	<0.1	
7A	0.04	0.004	0.2	0.003	0.01	0.4	
8	0.26	0.003	<0.1	0.004	0.01	0.5	
8A	0.26	0.002	<0.1	0.003	0.01	0.5	
9	0.52	0.003	<0.1	0.003	0.02	1.0	
9A	0.05	0.003	<0.1	0.007	0.02	0.4	
10	0.06	0.056	0.2	0.010	0.03	0.4	
10A	0.32	0.003	<0.1	0.005	0.02	0.8	
11	0.01	0.002	0.2	0.008	0.13	0.2	
11A	<0.01	0.003	0.3	0.006	0.04	0.2	
12	<0.01	0.002	11.4	0.004	<0.01	<0.1	
12A	0.48	0.037	3.8	0.003	<0.01	1.0	
13	0.01	0.003	3.6	0.003	<0.01	0.4	
13A	0.05	0.008	3.8	0.006	<0.01	0.4	
14	0.32	0.004	0.1	0.004	<0.01	0.6	
14A	0.53	0.001	<0.1	0.003	<0.01	1.0	
15	0.02	0.002	2.8	0.010	<0.01	0.4	
15A	<0.01	0.002	2.1	0.005	<0.01	0.3	
16							
16A							
17	<0.01	0.003	6.7	0.008	<0.01	0.4	
17A	<0.01	0.003	5.1	0.008	<0.01	0.4	
18	<0.01	0.003	4.8	0.008	<0.01	0.6	
18A	<0.01	0.003	6.0	0.012	<0.01	0.5	
19	<0.01	0.004	2.8	0.008	0.02	0.3	
19A	<0.01	0.012	5.4	0.005	0.02	0.3	
20	<0.01	0.005	3.4	0.008	0.01	0.5	
20A	<0.01	0.007	3.1	0.012	0.01	0.3	
21	<0.01	0.003	5.5	0.008	0.01	0.5	
22	<0.01	0.003	0.5	0.007	0.01	0.5	
23	0.03	0.003	0.1	0.003	0.03	0.2	
24	0.24	0.003	<0.1	0.002	<0.01	0.2	
25	0.03	0.003	2.1	0.005	<0.01	<0.1	
26	0.18	0.015	2.2	0.011	<0.01	0.6	
27	0.04	0.003	8.4	0.013	<0.01	<0.1	
28							
29	0.06	0.005	1.8	0.011	0.01	<0.1	
30	0.06	0.003	6.4	0.010	<0.01	<0.1	
31	0.13	0.004	11.6	0.010	0.02	<0.1	
32	0.06	0.003	3.9	0.006	0.01	<0.1	
Lagoon 1	23.2	0.024	0.6	3.28	18.1	13.6	
Lagoon 2	22.3	0.012	0.1	5.23	6.20	28.0	
Tank 1	23.6	0.183	0.4	5.19	5.91	28.5	
Tank 2	23.7	0.185	0.4	5.23	5.93	28.7	

Table A. (Continued)

Date 8/03

Sampling Site	NH_3	NO_2	NO_3	$i\text{-}PO_4$	t-P	TKN	TOC
	ppm						
1	0.10	0.020	2.1	0.015	<0.01	0.1	13
1A	0.06	0.018	4.7	0.010	<0.01	0.1	9
2	0.12	0.013	6.7	0.009	<0.01	0.2	29
2A	0.14	0.067	6.6	0.009	<0.01	0.2	15
3	0.15	0.014	8.2	0.017	<0.01	0.1	12
3A	0.12	0.030	8.3	0.009	<0.01	0.1	12
4	0.05	0.017	6.6	0.005	<0.01	0.1	10
4A	0.17	0.062	6.4	0.009	<0.01	1.0	11
5	0.73	0.011	<0.1	0.002	0.01	1.5	14
5A	1.22	0.011	<0.1	0.002	<0.01	0.1	15
6	0.12	0.013	7.6	0.009	<0.01	0.1	9
6A	0.04	0.024	6.0	0.006	<0.01	0.1	9
7	0.03	0.024	1.0	0.006	<0.01	0.1	7
7A	0.09	0.020	0.4	0.006	<0.01	0.4	7
8	0.24	0.012	<0.1	0.008	<0.01	0.2	21
8A	0.28	0.014	<0.1	0.007	<0.01	0.7	15
9	0.70	0.014	<0.1	0.005	<0.01	0.1	16
9A	0.10	0.012	<0.1	0.009	<0.01	0.1	12
10	0.08	0.058	0.1	0.009	<0.01	0.7	14
10A	0.33	0.014	0.1	0.007	<0.01	0.2	11
11	0.01	0.012	0.1	0.006	0.01	0.2	10
11A	0.01	0.017	0.2	0.005	0.01	0.1	13
12	0.04	0.014	16.4	0.009	0.02	0.2	10
12A	0.38	0.070	8.1	0.005	<0.01	0.1	10
13	0.01	0.017	5.0	0.005	<0.01	0.1	10
13A	0.06	0.039	2.8	0.003	<0.01	0.2	8
14	0.36	0.017	0.3	0.001	<0.01	0.5	12
14A	0.68	0.011	0.1	0.001	<0.01	0.8	7
15	0.05	0.013	1.6	0.005	<0.01	0.2	14
15A	0.01	0.014	2.2	0.003	<0.01	0.4	13
16							
16A							
17	<0.01	0.014	6.6	0.007	<0.01	<0.1	10
17A	<0.01	0.014	5.4	0.007	<0.01	<0.1	8
18	<0.01	0.014	10.3	0.009	<0.01	<0.1	11
18A	<0.01	0.014	7.1	0.009	<0.01	<0.1	15
19	<0.01	0.014	4.2	0.007	0.01	0.1	6
19A	<0.01	0.017	5.3	0.003	0.01	0.1	9
20	<0.01	0.014	5.2	0.010	0.01	0.1	13
20A	<0.01	0.014	4.4	0.010	0.01	<0.1	8
21	<0.01	0.012	5.9	0.011	0.01	0.3	10
22	<0.01	0.011	0.4	0.005	<0.01	0.3	11
23	<0.01	0.008	0.2	0.002	<0.01	0.1	10
24	0.03	0.008	0.2	0.002	<0.01	0.1	16
25	0.12	0.008	3.7	0.002	0.01	0.1	12
26	0.05	0.009	2.3	0.038	<0.01	0.5	16
27	<0.01	0.011	10.0	0.013	<0.01	0.1	20
28							
29	<0.01	0.007	2.9	0.005	<0.01	0.5	8
30	<0.01	0.012	8.3	0.005	<0.01	<0.1	
31	<0.01	0.017	18.6	0.003	<0.01	<0.1	7
32	0.05	0.013	4.9	0.001	<0.01	<0.1	9
Lagoon 1	28.34	0.009	0.9	3.98	7.42	50.00	157
Lagoon 2	22.46	0.003	0.1	5.00	6.25	28.20	80
Tank 1	22.36	0.017	0.4	5.37	5.96	25.0	36
Tank 2	22.57	0.020	0.5	5.48	5.93	26.5	36

Table A. (Continued)

Date 8/06

Sampling Site	NH_3	NO_2	NO_3	i-PO_4	t-P	TKN	TOC
	ppm						
1	0.23	0.024	2.3	0.028	<0.01	0.1	
1A	0.12	0.012	4.4	0.011	<0.01	<0.1	
2	0.11	0.014	7.1	0.011	<0.01	<0.1	
2A	0.14	0.040	7.5	0.012	<0.01	<0.1	
3	0.05	0.011	6.4	0.009	<0.01	0.2	
3A	0.10	0.018	8.0	0.009	<0.01	0.2	
4	0.08	0.012	7.1	0.007	<0.01	0.1	
4A	0.16	0.043	6.4	0.008	<0.01	0.1	
5	0.70	0.013	<0.1	0.005	<0.01	1.0	
5A	1.30	0.014	<0.1	0.001	<0.01	1.6	
6	<0.01	0.020	7.9	0.001	<0.01	0.2	
6A	0.03	0.020	7.8	0.001	<0.01	<0.1	
7	0.01	0.014	0.9	0.001	<0.01	<0.1	
7A	0.11	0.009	0.6	0.001	<0.01	<0.1	
8	0.24	0.009	<0.1	0.001	<0.01	0.2	
8A	0.23	0.010	<0.1	0.001	<0.01	<0.1	
9	0.77	0.012	<0.1	0.001	<0.01	0.5	
9A	0.09	0.010	<0.1	0.005	<0.01	<0.1	
10	0.06	0.025	<0.1	0.009	0.02	<0.1	
10A	0.33	0.011	<0.1	0.001	<0.01	0.5	
11	0.03	0.010	0.2	0.014	<0.01	<0.1	
11A	0.03	0.011	0.2	0.009	<0.01	<0.1	
12	0.03	0.011	15.2	0.008	<0.01	<0.1	
12A	0.43	0.048	9.5	0.007	<0.01	<0.1	
13	0.25	0.011	4.6	0.005	<0.01	<0.1	
13A	0.11	0.018	5.4	0.005	<0.01	<0.1	
14	0.47	0.015	0.4	0.009	0.01	0.5	
14A	0.71	0.011	<0.1	0.006	<0.01	0.7	
15	0.06	0.010	1.4	0.007	<0.01	0.1	
15A	0.08	0.011	1.9	0.007	<0.01	0.1	
16							
16A							
17	<0.01	0.010	12.5	0.009	<0.01	<0.1	
17A	<0.01	0.014	4.2	0.009	<0.01	<0.1	
18	0.01	0.014	11.2	0.009	<0.01	<0.1	
18A	<0.01	0.010	8.2	0.009	<0.01	<0.1	
19	<0.01	0.013	5.7	0.009	<0.01	<0.1	
19A	<0.01	0.023	5.4	0.009	<0.01	<0.1	
20	<0.01	0.012	4.2	0.009	<0.01	<0.1	
20A	<0.01	0.028	4.0	0.011	<0.01	<0.1	
21	<0.01	0.014	6.1	0.009	<0.01	<0.1	
22	<0.01	0.014	0.1	0.008	<0.01	0.3	
23	0.14	0.003	<0.1	0.009	<0.01	0.1	
24	<0.01	0.003	<0.1	0.006	<0.01	0.2	
25	0.05	0.003	4.6	0.004	<0.01	<0.1	
26	<0.01	0.003	2.7	0.016	0.01	0.6	
27	<0.01	0.014	10.0	0.009	<0.01	<0.1	
28							
29	0.03	0.008	7.3	0.010	<0.01	<0.1	
30	<0.01	0.010	15.0	0.009	<0.01	<0.1	
31	<0.01	0.013	19.4	0.010	0.01	<0.1	
32	0.01	0.011	5.6	0.009	<0.01	<0.1	
Lagoon 1	37.75	0.009	0.8	3.61	4.74	32.60	
Lagoon 2	34.46	0.003	<0.1	5.50	6.35	26.50	
Tank 1	32.06	0.021	0.4	5.21	5.90	24.50	
Tank 2	21.24	0.021	0.4	5.27	5.84	24.40	

Table A. (Continued)

Date 8/10

Sampling Site	NH_3	NO_2	NO_3	i-PO_4	t-P	TKN	TOC
	ppm						
1	<0.01	0.003	1.9	0.007	<0.01	<0.1	
1A	<0.01	0.003	3.3	0.029	<0.01	<0.1	
2	0.14	0.003	5.8	0.005	<0.01	<0.1	
2A	<0.01	0.031	6.8	0.001	<0.01	0.2	
3	<0.01	0.005	7.3	0.001	<0.01	0.1	
3A	<0.01	0.011	6.7	0.011	<0.01	0.1	
4	<0.01	0.005	5.5	0.005	<0.01	0.1	
4A	<0.01	0.020	5.4	0.001	<0.01	0.1	
5	0.81	0.010	<0.1	<0.001	<0.01	0.8	
5A	1.15	0.005	<0.1	<0.001	<0.01	1.2	
6	<0.01	0.008	5.7	<0.001	<0.01	0.1	
6A	<0.01	0.005	9.6	<0.001	<0.01	0.1	
7	<0.01	0.012	0.8	<0.001	<0.01	0.2	
7A	<0.01	0.005	0.7	<0.001	<0.01	0.2	
8	0.26	0.003	<0.1	<0.001	<0.01	0.4	
8A	0.17	0.005	<0.1	<0.001	<0.01	0.1	
9	1.54	0.020	<0.1	<0.001	<0.01	1.0	
9A	0.04	0.009	<0.1	<0.001	<0.01	0.2	
10	0.04	0.008	<0.1	0.005	<0.01	0.2	
10A	0.24	0.008	<0.1	<0.001	<0.01	0.5	
11	<0.01	0.005	0.3	0.001	<0.01	0.1	
11A	<0.01	0.003	0.2	0.003	<0.01	0.1	
12	<0.01	0.003	12.2	0.001	<0.01	0.1	
12A	0.67	0.037	6.6	<0.001	<0.01	0.6	
13	0.04	0.009	8.4	<0.001	<0.01	0.3	
13A	0.02	0.012	11.4	0.005	<0.01	0.3	
14	0.37	0.010	0.2	<0.001	<0.01	0.5	
14A	0.87	0.009	<0.1	<0.001	<0.01	0.8	
15	0.06	0.005	2.7	0.002	<0.01	0.3	
15A	<0.01	0.005	1.8	0.002	<0.01	0.3	
16							
16A							
17	<0.01	0.005	15.7	0.007	<0.01	<0.1	
17A	<0.01	0.005	4.0	0.006	<0.01	<0.1	
18	<0.01	0.005	17.7	0.003	<0.01	<0.1	
18A	<0.01	0.005	17.5	0.005	<0.01	<0.1	
19	<0.01	0.005	9.0	0.005	<0.01	<0.1	
19A	<0.01	0.005	6.3	0.003	<0.01	<0.1	
20	<0.01	0.009	2.5	0.002	<0.01	<0.1	
20A	<0.01	0.009	5.6	0.016	<0.01	<0.1	
21	<0.01	0.003	5.6	0.007	<0.01	<0.1	
22	<0.01	0.005	<0.1	0.003	<0.01	<0.1	
23	<0.01	0.010	<0.1	0.003	<0.01	<0.1	
24	0.01	0.009	<0.1	0.003	<0.01	<0.1	
25	0.27	0.008	<0.1	0.003	<0.01	<0.1	
26	0.04	0.005	4.4	0.005	<0.01	<0.1	
27	0.04	0.010	2.8	0.004	<0.01	<0.1	
28							
29	0.01	0.003	8.9	0.003	0.01	<0.1	
30	0.01	0.038	8.5	0.009	0.03	<0.1	
31	0.01	0.024	12.7	0.007	0.02	<0.1	
32	0.13	0.101	17.1	0.010	0.10	<0.1	
Lagoon 1	30.69	0.009	0.4	4.84	6.60	43.7	
Lagoon 2	22.69	0.014	0.2	5.46	6.50	28.2	
Tank 1	20.76	0.011	2.0	5.14	5.20	23.6	
Tank 2	20.76	0.011	2.9	5.11	5.10	23.9	

Table A. (Continued)

Date 8/13 Sampling Site	NH_3	NO_2	NO_3	i-PO_4	t-P	TKN	TOC
	ppm						
1	0.04	0.009	1.8	0.008	<0.01	0.3	
1A	0.04	0.007	3.6	0.010	<0.01	0.5	
2	0.04	0.014	6.8	0.007	<0.01	0.2	
2A	0.09	0.031	5.9	0.010	<0.01	0.6	
3	0.01	0.010	8.3	0.009	<0.01	0.3	
3A	0.13	0.017	8.0	0.012	<0.01	0.4	
4	0.01	0.009	5.4	0.006	<0.01	0.5	
4A	0.17	0.009	6.3	0.003	<0.01	0.2	
5	1.03	0.015	<0.1	<0.001	<0.01	2.5	
5A	1.54	0.009	<0.1	<0.001	<0.01	0.5	
6	<0.01	0.008	3.9	0.009	<0.01	0.3	
6A	0.02	0.010	9.3	0.007	<0.01	0.3	
7	0.02	0.039	1.4	0.006	<0.01	0.3	
7A	0.04	0.017	0.4	0.006	<0.01	0.3	
8	0.32	0.008	<0.1	0.006	<0.01	0.3	
8A	0.30	0.008	<0.1	0.002	<0.01	0.3	
9	0.68	0.009	<0.1	0.002	<0.01	0.3	
9A	0.09	0.008	<0.1	0.007	<0.01	0.3	
10	0.09	0.008	<0.1	0.009	<0.01	1.3	
10A	0.32	0.008	<0.1	0.019	<0.01	1.5	
11	0.03	0.009	0.4	0.011	<0.01	0.1	
11A	0.04	0.010	0.3	0.007	<0.01	0.1	
12	0.04	0.009	13.2	0.009	<0.01	0.1	
12A	0.61	0.046	8.6	0.011	<0.01	0.1	
13	0.09	0.011	11.7	0.006	<0.01	0.3	
13A	0.04	0.010	16.1	0.001	<0.01	0.3	
14	0.45	0.010	0.3	0.004	<0.01	0.5	
14A	0.74	0.009	<0.1	0.009	<0.01	0.1	
15	0.09	0.009	5.2	0.003	<0.01	<0.1	
15A	0.02	0.003	4.4	0.002	<0.01	<0.1	
16							
16A							
17	0.08	0.010	18.4	0.006	<0.01	0.3	
17A	0.08	0.010	8.3	0.011	<0.01	0.1	
18	0.08	0.010	20.6	0.007	<0.01	<0.1	
18A	0.08	0.010	20.9	0.020	<0.01	0.1	
19	0.08	0.010	12.4	0.009	<0.01	0.1	
19A	0.08	0.012	12.1	0.005	<0.01	0.1	
20	0.08	0.014	3.2	0.004	<0.01	0.4	
20A	0.08	0.013	5.2	0.014	<0.01	0.5	
21	0.08	0.010	5.6	0.006	<0.01	0.1	
22	0.08	0.014	<0.1	0.003	<0.01	0.1	
23	0.02	0.009	<0.1	0.005	<0.01	<0.1	
24	0.17	0.009	<0.1	0.013	<0.01	0.1	
25	0.02	0.010	<0.1	0.004	<0.01	0.1	
26	0.02	0.009	5.0	0.005	<0.01	0.1	
27	0.02	0.009	3.0	0.005	<0.01	0.1	
28							
29	0.02	0.009	8.7	0.019	<0.01	<0.1	
30	0.02	0.007	14.6	0.009	<0.01	<0.1	
31	0.02	0.009	20.1	0.005	<0.01	<0.1	
32	0.06	0.014	23.1	0.009	<0.01	<0.1	
Lagoon 1	38.72	0.008	0.2	5.41	7.10	46.50	
Lagoon 2	25.01	0.014	0.2	5.52	6.60	30.80	
Tank 1	12.90	0.009	9.5	4.64	5.80	12.00	
Tank 2	12.55	0.009	9.5	4.66	5.80	12.80	

Table B. Nutrient Concentrations of the Soil on the Barriered Landscape Water Renovation System at the Coldwater Rest Area

		Spray			Non-Spray		
Date	Nutrient	0-15 cm	15-30 cm	30-45 cm	0-15 cm	15-30 cm	30-45 cm
		ppm					
4/16	NH_3			2.65			5.89
	NO_3^-			0.80			0.50
	TKN			1099			437
	t-P			204			166
	Bray-P			5.2			4.4
6/22	NH_3	0.86	0.90	1.13	0.86	1.21	2.94
	NO_3^-	2.9	1.6	1.4	1.8	1.6	1.3
	TKN	1096	608	543	1156	798	622
	t-P	266	211	193	267	216	187
	Bray-P	6.7	4.1	3.9	7.6	5.1	4.7
7/09	NH_3	1.43	1.11	0.95	1.12	1.01	0.82
	NO_3^-	4.6	1.9	1.7	1.9	1.6	1.5
	TKN	904	706	622	1444	804	573
	t-P	265	260	268	327	239	186
	Bray-P	9.1	4.7	5.1	8.6	6.3	4.7
8/07	NH_3	5.86	3.08	2.55	1.61	1.14	1.61
	NO_3^-	6.1	3.2	2.8	1.6	1.2	1.6
	TKN	1240	752	647	724	645	670
	t-P	290	250	192	202	219	230
	Bray-P	5.4	3.6	3.2	1.8	1.8	2.8

Table C. Moisture Content of the Soil on the Barriered Landscape Water Renovation System at the Coldwater Rest Area

Date of Sampling	Spray			Non-Spray		
	0-15 cm	15-30 cm	30-45 cm	0-15 cm	15-30 cm	30-45 cm
	%					
4/16			13.29			12.18
6/22	13.90	12.45	10.51	8.91	8.73	8.79
7/09	18.04	15.17	15.08	13.88	10.21	9.13
8/07	23.13	17.59	16.09	11.63	10.88	9.93

Table D. Biological Oxygen Demand of the Barriered Landscape Water Renovation System at the Coldwater Rest Area.

Well	6-29	7-26	Well	6-29	7-26
	ppm				
1	1.8	3.0	16	—	—
1A	7.8	4.2	16A	—	—
2	2.4	3.6	17	1.8	1.2
2A	3.6	6.0	17A	3.0	2.4
3	3.6	2.4	18	3.0	1.8
3A	3.0	9.6	18A	2.4	1.2
4	6.0	4.8	19	5.4	7.2
4A	9.6	9.0	19A	4.2	10.8
5	6.0	10.2	20	5.4	8.4
5A	12.0	11.4	20A	3.6	10.8
6	3.6	2.4	21	3.0	2.4
6A	10.2	6.0	22	4.2	6.0
7	4.2	10.8	23	3.0	3.6
7A	7.2	5.4	24	3.0	6.6
8	9.0	15.0	25	1.2	2.4
8A	9.0	10.8	26	3.6	5.4
9	13.8	18.0	27	3.6	2.4
9A	9.0	9.6	28	1.8	—
10	18.0	6.6	29	0.6	1.2
10A	18.0	13.2	30	4.8	5.4
11	6.6	5.4	31	4.2	7.2
11A	5.4	9.0	32	5.4	5.4
12	3.0	6.0			
12A	9.6	20.4			
13	5.4	3.0	Lagoon 1	15.0	59.0
13A	6.6	13.2	Lagoon 2	24.0	23.0
14	9.0	7.8	Tank 1	20.0	17.0
14A	6.6	9.6	Tank 2	20.0	17.0
15	3.6	1.8			
15A	5.4	5.4			

Table E. Effluent Applied and Environmental Data at the Coldwater Rest Area

Date	Effluent Applied	Rainfall	Evaporation	Radiation (total langleys)	Temperature Avg. Max. (°C)	Temperature Avg. Min. (°C)	Relative Humidity Avg. Max. (%)	Relative Humidity Avg. Min. (%)
	mm	mm	mm					
6/12-14	10.50	0.00	20.00	128.88	22.2	11.1	71	36
6/15-17	10.50	0.75	21.25	125.28	26.7	16.1	69	41
6/18-21	20.50	9.75	24.75	180.48	24.4	16.1	94	53
6/22-24	15.75	0.00	18.25	136.08	20.6	11.7	88	51
6/25-28	42.00	4.25	27.25	222.72	32.8	20.6	96	54
6/29-7/01	26.25	1.25	19.50	34.56	27.8	22.2	100	66
7/02-05	35.00	23.00	23.00	212.16	23.9	11.7	99	53
7/06-08	26.25	3.00	14.25	124.56	25.0	11.7	100	51
7/09-12	35.00	0.00	18.75	181.44	28.3	17.2	100	65
7/13-15	26.25	0.75	19.00	77.04	27.8	18.9	99	69
7/16-19	35.00	0.00	25.00	231.36	26.7	12.8	96	48
7/20-22	26.25	0.00	18.75	113.76	27.8	13.9	98	47
7/23-26	35.00	8.00	11.75	139.20	27.2	20.0	96	73
7/27-29	26.25	6.50	19.00	97.92	27.8	17.7	97	56
7/30-8/02	35.00	15.00	20.75	111.36	25.0	19.4	88	67
8/03-05	26.25	14.50	22.50	85.68	27.2	17.2	89	61
8/06-09	35.00	18.75	18.75	173.76	28.3	19.4	87	57
8/10-12	26.25	0.00	13.75	84.24	22.8	13.9	88	53
Total	493.00 (19.72 in.)	105.50 (4.11 in.)	356.25 (13.89 in.)	2460.40				

Table F. Total Coliform Concentration in the Ground Water Monitoring Wells (MPN/100 ml)

Sampling Site	Date					
	4-18	5-15	6-18	7-06	7-20	8-03
1	43	<3	150	93	>1,100	430
1A	240	43	93	230	>1,100	240
2	21	430	240	43	9	750
2A	93	<3	23	43	<110,000	110,000
3	240	43	240	230	15	150
3A	930	<3	240	43	>110,000	460
4	2,400	230	93	23	93	4,600
4A	240	23	240	930	4,300	150
5	2,400	21	150	230	4,300	93
5A	120	430	23	2,300	93,000	430
6	23	210	>1,100	1,500	23	230
6A	1,500	43	23	15	2,300	2,400
7	93		150	43	4,300	
7A	43	43	460	93	240	430
8		2,300	150	930	23,000	210
8A		4	2,100	430	43	43
9		15	240	4,300	15,000	430
9A	23	4	15,000	24,000	>110,000	750
10	4,600	1,100	9,300	7,500	4,600	430
10A	<4	9,300	210	24,000	46,000	2,300
11	460	120	93	15	110,000	4,300
11A	240	43	430	240	150	430
12	23	<3	93	240	93	230
12A	9	<3	240	23	240	15,000
13	210	930	93	3	240	230
13A	1,100	4,300	43	240	46,000	1,100
14	750	43	1,100	9	4,300	1,500
14A	23	9	93	43	1,500	230
15	240	2,100	>1,100	9	9,300	200
15A	240	39	150	<3	4	93
16	2,400	9	210	<3		
16A	460	<3	43	43		
17	46,000	23	93	<3	900	750
17A	2,400	75	43	4	900	230
18	1,100	43	1,100	43	150	430
18A	2,400	7	460	<3	210	43
19	43	<3	46,000	4	120	15
19A	75	<3	43	<3	9	<3
20	<4	<3	93	<3	4	<3
20A	<4	<3	23	15	4	43
21	<4	<3	<3	<3	<3	<3
22	<4	<3	240	<3	<3	<3
23	<4	<3	<3	<3	<3	<3
24	<4	<3	<3	<3	<3	<3
25	<4	<3	<3	<3	<3	<3
26	<4	<3	7	<3	<3	<3
27	<4	<3	93	<3	<3	4
28	<4	<3	>1,100	<3		
29	<4	<3	93	<3	<3	<3
30	<4	<3	>1,100	4	<3	<3
31	<4	<3	9	43	<3	<3
32	<4	<3	43	9	9	43
Lagoon 1	23	93	14,000	93,000	9,300	>110,000
Lagoon 2	>110,000	9,300	11,000	43,000	21,000	43,000
Tank 1			2,800	230,000	7,500	9,300
Tank 2			20,000	150,000	15,000	4,000

Table G. Fecal Coliform Concentration in the Ground Water Monitoring Wells (MPN/100 ml)

Sampling Site	Date 4-18	5-15	6-18	7-06	7-20	8-03
1	<4	0	<3	<3	900	<4
1A	93	<3	<3	<3	<4	<4
2	0	<30	240	<3	<3	<4
2A	<4	0	<3	<3	<3	15,000
3	<40	<3	240	<3	<3	9
3A	<40	0	<4	<3	23,000	150
4	<40	<30	<3	<3	11	40
4A	<40	<3	<3	<3	<4	21
5	<40	<3	<3	<3	4,300	<3
5A	<4	<3	<3	<3	2,100	90
6	<4	<3	<4	<3	<3	<4
6A	<40	<3	<3	<3	2,300	400
7	<4		<3	<3	4,300	
7A	0	<3	<4	<3	230	70
8		<300	<3	40	<4	7
8A		<3	<4	40	43	4
9		<3	<3	4,300	2,800	90
9A	<4	<3	<4	<4	240,000	90
10	0	<30	<4	40	4,600	90
10A	0	<300	90	>11,000	46,000	400
11	<40	<3	<3	4	4,000	<4
11A	<40	<3	<4	<3	150	40
12	<4	0	<3	<3	<3	90
12A	0	0	<3	<3	40	<4
13	0	<3	<3	<3	<4	<4
13A	<40	<3	<3	<3	7,000	700
14	<40	<3	<3	<3	4,300	<4
14A	0	<3	<3	<3	1,500	90
15	0	<30	<4	<3	<4	7
15A	<40	<3	<3	0	<3	<4
16	<400	<3	<4	0		
16A	<40	0	<3	<3		
17	<4,000	<3	<3	0	<3	<4
17A	460	<3	<3	<3	<3	<4
18	<40	<3	<3	<3	7	40
18A	0	<3	<4	0	<3	<4
19	9	0	<3	<3	<3	<4
19A	0	0	<3	0	<3	0
20	0	0	<3	0	<3	0
20A	0	0	<3	<3	<3	<4
21	0	0	0	0	0	0
22	0	0	<3	0	0	0
23	0	0	0	0	0	0
24	0	0	0	0	0	<4
25	0	0	0	0	0	0
26	0	0	<3	0	0	0
27	0	0	<3	<3	0	<3
28	0	0	<4	0		
29	0	0	<3	0	0	<3
30	0	0	<4	<3	0	0
31	0	0	<3	<3	0	<3
32	0	0	<3	9	<3	4
Lagoon 1		23	14,000	93,000	9,300	9,000
Lagoon 2		900	11,000	43,000	12,000	<4
Tank 1			2,800	23,000	400	2,300
Tank 2			20,000	150,000	700	4,300

Table H. Total and Fecal Streptococci Concentration in the Ground Water Monitoring Wells (MPN/100 ml)

Sampling Site	Total Enterococci			Fecal Streptococci	
	Date			Date	
	4-18	7-20	8-03	7-20	8-03
1	43	390	430	390	70
1A	1,100	>1,100	0	2,300	0
2	<40	240	430	<4	<4
2A	<40	9,300	7,500	9,300	1,500
3	93	93	0	<3	0
3A	15	>110,000	430	230,000	430
4	240	4,300	230	400	40
4A	460	460,000	230	240,000	230
5	210	430	230	430	230
5A	240	2,300	2,400	2,300	400
6	240	240	0	<4	0
6A	460	7,500	430	700	40
7	240	2,300		<4	
7A	<4	2,300	0	<4	0
8		4,300	430	4,300	90
8A	93	300	2,300	300	<4
9	43	930	430	930	230
9A	<40	>110,000	2,300	240,000	2,300
10	43	2,400	430	2,300	430
10A	240	2,300	4,300	2,300	<4
11	<40	900	2,300	900	400
11A	<40	430	0	30	0
12	240	2,400	0	<4	0
12A	43	93	930	93	430
13		430	230	430	<4
13A		7,500	24,000	7,500	23,000
14	460			1,500	<4
14A	43			2,300	430
15	1,100			<4	0
15A	240			<4	<4
16	240				
16A	240				
17	460			400	<4
17A	1,100			430	<4
18	460			<4	0
18A	240			<4	0
19	240			40	0
19A	460			<4	0
20	<40			<4	
20A	<40			<3	
21	<40			0	
22	<40			<3	
23	<40			4	
24	<40			<3	
25	<40			<4	
26	<40			<4	
27	<40			<3	
28	<40				
29	<40			<3	
30	<40			<3	
31	<40			<3	
32	<40			<4	
Lagoon 1	93	7,500	75,000	7,500	9,000
Lagoon 2	4,300	930,000	9,300	30,000	9,300
Tank 1		4,300	7,500	4,300	1,500
Tank 2		9,300	21,000	1,500	900