Water Resources Research Center
Annual Technical Report
FY 2001

Introduction

For the period of this report, the University of Hawaii Water Resources Research Center continued to focus on water supply and water quality problems relevant to tropical climates and cultures, and to disseminating research results within those cultures. We have especially promoted projects that leverag state and federal appropriations by facilitating cooperation with faculty from other units of the University.

WRRC had no faculty turnover during the reporting period. At this writing, recruitment is under way to add a hydrologist to the faculty, bringing the state-funded faculty up to 10 individuals occupying 6.4 FTE positions. In addition, two affiliate faculty had active WRRC-funded projects. State funding also supported one full time technical assistant, three editorial/graphics persons and three secretarial/clerical positions.

The USGS State Water Institutes grant supported one new and two continuing research projects, in addition to technology transfer and directors office activities. The new WRRIP project, by Economics Professor James Roumasset, will construct a dynamic optimization model integrating economic and hydrological factors to improve the allocation of water on Hawaiis largest island, Oahu. In addition, supplemental funds underwrote continued work for a U.S. Army installation. USGS WRRIP funds were leveraged with $685,000 appropriated by Hawaiis State Legislature to cover base salaries of faculty and staff and external grants of nearly $1 million.

Aside from the WRRIP projects reported below, new acativities include a US EPA grant to sample coastal water quality; state Department of Agriculture funding of a study of pesticide leaching under Hawaii soil conditions; US Department of the Army grants for studying operation anomalies at a military wastewater treatment plant; and City & County of Honolulu funding for monitoring the ocean for potential effects of treated wastewater disposed in deep ocean sites.

Research Program

In this reporting period, four research projects were active:

1. Dr. Roger Fujioka investigated appropriate organisms to indicate the presence of fecal bacteria in recreational waters;

2. Dr. Clark Liu, in the second year of a two-year project, refined a mechanism for removal of aquaculture wastes by a completely wind-powered reverse osmosis system;

3. Dr. Chittaranjan Ray began research to refine standard rainfall/runoff models to account for the flashy nature of tropical rainfall in Hawaii and similar locales.

4. Dr. Victor Moreland has continued a project to refine operations at a U.S. Army wastewater treatment plant on Oahu, to avert future violations of effluent regulations.

Removal of Nitrogeous Aquaculture Wastes by a Wind-Powered Reverse Osmosis System

Basic Information

Title:	Removal of Nitrogeous Aquaculture Wastes by a Wind-Powered Reverse Osmosis System
Project Number:	2001HI701B
Start Date:	3/1/2001
End Date:	2/28/2003
Funding Source:	104B
Congressional District:	First
Research Category:	Water Quality
Focus Category:	Nitrate Contamination, Water Supply, Waste Water
Descriptors:	nitrogen, aquaculture waste, membrane, reverse osmosis, water reuse
Principal Investigators:	Clark C.K. Liu

Publication

1. Liu, C.C.K.; J.W. Park; J. Migita; G. Qing, Experiments of a prototype wind-driven reverse osmosis desalination system for Pacific islands, Journal of Desalination, under review.

Problem and Research Objectives

Advanced treatment must be provided to wastewater used for freshwater aquaculture in order to meet effluent water quality standards. Because such treatment can be expensive and because freshwater is also increasingly in short supply around the world, an attractive management alternative is to develop a closed aquaculture system that supports effluent treatment and reuse while overcoming obstacles of high treatment cost and a short freshwater supply. The research objectives are (1) to investigate the nitrogen build-up in freshwater aquaculture of tilapia, (2) to develop a wind-powered reverse osmosis nitrogen removal system, and (3) to evaluate the economic feasibility of the wind-powered reverse osmosis system for removing nitrogen from aquaculture wastes.

Methodology

This is a two-phase project, with each phase lasting about one year. The focus of the first year's research (activities and findings reported here) is to study the characteristics of aquaculture waste, especially the concentration of nitrogen at different stages of fish (tilapia) growth. The second year's research will be conducted to investigate the performance of nitrogen removal by the reverse osmosis process and to develop a water recirculating system for tilapia production.

Principal Findings and Significance

An experimental system, which consists of an aquaculture subsystem or a fish tank for tilapia culture and a wind-powered reverse osmosis treatment subsystem, was constructed at the research facilities of the Hawaii Institute of Marine Biology on Coconut Island, Oahu, Hawaii.

Water samples were collected from the tilapia culture tank from June 2001 to February 2002. Samples were analyzed in the water quality laboratory of the Water Resources Research Center at the University of Hawaii at Manoa. Table 1 shows the nitrogen concentration data for the aquaculture subsystem. Feedwater is the freshwater provided to the fish tank. Discharge indicates the aquaculture waste flow out of the fish tank. The waste discharge

Table 1. Nitrogen Concentrations of Aquaculture Subsystem Under Normal Conditions

Date	NH_3-N (mg/l)		NO_3-N (mg/l)		NO_2-N (mg/l)	
	Feedwater	Discharge	Feedwater	Discharge	Feedwater	Discharge
06/13/2001	UD*	0.19	0.17	0.14	0.001	0.006
06/14/2001	UD	0.14	0.17	0.14	0	0.001
06/15/2001	UD	0.11	0.21	0.17	0.003	0.004
06/21/2001	UD	0.12	0.20	0.16	0.003	0.002
07/10/2001	UD	0.07	0.15	0.13	0.002	0.001
01/07/2002	UD	0.40	0.17	0.17	0.001	0.001
01/09/2002	UD	0.32	0.17	0.17	0.001	0.003
01/17/2002	UD	0.50	0.16	0.16	0	0
01/22/2002	UD	0.23	0.17	0.20	0	0.001
01/24/2002	UD	0.20	0.17	0.18	0.001	0.002
01/31/2002	UD	0.09	0.17	0.17	0.002	0.001
02/05/2002	UD	0.22	0.14	0.16	0	0.001
02/12/2002	UD	0.26	0.16	0.16	0.001	0.002
02/14/2002	UD	0.06	0.18	0.16	0	0.002
02/21/2002	UD	0.09	0.14	0.14	0	0
02/26/2002	UD	0.25	0.12	0.12	0.004	0.003

*****UD = undetectable.

becomes the feedwater for the wind-powered reverse osmosis treatment subsystem. The hydraulic retention time in the aquaculture subsystem or fish tank was about 500 minutes (8.3 hours). During this time, the feedwater and waste discharge rates were both about 73 gal/h (4.6 l/min).

The feedwater provided to the fish tank contained ammonia nitrogen (NH_3-N) at a concentration of less than 0.03 mg/l, whereas the concentration in the aquaculture waste discharge averaged 0.20 mg/l with an unbiased standard deviation of ±0.12 mg/l. The average feedwater nitrate nitrogen (NO_3-N) concentration was 0.17 ± 0.02 mg/l, and the discharge concentration was 0.16 ± 0.02 mg/l. The nitrite nitrogen (NO_2-N) concentration was 0.0012 ± 0.0012 mg/l for the feedwater and 0.0019 ± 0.0015 mg/l for the discharge.

Performance of the reverse osmosis treatment subsystem to remove nitrogen has been evaluated by studying nitrogen concentrations in the feedwater and product water (permeate), as well as by studying the operating flow rate and feed water pressure. Preliminary data indicated that the subsystem removes about 93% of the ammonia and nitrate from the feedwater. The effluent from the treatment subsystem, with very low concentrations of nitrogen, would be suitable for reuse in tilapia culture.

A paper, “Experiments of a prototype wind-driven reverse osmosis desalination system for Pacific islands,” by C.C.K. Liu, J.W. Park, J. Migita, and G. Qing has been submitted to the *Journal of Desalination.* It is currently under review.

The second phase of this project began in March 2002.

Confirming the Natural Presence of Fecal Indicator Bacteria in Environmental Soil and Water on the Islands of Kauai and Hawaii

Basic Information

Title:	Confirming the Natural Presence of Fecal Indicator Bacteria in Environmental Soil and Water on the Islands of Kauai and Hawaii
Project Number:	2001HI2082B
Start Date:	3/1/2001
End Date:	2/28/2002
Funding Source:	104B
Congressional District:	First
Research Category:	Water Quality
Focus Category:	Water Quality, Non Point Pollution, Water Use
Descriptors:	health effects, tropical environment, water quality standards, fecal indicator bacteria
Principal Investigators:	Roger S. Fujioka

Publication

Problem and Research Objectives

Based on studies conducted on the island of Oahu over many years, we have determined that the U.S. Environmental Protection Agency (EPA) recreational water quality standards are not applicable in the state of Hawaii. The reason is that the two assumptions used by EPA in interpreting the public health significance of exceeding water quality standards do not apply to the state of Hawaii. The first assumption is that there are no significant environmental sources of fecal indicator bacteria other than feces and sewage. We have determined that soil in Hawaii is a natural habitat for fecal indicator bacteria. The second assumption is that the fecal indicator bacteria cannot multiply under natural environmental conditions. We have determined that environmental conditions (temperature, moisture, nutrients) in Hawaii's soil environment enable these fecal indicator bacteria to multiply.

All streams on Oahu consistently contain excessively high concentrations of fecal indicator bacteria (fecal coliform, *Escherichia coli*, enterococci) and exceed EPA recreational water quality standards. The monitoring data from Hawaii based on EPA-approved fecal indicator bacteria cannot be used to determine when streams are actually contaminated with sewage. We have also determined that other fecal indicators (*Clostridium perfringens*, FRNA coliphages) can be used to determine when streams are contaminated with sewage. Although we have obtained sufficient monitoring data for Oahu, we have not obtained collaborative monitoring data for the neighbor islands. The primary objective of this study was to determine whether similar monitoring data would be obtained from stream water samples taken from the islands of Kauai and Hawaii when the methods used on Oahu are applied.

Methodology

EPA-approved methods were used to assay stream water samples obtained from Kauai for fecal coliform, *E. coli*, and enterococci. These same water samples were also assayed for *C. perfringens* and FRNA coliphages using methods published by EPA and established in our laboratory. Arrangements were made to have water samples sent to us from Kauai on a monthly basis. In addition, we traveled to Kauai on three occasions to obtain water samples. The Hanalei watershed and the Nawiliwili watershed were the study sites.

Principal Findings and Significance

We analyzed stream water samples from various sites on Kauai but primarily from the Hanalei watershed and from the Nawiliwili watershed. The results of the monitoring data showed that the EPA-approved fecal indicator bacteria (fecal coliform, *E. coli*, enterococci) are naturally present in high concentrations that exceed EPA recreational water quality standards. These results are similar to the results obtained for Oahu and indicate that the conclusions made from monitoring data on Oahu are applicable to Kauai and most likely to other islands throughout the state of Hawaii. Analysis of the same stream and coastal water samples from Kauai was also made for *C. perfringens* and FRNA coliphages, two indicators of sewage contamination in streams in Hawaii. The results showed high concentrations of *C. perfringens* and FRNA coliphages, similar to the results obtained for Oahu. These results confirm that monitoring environmental waters for *C. perfringens* is the most reliable test to determine when environmental waters are contaminated or are not contaminated with sewage throughout the state of Hawaii. Our studies have also shown much higher concentrations of FRNA coliphages in environmental water samples from Kauai than from Oahu. All sources of FRNA coliphages have not been determined, but these coliphages are always present in human sewage. The most likely sources of FRNA coliphages on Kauai are cesspools and septic tanks. This conclusion is based on two supporting observations. The first is that there are many more cesspools and septic tanks on Kauai than on Oahu. The second is that rain is much more prevalent on Kauai than on Oahu. More studies are needed to better characterize the sources of FRNA coliphages on Kauai.

The Hawaii island portion of this study, which was to begin in March 2002, was not funded.

An Accurate Evaluation of Water Balance to Predict Surface Runoff and Percolation

Basic Information

Title:	An Accurate Evaluation of Water Balance to Predict Surface Runoff and Percolation
Project Number:	2001HI2141B
Start Date:	3/1/2001
End Date:	2/28/2002
Funding Source:	104B
Congressional District:	First
Research Category:	Climate and Hydrologic Processes
Focus Category:	Surface Water, Groundwater, Models
Descriptors:	models, runoff, best management practices, vadose zone, ground water, infiltration, recharge
Principal Investigators:	Chittaranjan Ray

Publication

Problem and Research Objectives

Hawaii, like many other states, has a number of unlined landfills that are potential groundwater contamination sources. Infiltration control is a major means of reducing leachate generation at unlined landfill sites. Use of synthetic materials for the closure of landfills is quite expensive, especially for small rural communities. Use of alternate capping technologies, such as vegetation caps, is not suitable in humid areas where the annual precipitation exceeds the evapotranspiration demand of growing crops. However, a combination of natural soil caps and runoff-enhancing structures can be a feasible capping method. Local plants growing on natural clay caps could transpire a large part of the percolating water. Making a portion of the landfill surface impervious (e.g., by use of rain gutters) and diverting the surface runoff offsite could reduce the entry of water through the landfill cap, thus reducing the potential for leachate generation. A recent demonstration by the U.S. Navy showed that, in tropical areas such as Hawaii, it is possible to cap landfills with natural soil cover if 20% to 40%of the surface area can be covered with rain gutters. However, the amount of error in the prediction was high. The model used daily water balance for calculating runoff and infiltration. In reality, rainfall in Hawaii occurs over a relatively short period of time. Higher-intensity rains cause significant surface runoff. Averaging a storm event over a day would significantly reduce the intensity, making it appear as if there is no runoff and all water is infiltrating the ground. For groundwater recharge studies, this may provide a false sense of security from modeling that a large part of the rainwater is entering the soil in source water areas and less water is lost through runoff. It is clear that an accurate estimate of partitioning of rainwater to surface runoff and infiltration and the subsequent movement of infiltrated water through subsoil media are quite important for a variety of applications.

The objectives of the first year (phase-1 effort) of this study are to measure percolate and runoff at frequent intervals daily at each of six test plots and to keep all instruments in working order. Our main focus is to calibrate and test a recharge model and a runoff-producing model against the collected data. These models will provide some insight into the mechanisms of percolate and runoff production in response to specific storm events. They will also indicate if improvements in modeling strategy are needed for better calibrate against the collected data.

The effort in the second year (March 2002 through February 2003) will focus on the validation of a regulatory model that is commonly used for the closure of landfill caps. The data will also help in the recalibration of the surface runoff and percolate production models and in the study of chemical transport through the soil.

Methodology

The study site is located at the Marine Corps Base Hawaii in Kaneohe, Hawaii. The site, located near a landfill site, has six test plots—all instrumented to collect surface runoff, percolate at a depth of 2 to 3 feet, and soil moisture data. In addition, weather data such as temperature, wind velocity, solar radiation, and rainfall are measured at the test site. The site is instrumented with pressure transducers, flow meters, soil moisture probes, and other sensors that are connected to data-logging devices to collect data at intervals ranging from a few minutes to twice daily. All collected data from the data loggers are downloaded to a computer (remotely located anywhere) via a modem and a cellular phone daily.

The year-1 activities include (1) repair and replacement of aging and malfunctioning sensors and instruments, (2) recalibration of instruments, (3) automated data collection, and (4) setting a framework for water balance calculations.

Although the plots were available to us at the start of the first year's effort, most instruments and sensors were not operational, so time was spent repairing and replacing them. Solar panels that charge batteries and nearly all batteries (12 of them) were replaced. Two sump pumps (which pump water out of runoff or leachate tanks) were repaired, while most flow counters (which record the pumpage out of the tanks) and level switches (that activate the pumps) were replaced. Erosion was quite severe on two faces of the project site, so gravel riprap and erosion cloths were installed on the slopes to reduce erosion. In addition, a watertight wall was installed at the north end of the plots to prevent the flow of surface water toward the plots. Other items replaced include the moisture packs in pressure transducers and in various storage areas of data loggers and sensors, the malfunctioning cellular phone, and the switch of one tipping-bucket rain gage.

After replacing the sensors, the instruments were recalibrated. This included the recalibration of the pressure transducers in runoff and leachate tanks. Pressure readings were calibrated against tank volumes. The flow counters

on the outflow lines of the sump pumps were calibrated for the amount of flow passing through the flow meters. Sensors on weather station were recalibrated.

Three CR21x data loggers, available from Campbell Scientific, Inc. (CSI), is used for the collection of data from the sensors at various intervals. A Windows-based software, also available from CSI, is used to download the data to a computer on the Manoa campus of the University of Hawaii using a cellular phone at the landfill site. All data are downloaded on a daily basis. The frequency of data collection for various sensors is 15 minutes, with the exception of the TDR probes, which are programmed to collect data twice a day. The frequency of data collection can easily be reprogrammed.

Precipitation, runoff, percolation, and change in storage are measured to determine the water balance. The only unknown parameter for the site is evapotranspiration, which can be estimated from the water balance equation.

Principal Findings and Significance

The primary effort for the first year was to set up instrumentation and revitalize the site. We found the durability of several sensors and instruments to be quite satisfactory, however. For example, the pressure transducers are still functional after seven years of service, and most of the rain gages are still working nicely. All sensors and equipment must be serviced at proper intervals for reliable operation, however. For example, because the domes of net radiometers crack in three to six months, allowing rainwater to easily get into the cracks, the domes need to be replaced every three months. A maintenance schedule was developed for all the equipment at the study site.

Preliminary data show that all sensors are working well. We are in the process of evaluating the collection of soil water data from TDR probes at more frequent intervals. All TDR probes are installed in the top 6 inches of soil. We plan to move some of these probes to deeper depths to obtain a moisture profile for the entire 24-inch cap.

Details of water balance analysis will be the focus of second year's effort. We will also conduct a vegetation survey twice a year for each of the six plots.

Optimize Aeration, Secondary Clarifier and Disinfection Processes

Basic Information

Title:	Optimize Aeration, Secondary Clarifier and Disinfection Processes
Project Number:	
Start Date:	9/1/2000
End Date:	12/31/2003
Funding Source:	Supplemental
Congressional District:	HI 01
Research Category:	Engineering
Focus Category:	Waste Water, Treatment, None
Descriptors:	wastewater treatment; aeration; disinfection
Principal Investigators:	Victor D. Moreland

Publication

Problem and Research Objectives

The U.S. Army's Schofield Barracks Wastewater Treatment Plant has a history of not consistently meeting the microbial requirements for discharge into the Waialua Sugar Company irrigation system. The plant was operating under a Compliance Plan requiring several actions, including the performance of research to develop preventive and corrective maintenance routines specific to the aeration basin, secondary clarifiers and disinfection system. The disinfection challenge of reducing the total coliform is that final effluent quality shall not exceed 23/100 ml for a 30 day median or exceed 240/100 ml in any sample.

Objectives of the project are:

- Determine whether the chlorine disinfection process is adequate for meeting the microbial requirements.
- Determine whether the upstream biological process should or can be improved to lessen the burden on the disinfection process.
- Assist in developing tests and preventive/corrective maintenance tasks for operations personnel to troubleshoot secondary process and disinfection process

Methodology

Review existing plant data for process variations that point to a need for process changes. Meet with operating staff, as a team building effort, to discuss past and current operating guidelines that have been used both successfully and unsuccessfully. Discuss possible changes to the operating guidelines and implement what as a team are felt to be the best testing concepts with the best opportunity of success.

Principle Findings and Significance

Chlorine disinfection process by itself would be inadequate without secondary process improvements.

Control guidance in the past has usually been either mixed liquor suspended solids (MLSS), concentration or mean cell residence time (MCRT), days. In this effort a somewhat newer approach called total mass (total pounds of suspended solids in the secondary process) was used.

Through experimenting with the process it was found that a far lower than normal dissolved oxygen (0.20 - 0.30 mg/l) was used very successfully resulting in single digit effluent total suspended solids (TSS). To date, this process has allowed the chlorine disinfection process to meet the disinfection requirements.

Information Transfer Program

Major activities of WRRCs information transfer program include (1) a seminar series; (2) maintenance of WRRCs website; (3) a database on water; (4) a series of newsletter and project bulletins. Reports on these projects appear below. Early planning began for a state-wide conference sponsored by WRRC on Scientific, Regulatory and Cultural Factors Influencing Water and Environmental Issues in Tropical Pacific Islands. (The conference was held January 15-16, 2003, with co-sponsorship from the USGS Hawaii District office and the Pacific Water Association. About 160 participants attended, from Hawaii as well as several Pacific islands.)

In addition, the Technology Transfer Office endeavors to respond to requests for public information; to produce poster materials and slides for faculty presentations and reports; and to deliver presentations and demonstrations in schools and community groups. An example of the latter is a presentation by the director and the technology transfer specialist to a group of science teachers from various states who were visiting Hawaii on a Close Up Foundation educational tour.

Information Transfer Projects

Basic Information

Title:	Information Transfer Projects
Project Number:	2001HI13B
Start Date:	3/1/2001
End Date:	2/28/2002
Funding Source:	104B
Congressional District:	HI 01
Research Category:	Not Applicable
Focus Category:	None, None, None
Descriptors:	seminars, website, newsletters, database
Principal Investigators:	Philip Moravcik

Publication

1. Moravcik, Philip (ed.) May 2001. Bulletin, Water Resources Research Center, University of Hawaii at Manoa. 6 pp. URL: www.hawaii.edu/wrrc/MAY2001.html

Information Transfer Projects

2000 WRRC Seminar Series

The Seminar Series is designed to foster communication amongst WRRC researchers, students, and the research audience of government officials, private sector personnel and members of the public interested in water resources. A WRRC faculty member is appointed each semester to draw up and invite a list of speakers. Topics vary depending on interests of the coordinator and availability of speakers. Typically, the seminars include reports of WRRC projects and discussions by government officials of emerging water-related issues. A list of seminars presented during the reporting period follows.

SPRING SEMESTER 2001 SEMINAR COORDINATOR: DR. ALY EL-KADI

3/1/2001	Eric Heinen De Carlo From the Mountains to the Sea: Water quality on Oahu Hawaii
3/15/2001	William Wong Safe Drinking Water Underground Injection Control Potential Impact of Agricultural Diversification on Water Quality
4/4/2001	Samir A. El-Swaify Potential Impact of Agricultural Diversification on Water Quality
4/19/2001	Chester Lao Sustainable Yield
5/17/2001	Roy Hardy The State Water Commission and Sustainable Yield in Hawaii

FALL SEMESTER 2001 SEMINAR COORDINATOR: DR. JOHN HARRISON

10/4/2001	Professor Joseph Sax Hawaii, Water, and the Public Trust Doctrine
10/18/2001	Malia K.H. Akutagawa, Esq The History of Water Law in Hawaii
11/1/2001	Dr. Chittaranjan Ray Studies of Bacteria & virus Transport in Oahu Soils
11/15/2001	Robert Nishimoto Muliwai: A critical Habitat Bridging the Stream (wai) to the Ocean (kai)
1/10/2002	James Parham Development of Spatially-Based Models of Hawaiian Streams and Stream Fish Habitats

SPRING SEMESTER 2002: SEMINAR COORDINATOR: PHILIP MORAVCIK

1/14/2002	David Hyndman Efficient Large-Scale Bioremediation in a Heterogeneous Aquifer: The Schoolcraft Bioaugmentation Experiment
2/7/2002	Dr. Wendy Wiltse Perspectives on Watershed Management in Hawaii
2/21/2002	Derek J. Chow US Army Corps of Engineers' West Honolulu Watershed Study

WRRC Website: 2001-2002

The website, at URL www.hawaii.edu/wrrc/WRRC.html, serves to provide current historical information to people and agencies interested in water issues and problems, as well as water topics in general. The site provides information generated through WRRC research projects, descriptions of current projects, background of faculty and extensive links to related University departments as well as federal, Hawaii and Pacific agencies and organizations.

The website is by nature a work in progress and is updated frequently. Increasingly, WRRC publications are posted on the site and hyperlinks provided to reports or related information. Abstracts of WRRC publications are provided at the website. Seminar announcements are posted on the website, and conference agendas and registration information is available there.

WRRC Water Database 2001-2002

Water agencies and the public frequently call WRRC for information on water and wastewater issues. Articles appearing the various newspapers published in the state are an important source of current and historical information. Pertinent articles are culled form Hawaii's newspapers and maintained in a searchable database by the technology transfer office.

The technology transfer office maintains a database of local newspaper articles pertaining to issues of water and wastewater. This database is made available to individuals from within the university community as well as to government agencies, the private sector and the interested public.

WRRC Newsletters and Project Bulletins

Researchers need channels of communication to potential users of their results. WRRC needs a means of publicizing its project results and other activities. Newsletters and project bulletins convey this information in an informal, non-technical manner. During the reporting period, one newsletter was produced. It can be viewed at www.hawaii.edu/wrrc/WRRC.html.

Student Support

Student Support					
Category	**Section 104 Base Grant**	**Section 104 RCGP Award**	**NIWR-USGS Internship**	**Supplemental Awards**	**Total**
Undergraduate	3	0	0	0	0
Masters	2	0	0	0	0
Ph.D.	0	0	0	0	0
Post-Doc.	0	0	0	0	0
Total	0	0	0	0	0

Notable Awards and Achievements

Publications from Prior Projects

1. El-Kadi, Aly I., 2001, Modeling hydrocarbon biodegradation in tidal aquifers with water-saturation and heat inhibition effects, Journal of Contaminant Hydrology 51(1-2), 97-125.
2. El-Kadi, Aly I.; Jill D. Torikai, 2001, Identifying variably saturated water-flow patterns in a steep hillslope under intermittent heavy rainfall, Hydrogeology Journal 9, 231-242.
3. DeCarlo, E.H.; S.S. Anthony, 2002, Spatial and temporal variability of trace element concentrations in an urban subtropical watershed, Honolulu, Hawaii, Applied Geochemistry 17, 475-492.