Water Resources Research Center
Annual Technical Report
FY 2006

Introduction

The University of Hawaii Water Resources Research Center, in the FY2006 reporting period, initiated three new projects under the 104(b) program and renewed funding for a fourth project. Work continued on a 104(g) award, begun under the FY 2005 appropriation. Two projects, sponsored by the U.S. Army using intergovernmental transfers of funds to USGS, were completed in FY 2006. In addition, a small allocation for information transfer was renewed. The administration program mainly funded faculty travel, an important function given the isolated location of Hawaii.

Funds for research projects cover mainly salary for graduate research assistants. Salaries have grown over the years. In order to continue covering four rather modest research projects, we have allocated other funds to supplement the 104(b) money. In the near future, if salaries continue to increase, it will be necessary to fund fewer projects or to rethink the type of grants made under this program: partial rather than full RA support, less ambitious projects, perhaps more community outreach and less actual research.

In addition to the USGS/WRRI Program, thirteen new projects were funded through WRRC this year. These projects allowed WRRC to leverage each dollar of USGS/WRRIP funding into more than $20 of other funding. Research covers assessment of veterinary antibiotics, hormones and termiticide treatments; improving conventional hydrological models; advancing water treatment processes (desalination, ultraviolet radiation and riverbank filtration); and recycling wastewater, among other topics. WRRC continues to support City and State agencies in implementation of various federal water and wastewater laws and regulations. WRRC faculty participate in several programs funded through other units of the University, notably the Pacific Regional Center for Marine Biomedicine.

In May 2006, WRRC's Technical Advisory Committee met and, using a version of the nominal group technique, identified directions of importance for future research efforts. In no particular order of priority, these areas are:

- Integrated water resources management, hydrology, economics, culture, externalities
- Watershed planning and management, and measurable indicators of success
- Modeling sediment containment
- Natural hazard assessment; floods and drought
- Updated rainfall recharge data and analysis
- Wastewater reuse over potable aquifers
- Forecasting the hydrologic cycle over a range of time and areal scales
- Risk assessment and management of water quality and quantity
- Water quality standards and regulation for Hawaii
- Pipeline forensics and asset replacement modeling

Research Program

Water use on Oahu, as in many other parts of the world, has drawn near to the sustainable capacity of underground aquifers. This has led to experiments in search of alternative sources such as desalination and recycling, as well as methods to protect and extend conventional sources.

Our 104(b) allocation supported four projects for FY2006: one (2006HI159B) began developing genetic fingerprinting methods to identify and control organisms that foul membrane bioreactors, used in water and wastewater treatment processes. A second (2005HI103B, in its second year) recognizes that before the island undertakes the massive investment for expensive treatment alternatives, much can be done to rationalize and conserve conventional sources of supply. To this end, researchers have investigated the economics of pricing reform as an inducement to water conservation. In the process, this research has integrated hydrology into economic models, notably in considering multiple, interconnected aquifers. A third project (2006HI144B) examines hydrological models for flood control and water quality management. This project responds to recent flood events on Oahu and Kauai. Finally, project 2006HI138B, in search of methods to protect water sources, studies the processes by which contaminants travel through soils into streams and aquifers.

A 104(g) project (2005HI125G) is in its second year. This project adapts optimal control models to consider external, as well as direct, effects of groundwater withdrawals.

Supplementary funding, via the Corps of Engineers, have been essentially completed. One (2005HI172S) cooperated with the State Department of Education to developed a storm water education program for use in elementary schools affected by Army installations on Oahu. The other (2005HI173S) studied the possibility of using ozone to replace conventional laundry detergents and to sanitize food preparation areas.

Integrated management of multiple aquifers with subsurface flows and inter-district water transport

Basic Information

Title:	Integrated management of multiple aquifers with subsurface flows and inter-district water transport
Project Number:	2005HI103B
Start Date:	3/1/2006
End Date:	2/28/2007
Funding Source:	104B
Congressional District:	HI 1st
Research Category:	Social Sciences
Focus Category:	Economics, Groundwater, None
Descriptors:	
Principal Investigators:	James A. Roumasset

Publication

1. Pongkijvorasin, Sittidaj, and James Roumasset. 2007. Optimal conjunctive water use over space and time. Journal of Environmental Economics and Management. (under review).
2. Pitafi, Basharat A., and James A. Roumasset. 2006. "Evaluating interdependent watershed conservation and ground water management reforms," Journal of the American Water Resources Association 42(6) (December), pp. 1441-1450.
3. Pitafi, Basharat A., and James A. Roumasset. "Pareto-improving water management over space and time: The Honolulu case," American Journal of Agricultural Economics (under review).

Problem and Research Objectives

The problem of groundwater management has been studied widely in the literature. However, all of the previous studies limit their attention to the single aquifer case. In many places, water can be extracted from more than one source to supply the demand. For example, the Honolulu Board of Water Supply (HBWS) currently extracts from both the Pearl Harbor and Honolulu aquifers, pumping the resource into an interconnected pipeline serving the Pearl Harbor and Honolulu water districts. HBWS imports water extracted from the Pearl Harbor aquifer to meet Honolulu demand. This calls for a single model integrating extraction, distribution, and consumption from the two sources. This model will provide an analysis of a situation much closer to that actually observed in HBWS practices. Particularly, we aim to analyze the principle of optimal water use when water can be extracted from two sources. We also discuss various possible extraction schemes.

Methodology

First, we develop a model integrating extraction, distribution, and consumption from the two water sources. Specifically, a social planner chooses the amount of water extracted from the two different aquifers and the amount of desalinated water used in order to maximize the present value of net social benefit (i.e., the benefit from water consumption minus the costs of extracting and distributing the water). The problem is then solved by dynamic optimization. Phase-diagrams and time paths of aquifer head and water price for the different scenarios are analyzed and discussed.

By extending the Pitafi-Roumasset Honolulu study to the water districts served by the Pearl Harbor aquifer we were able to study optimal water extraction over space and time. When the aquifers are managed separately, the Honolulu efficiency price increases more quickly than the Pearl Harbor price, implying that water needs to be increasingly transferred to Honolulu. This results in the Honolulu price rising more slowly and reaching the desalination steady-state at a later time than without said transfers. Alternative pricing schemes are also compared.

Principal Findings and Significance

From the developed model, we find that, in the optimal solution:

1. Both aquifer swill be used and built up if both have lower head levels than their steady states.
2. Both aquifers will be depleted if their heads are higher than their steady states. However, if one aquifer requires a higher initial price than the other, it is optimal to extract water from only one aquifer, leaving the other to build up.
3. If one aquifer head is lower than its steady state, it is optimal not to use that aquifer but to let the head build up. The water is extracted only from the other aquifer in this case. If the building head reaches its steady state while the depleting one does not, the building one can go higher and then be depleted.
4. If an alternate source is available at a cost no more than the steady-state price that would prevail without it, the alternate source will be used in steady state.
5. If an alternate source is available at a cost higher than the steady state price that would prevail without it, the alternate will not be used in steady state. If both aquifer heads are initially lower than their steady states, both will not be used at the beginning. The alternate will be used in the beginning period, leading to the case of so-called “frontstop.”
6. Marginal cost pricing is feasible when block-pricing schemes are used for natural monopoly goods. Switching to marginal cost pricing is a more effective way to increase revenues and conservation than standard price increases. Users at different elevations face different distribution costs, therefore a pricing scheme which does not take this disparity into account effectively cross-subsidizes residents at higher elevations facing higher user costs but not required to pay the difference.
7. Preliminary analysis suggests that welfare gains for integrated management of the two aquifers, relative to the status quo, are somewhat larger, even in percentage terms, than efficient, but separate, management of single districts. The use of desalination in the Honolulu district was delayed as much as 20 years in the integrated management scenario relative to status quo management.

8. When the Honolulu and Pearl Harbor aquifer models are run separately, there is a greater spatial effect in the Honolulu case. Moving from separate optimization to integrated optimization increases the tendency to import water into Honolulu. Thus, moving from status quo management to the integrated, optimized solution causes two offsetting effects. On the one hand, charging high-elevation Honolulu customers the full marginal cost reduces the need to import water from the Pearl Harbor aquifer. On the other hand, the more slowly increasing Pearl Harbor efficiency price increases the tendency toward Honolulu imports.

The following presentations reported on project findings:

1. Pongkijvorasin, Sittidaj; James A. Roumasset; Basharat A. Pitafi, 2006, How to stop worrying and learn to love bathtub economics, presented at the First Occasional Giannini Retreat on Water Economics, University of California, Davis, December 19, 2006.
2. Roumasset, James A.; M. Rosegrant, 2006, Efficient irrigation management, with return flows, groundwater recharge, and pollution, presented at the IAAE meeting, Brisbane, Australia. August 12–18, 2006.
3. Pitafi, Basharat A.; James A. Roumasset, 2006, Integrated management of multiple aquifers with subsurface flows and inter-district water transport, presented at the AAEA annual meeting, Long Beach, Calif., July 24–28, 2006.
4. Pitafi, Basharat A.; James A. Roumasset, Pareto-improving water management over space and time: The Honolulu case, presented at the 3rd World Congress of Environmental and Resource Economist, Kyoto, Japan, July 3–7, 2006.
5. Pitafi, Basharat A.; James A. Roumasset; R. Smith, When a backstop becomes a frontstop: Managing groundwater aquifers with low cost substitutes, presented at the WEAI annual conference, San Diego, Calif., June 29–July 3, 2006.
6. Pitafi, Basharat A.; James A. Roumasset, 2006, Integrated management of multiple aquifers with subsurface flows and inter-district water transport, presented at the WEAI annual conference, San Diego, Calif., June 29–July 3, 2006.
7. Pitafi, Basharat A.; Sittidaj Pongkijvorasin; James A. Roumasset, 2006, Coastal groundwater management in the presence of positive stock externalities, presentation at the WEAI annual conference, San Diego, Calif., June 29–July 3, 2006.
8. Roumasset, James A., 2006, Economic principles for Oahu's water and watershed management, luncheon address to the Hawaiian Economic Association, Plaza Club Honolulu, Hawaii, January 26, 2006.

Coastal Groundwater Management in the Presence of Positive Stock Externalities

Basic Information

Title:	Coastal Groundwater Management in the Presence of Positive Stock Externalities
Project Number:	2005HI125G
Start Date:	9/1/2005
End Date:	8/31/2008
Funding Source:	104G
Congressional District:	HI 1
Research Category:	Social Sciences
Focus Category:	Hydrology, Economics, Ecology
Descriptors:	None
Principal Investigators:	Kaeo Duarte, James A. Roumasset

Publication

1. Pongkijvorasin, Sittidaj. 2007. Stock-tostock Externalities and multiple Resources in renewable resource economics: Watersheds, conjunctive water use, reefs, and mud. "Ph.D. Dissertation, Department of Economics, University of Hawaii at Manoa (forthcoming), Honolulu, Hawaii, x+117 pp.
2. Pongkijvorasin, Sittidaj, and James Roumasset. 2007. "Optimal conjunctive use of surface and groundwater with recharge and return flows: Dynamic and spatial patterns." Review of Agricultural Economics 29(3) (forthcoming)

Problem and Research Objectives

Hawaii's nearshore marine environment, which is a major recreational and ecological resource, is dependent on fresh groundwater discharge. Freshwater discharges from the groundwater aquifer into the ocean and mixes with the seawater, creating a nearshore ecological system that has evolved with less than seawater salinity and which supports indigenous fish and marine vegetation. Thus, the state of the groundwater aquifer directly affects the cultural, recreational, and economic values of the community. As water is extracted from the groundwater aquifer to meet demand, lower aquifer head levels will decrease freshwater discharge into the ocean, thus increasing salinity and damaging the balance of the nearshore marine ecosystem. Traditionally, models of optimal groundwater extraction do not include such environmental effects. The problem, therefore, is to govern groundwater extraction based on considerations of environmental consequences as well as present and future benefits of water consumption.

In order to assess the economic, biological, and cultural significance of varied levels of submarine groundwater discharge on the nearshore environment, we develop a botanical research activity for studying the effects of aquifer-induced freshwater discharge on native marine algae. Since native algae play a key role as the primary producers that support a unique food web of endemic organisms, the overall health of the nearshore marine environment is of great concern. By monitoring the response of marine algae to varied levels of nutrients and salinity in a controlled laboratory environment, we will gain a better understanding of the physiological effects of variable amounts submarine groundwater on marine algae species and the nearshore marine environment as a whole. The physiological parameters measured in this investigation include growth rate, branch development, and light absorbance.

Methodology

This research has two phases, which will be melded in the third year. The first involves an integrated bio-hydro-economic model to search for optimal levels of groundwater use and limu (Hawaiian seaweed) production. The second is a laboratory phase designed to provide understanding of the relationship between salinity and biological productivity of freshwater-impacted ocean areas.

Integrated Bio-hydro-economic Model

The model structure applied here closely follows that of D.L. Krulce, J.A. Roumasset, and T. Wilson (1997, Optimal management of a renewable and replaceable resource: The case of coastal groundwater, *American Journal of Agricultural Economics* 79:1218–1228), whose model in turn is an application of optimal control mathematics. The objective is to choose a path over time for extraction of groundwater and production of desalinated water in order to maximize the present value of net social surplus from water. The social surplus covers both traditional water uses and external benefits from production of indigenous fish and marine vegetation in nearshore waters affected by the discharge of freshwater from aquifers. We are particularly interested in limu as a nearshore resource that is affected by groundwater discharge. However, the model is general and can be applied to other nearshore resources.

The social planner's problem is to choose the paths of groundwater extraction and desalinated water over time in order to maximize the social net benefit, which includes the benefits from water and limu consumption minus the costs of supplying water and harvesting limu, i.e.:

$$\max_{q_t, b_t} \int_0^{\infty} e^{-rt} \left[\int_0^{q_t + b_t} p(x)dx - c(h_t)q_t - \bar{p}b_t + \int_0^{m_t} p_m(y)dy - c_m(S_t)m_t \right] dt$$

$$s.t. \quad \dot{h}_t = a[R - l(h_t) - q_t]$$

$$\dot{S}_t = g(S_t, h_t) - m_t$$

The Hamiltonian has two constraints, one for head level (which gives the shadow price of water in situ) and one for limu stock. First-order conditions for this problem yield the price path:

$$p = c(h) + \frac{\dot{p} - a(R - l(h))c'(h)}{r + al'(h)} + \frac{ag_h(S,h)\lambda}{r + al'(h)}$$

If the desalination technology is used, p is also equal to the cost of desalination.

Botanical Research

In this study, the endemic edible species *Gracilaria coronopifolia* was chosen for investigation. To accurately measure the physiological response of this marine alga to isolated variables, a digital growth chamber was modified to support a unidirectional flow-through saltwater system. Growth conditions are fully controlled.

In order to quantify changes in wet weight and morphology, three variables were calculated. The specific growth rate was calculated as follows: [(final wet mass – initial wet mass) / initial wet mass] / 16 days. The percent change in apical tip number relative to initial tip number was calculated in a similar manner: 100 * [(final apical tip number – initial apical tip number) / initial apical tip number] / 16 days. In order to quantify the number of apical tips in reference to initial weight, apical tip number / mass is calculated as the tip score. The change in tip score can then be calculated as follows: [(final tip score – initial tip score) / initial tip score] / 16 days.

Principal Findings and Significance

Integrated Bio-hydro-economic Model

From the integrated model, we show that accounting for limu value increases the optimal groundwater steady state whether or not desalination technology is used. We analyze four possible patterns of water use, including the use of desalinated water as a backstop and "frontstop."

Numerically, using data from the Kukio area, located along the North Kona coast of the island of Hawaii, we solve for optimal groundwater management considering its nearshore externalities. Two different approaches to incorporate the limu consideration are discussed. The first approach is to include the market value of limu in the model. The other approach is to impose a "safe minimum standard" level for limu stock as a constraint. Results show that, taking into account the market value of limu, the water extraction rate should be lower than when limu value is ignored. However, the difference is small because the value of limu is relatively insignificant compared to the value of water. However, it should be emphasized that the value of limu in this example accounts only for the consumption value and ignores other possible values, e.g., cultural or ecological value. When the model incorporates a minimum limu stock as a constraint, the paths over time of water extraction, head level, and water price are non-monotonic. It is optimal to deplete the aquifer below the steady-state level, followed by a conservation period in which the head level is increased to the steady-state level.

For the final year of this project, we plan to incorporate the laboratory results discussed below into the model. For example, nitrogen will be included as another water quality indicator determining the growth of limu. Also, we will explore imposing a constraint on limu growth or on water quality indicators such as salinity.

Botanical Research

Four levels of salinity were investigated: 11‰, 19‰, 27‰, and 35‰. The mean growth rate, percent change in apical tip number, and apical tip number / mass were calculated for each salinity level. The 11‰ treatment differed significantly from the other three in mean specific growth rates. About half of the samples in the 11‰ treatment died and rapidly lost their initial mass and pigments, while the rest increased in mass at rates similar to other treatments. Thus, it is likely that the lower threshold of the salinity concentration for *G. coronopifolia* viability is close to 11‰. The 27‰ treatment had a significantly higher percentage of new apical tips per day than all other treatments. A similar result holds for the apical tip number / mass variable. In vivo absorbance on day 16 of the trial showed a similar pattern: no difference among the 19‰, 27‰, and 35‰ treatments, but a significantly higher value for the 11‰ treatment.

This study may be the first to show that the calculation of tip scores as well as percentage of new apical tips is a valid and useful method for quantifying changes in morphology of marine algae. Since most growth occurs at the apical tips of marine algae, it is clear that those samples with more tips per mass will have higher growth rates.

A nitrogen trial using variable concentrations of ammonium is ongoing. Future trials will include variable amounts of phosphate and nitrate. Also, a synergistic trial where nutrients and salinity are varied together in a manner consistent with hydrodynamics of submarine ground water discharge in the field will be conducted. The combined effect of increased nutrients and decreased salinity should increase growth rates and apical tip development; it could alter pigment absorbance in some treatments as well. This trial should give the most insight to the biological response of marine algae to submarine groundwater discharge in the field.

Grant No. 05HQGR0171 Stormwater Education on US Army Installations on Oahu

Basic Information

Title:	Grant No. 05HQGR0171 Stormwater Education on US Army Installations on Oahu
Project Number:	2005HI172S
Start Date:	9/15/2005
End Date:	9/14/2007
Funding Source:	Supplemental
Congressional District:	First
Research Category:	Social Sciences
Focus Category:	Education, Water Quality, Surface Water
Descriptors:	Environmental education, Watersheds, Stormwater
Principal Investigators:	John Cusick

Publication

1. Cusick, John, 2006, Stormwater Education on US Army Installations on Oahu: Status Report for the Period September 15, 2005 May 15, 2006, University of Hawaii at Manoa Environmental Center, 44 pages.

Problem and Research Objectives

Current water quality measurements within storm-drain discharge locations on military bases on Oahu indicate that the U.S. Army will not meet standards for total suspended solids, nitrogen, and phosphorous. Assessments suggest that exceedances are due to erosion of non-vegetated areas, including housing facilities. As part of an overall remedy, the Army needs to develop a permanent program that involves stormwater education at the schools on its base installations.

This project introduces stormwater education to public elementary- and middle-school students living on Wheeler Army Airfield and Schofield Barracks installations. The primary objective is to ameliorate negative impacts to water quality (i.e., those originating on Army installations) while introducing best management practices to students and their families. A goal of this project is to increase awareness and understanding of stormwater-related problems in the watersheds of central Oahu, particularly that of Waikele Stream. Located, in part, on Army installations, it is identified by the State of Hawaii as a watershed at risk.

Methodology

The Environmental Center at the University of Hawaii at Manoa collaborated with Bishop Museum and Pacific Consulting Services, Inc. to determine relevant and effective stormwater education materials and curriculum activities. The principal investigator, with input from Bishop Museum science educators and DOE content specialists, reviewed existing curricula related to watershed education in secondary and elementary schools. This information was used for curriculum development to comply with State of Hawaii Content Standards for Science.

The project developed a "Water Works Festival" presented to elementary- and middle-school students and their families at Wheeler and Schofield Army installation. Bishop Museum science and cultural education specialists prepared exhibits for an event held at Wheeler elementary School. The festival engaged visitors in a diverse array of hands-on science, engineering, and cultural activities designed for multi-generational, interactive learning. Topics included watersheds, the water cycle, aquatic ecosystems and biota, groundwater and surface-water resources, water quality, stormwater and wastewater infrastructure, and prevention of pollution.

Principal Findings and Significance

The project final report is being prepared for submission by the project end date of September 15, 2007. The literature review, stakeholder meetings, consultations with Bishop Museum and Pacific Consulting Services, Inc., exhibit preparation, and festival have been completed. The festival provided a venue to teach about watersheds, stormwater, and pollution prevention. The exhibits are available for future use by Bishop Museum science educators in conjunction with their traveling science programs.

Grant No. 05HQGR0178 Evaluating the Effectiveness and Feasibility of Commercial Ozone Technologies Used for Sanitation of Work Area and Laundry Services

Basic Information

Title:	Grant No. 05HQGR0178 Evaluating the Effectiveness and Feasibility of Commercial Ozone Technologies Used for Sanitation of Work Area and Laundry Services
Project Number:	2005HI173S
Start Date:	9/1/2005
End Date:	12/31/2006
Funding Source:	Supplemental
Congressional District:	First
Research Category:	Water Quality
Focus Category:	Water Quality, Treatment, Water Use
Descriptors:	ozone, disinfection, bacteria, water quality
Principal Investigators:	Roger Fujioka

Publication

1. Fujioka, R.S.; D.M. Sato; B.S. Yoneyama, 2006, Evaluating the Effectiveness and Feasibility of Commercial Ozone Technologies Used for Sanitation of Work Area and Laundry Services, WRRC-2006-04, Water Resources Research Center, University of Hawaii at Manoa, Honolulu, Hawaii, 82 pages (final project report to U.S. Army Pacific (USARPAC), Fort Shafter, Hawaii 96858 and to U.S. Geological Survey, Office of Acquisition and Grants, Reston, Virginia, 20192).

Problem and Research Objectives

The U.S. Army Pacific (USARPAC) has a mandate to improve its operational needs in terms of efficiency, cost, and safety for personnel and the environment. Many of the existing technologies it uses require harsh chemicals (chlorine, solvents, acids) that increase loads of pollution to the environment. For systems such as laundry services, the energy used to heat water is costly, and the discharge of detergents and other harsh chemical additives are sources of environmental pollution. Currently, several commercial companies advertise that application of ozone technology will address many of the negative effects associated with such systems. One commercial company in Hawaii, Ozone Industries, Inc., provides ozone technology to enhance laundry services at Fort Shafter Laundry Services and to enhance sanitation of workplace areas at Times Supermarkets. This technology is used because ozone, considered the fifth most-reactive chemical, is the only highly reactive chemical that can be practically applied.

There are two desirable chemical reactions with ozone. At relatively high concentrations, it oxidizes or breaks down the structural bonds of a complex organic molecule (e.g., proteins, fats, sugars, carbohydrates) to basic, nontoxic molecules such as CO_2 and H_2O. When this occurs, any undesirable property associated with a specific structure of an organic molecule is destroyed without forming intermediate products. At lower concentrations, ozone is an effective disinfectant of microorganisms, including the more resistant forms. However, there are two disadvantages with ozone use. First, only a limited concentration can be dissolved in water. Second, because ozone reacts with almost everything, its concentration is quickly reduced during application.

The goal of this study was to obtain independent laboratory-based performance data to evaluate the effectiveness, feasibility, and safety of commercial ozone technologies (Ozone Industries, Inc.) as applied in the state of Hawaii for sanitation of workplaces (e.g., disinfecting cutting boards at Times Supermarkets) and enhancement of laundry services (disinfecting linen, towels, sheets at Fort Shafter).

Methodology

The experimental design of this study was to measure the visual and bacterial quality (concentration of total bacteria) of food cutting boards used at supermarkets and fabrics cleaned at a military laundry facility before and after ozone treatment and then to compare the results with cleaning procedures that did not use ozone. Treatment was accomplished by generating ozone gas in water and then using the ozonated water to disinfect cutting boards. The ozone water was also used in some of the laundry cycles to clean fabrics. Concentrations of ozone in the water before and after it was used were measured using the Hach 8311 indigo method. Concentrations of total bacteria on cutting boards and on laundry products were measured using the semiquantitative Rodac plate method or the quantitative alginate swab method which allowed total bacterial colonies to be counted on Tryptic Soy Agar plates. Visual, textural, and odor assessments of fabrics before and after laundry cycles were also made. In some experiments, fabrics were purposely stained with food, blood, and ink to determine effectiveness of laundry cycles with and without ozone treatments.

Principal Findings and Significance

During phase 1 of this study, the effectiveness of ozone technology to clean cutting boards at supermarkets was assessed. It was determined that the amount of residual bacteria recovered from cutting boards with and without ozone treatment was similar. Although ozonated water was shown to be capable of inactivating 90% of bacteria in water, most of the bacteria on cutting board surfaces were already removed by standard cleaning procedures, which includes hot detergent scrubbing, followed by rinsing with tap water and then treatment with surfactants, a kind of disinfectant. The residual concentration of total bacteria recovered from cutting boards cleaned only with standard cleaning procedures and that recovered after additional treatment with ozone were similar. The residual level of bacteria was determined to be due to the formation of a biofilm of bacteria which occurs on all moist surfaces. The level of total bacteria on cutting board surfaces are most likely not related to health effects, as similar levels of total bacteria can be recovered from vegetables that are consumed raw. In summary, standard cleaning procedures (hot detergent scrubbing, rinsing, disinfecting with surfactant) effectively removed the bacteria left on cutting boards by the foods used during that day, so

final treatment with ozone was not required because bacteria in biofilm remained on the cleaned cutting boards even after ozone treatment as well as after additional treatment with chlorine. These results support those of previous reports that bacteria in biofilm are known to be resistant to disinfectants, but they generally do not cause a health effect for humans. Since no health effects were observed on people at the supermarket utilizing ozone technology, the use of this technology at supermarkets appears to be safe.

During phase 2 of this study, the effectiveness of ozone technology in cleaning fabrics at a military laundry service was assessed. The primary approach was to assess the impact of ozone technology in reducing the concentration of total bacteria and in destaining fabrics by using ozone in the wash cycles. However, the cleaning effectivenss of ozone versus detergent could not be easily distinguished because ozonated water and detergent were used in all cleaning cycles at Fort Shafter Laundry Services. Under experimental conditions, samples of tablecloths and napkins purposely smeared with lipstick, oil-based dressing, and fish blood were laundered using selected cleaning cycles to include washing with only ozonated water. It was revealed that cleaning with cold ozonated water alone was not as effective as cleaning with hot detergent in terms of removing stains and reducing bacterial counts from the fabrics. All of the cycles used were effective in cleaning the fabrics because the laundry facility had already selected appropriate wash cycles to specifically clean different types of fabrics. In summary, the cumulative data showed that ozone technology as applied to Fort Shafter Laundry Services does not appear to measurably enhance laundering performance. A basic problem was the relatively low concentration of ozone in the water and the routine use of this water in all cleaning cycles. Thus, at this facility, ozone was not used in a strategic manner compared to other companies which report using ozone separately as one of the steps in the laundering cycle to enhance the whole cleaning procedure so that detergent use is reduced and lower temperature water is used. Since no health effects were observed on people at this laundry facility, the use of ozone technology for laundry services appears to be safe.

Fate and Transport of Contaminants in a Stream-Aquifer System

Basic Information

Title:	Fate and Transport of Contaminants in a Stream-Aquifer System
Project Number:	2006HI138B
Start Date:	3/1/2006
End Date:	2/28/2008
Funding Source:	104B
Congressional District:	1st
Research Category:	Ground-water Flow and Transport
Focus Category:	Geochemical Processes, Solute Transport, Sediments
Descriptors:	
Principal Investigators:	Chittaranjan Ray

Publication

Problem and Research Objectives

Streams and rivers transport sediments, natural organic matter, and land-applied chemicals. Many drinking water wells located on riverbanks induce a portion of the river water to flow to well screens through the aquifer. The pumped water is a mixture of groundwater and induced infiltration water. This process is known as riverbank filtration. River water contaminants are removed through straining, colloidal filtration, chemical precipitation, sorption, and microbial degradation. Also, dilution is possible if the respective contaminants in surface water are lower in concentration than those in groundwater. Riverbank filtration is a viable and low-cost water treatment technology for water utilities. As this natural filtration process works somewhat differently than engineered filtration systems, knowledge of the dynamic behavior of the system for various flow regimes of the river is important for safe and sustainable operation. Knowledge of changes in water quality due to bed clogging and scouring would enable the utilities to deal with filtrate quality during flooding or periods of heavy sedimentation. Scouring and clogging of the stream bottom affect the rate of infiltration and the fate of the soil-resident or percolating contaminants. A clogged streambed would have a slower infiltration rate and a more reduced condition than a normal streambed. Scouring during floods can introduce oxygen-rich water into the aquifer, thus disturbing established redox conditions. It is not easy to study these processes in field settings because of high velocity in streams during high flow events and because of our inability to measure redox and clogging processes accurately.

The objectives of this project are as follows:

1. To retrofit a recirculating flume to serve as a model stream channel and attach a column to the stream bottom to simulate conditions in an aquifer under the riverbed (the bed will contain sediments similar to that found in stream bottoms)
2. To study the impact of velocity profile on the scouring and deposition processes of particles
3. To study the redox conditions in the column as a function of stream velocity, particle deposition rate, natural organic matter content of the recirculating water, and the travel distance
4. To examine the effect of channel bed scouring on the change in the redox conditions of the upper portions of the column and its impact on water quality

Methodology

Retrofitting of Flume/Column

A small recirculating flume (15-cm wide), available in the Hydraulics Laboratory of the Civil and Environmental Engineering Department of the University of Hawaii at Manoa , was retrofitted for this research. The flume can be tilted to change the bed slope. A mechanically operated flap controls the water level on the bed. A 10-cm-diameter column attached to the bed of the flume channel simulates the porous media that are typically present between the river and the well screen. A peristaltic pump draws water at a set rate from the bottom of the column. A layer of silica sand simulates the riverbed. A pump provides water at the upstream end of the flume, and the drainage water from the flume is recycled back. Clogging of the bed is simulated by adding fine particles such as silica into the flow stream. Scouring is simulated by increasing the flow velocity by enhancing the channel bed slope.

Velocity Profile and Scour/Deposition Study

The sediment composition and flow velocity in the recirculation system can be adjusted to have distinct particle distributions in the flow systems. For each set of experiments, the corresponding heads in piezometers at various depths below the channel bed will be examined. Effort is being made to use a recently acquired particle image velocimetry system to obtain the velocity profile in the flume. The velocity profile obtained from laboratory measurements will be used to calculate bed shear stress for the channel.

The boundary shear stress, using calculated shear velocity and the density of water, is a good indicator of whether a particle can be lifted from the bed.

Clogging of the streambed due to particle transport into the column of aquifer sand can be examined using measurements of the flow resistance (or head loss) in the column. For an unclogged column with uniform material, the head gradient is generally linear. However, if fine particles accumulate on the channel floor, most of the head loss will be experienced in that zone.

Redox Dynamics

Water samples collected from the channel and various sampling ports in the column will be analyzed for dissolved oxygen, oxidation-reduction potential, dissolved organic carbon (DOC), and selected redox-sensitive species such as nitrate, nitrite, ammonium, iron, and manganese. Frequent measurements of the velocity profile and the size distribution of the flowing particles will give a good indication of the small particle load in the flow stream. Head loss due to particle clogging of the column surface will be correlated with the sizes of the flowing particles. Redox parameters of the flowing water and the sampled water will be correlated with the velocity profile in the channel, particle size distribution, DOC in the channel water, and water extraction rate through the column.

*Scouring Effect on Redo*x

Once a redox regime in the column is established based on a flow regime in the channel, DOC content of the water, and the sediment load in the channel water, conditions in the channels will be changed to that of incipient scour. We will examine head loss in the column and monitor select redox parameters in the column. Following a given period of disturbance (i.e., simulation of a flood passage), we will examine the time needed to re-establish a redox condition that is conducive for denitrification and for the degradation of other chemicals.

Principal Findings and Significance

The construction and retrofitting of the flume were completed. Other tasks have not been initiated as the flume was not ready until recently. A no-cost extension has been requested, and other tasks will be carried out in the next reporting period.

Hydrologic Analysis of Hawaii Watersheds for Flood Control and Water Quality Management

Basic Information

Title:	Hydrologic Analysis of Hawaii Watersheds for Flood Control and Water Quality Management
Project Number:	2006HI144B
Start Date:	3/1/2006
End Date:	2/28/2008
Funding Source:	104B
Congressional District:	1
Research Category:	Engineering
Focus Category:	Hydrology, Floods, Non Point Pollution
Descriptors:	
Principal Investigators:	Clark Liu

Publication

Problem and Research Objectives

The establishment of the rainfall-runoff relationship of a watershed is an important and difficult problem in applied hydrology. The rainfall-runoff relationships of Hawaii watersheds are even more difficult to establish because local watersheds have steep slopes, small drainage area, and high infiltration rate. Currently, the simple *rational formula* is used for urban drainage design in Hawaii, while the more sophisticated *unit hydrograph method* is used for the design of large flood-control facilities.

The unit hydrograph method is based on the linear systems theory. The system impulse response function of a linear system describes the overall system characteristics which affect the input-output relationship. The determination of the system response function of a particular system is called system identification. By the unit hydrograph method, a watershed is taken as a linear system and its system response function is called the instantaneous unit hydrograph (IUH). Its input function is effective rainfall and its output function is direct runoff. After the IUH of a watershed is identified, runoff generated by future rainstorms in the watershed can be calculated by a convolution integration of IUH and rainfall input. Therefore, the problem of establishing the rainfall-runoff relationship of a watershed becomes the problem of system identification or the derivation of IUH.

The principal objective of this research is to develop techniques for deriving the IUH of a watershed. These techniques will then be used for rainfall-runoff analysis of Hawaii watersheds relative to flood control and water quality management.

Methodology

The linear systems approach has been successfully used in watershed hydrology to relate rainfall to runoff. This type of approach has also been used recently in river water quality analysis and in chemical transport in soils. Following the linear systems approach, storm runoff from a watershed at any time can be calculated by a simple convolution of the IUH and the effective rainfall. The IUH of a particular watershed is usually derived by performing an inverse operation based on one set of historical rainfall-runoff data. For watersheds that have no historical data, the synthetic IUH method is used.

Using a linear systems approach, a watershed rainfall-runoff model can be expressed as a convolution integral:

$$Q(t) = \int_0^t X(\tau)h(t-\tau)d\tau \qquad (1)$$

where $Q(t)$ is the system output function, or direct runoff generated from the watershed; $X(\tau)$ is system input function, or effective rainfall; and $h(t-\tau)$ is the system impulse response function, or instantaneous unit hydrograph.

Similarly, by using a linear systems approach, a watershed transport model can be expressed as

$$C(t) = \int_0^t W(\tau)g(t-\tau)d\tau \qquad (2)$$

where $C(t)$ is the output function, $W(\tau)$ is the pollutant input function, and $g(t-\tau)$ is the system impulse response function, or pollutograph.

The impulse response function of a linear system model describes the overall system behavior. The success of system modeling depends largely on how accurately and efficiently the impulse response function can be evaluated. In this research, the gray-box approach of system identification is used, such that the pollutograph of tropical watershed transport systems can be evaluated based on watershed parameters such as size, roughness, slope, soils, and imperviousness. These parameters can be easily obtained from a geographic information system.

Principal Findings and Significance

In this research, the gray-box approach of system identification is used, and an IUH, $h(t)$, takes the general form of a gamma distribution function:

$$h(t) = \frac{1}{\Gamma(N)} \frac{A}{K} \left(\frac{t}{K}\right)^{N-1} \exp\left(\frac{-t}{K}\right) \quad (3)$$

The system identification for any given watershed is used to estimate values of two parameters, or N and K, in Equation (3). These parameters are related to the peak discharge (Q_p) and time to peak (t_p) in an IUH by the following equations:

$$Q_p = \frac{1}{\Gamma(N)} \frac{A}{t_p 12} (N-1)^N \exp(1-N) \quad (4)$$

$$t_p = (N-1)\, K \quad (5)$$

This study uses historical rainfall-runoff data collected at nine watersheds on Oahu. The watershed areas vary between 303 hectares and 11,399 hectares (Figure 1).

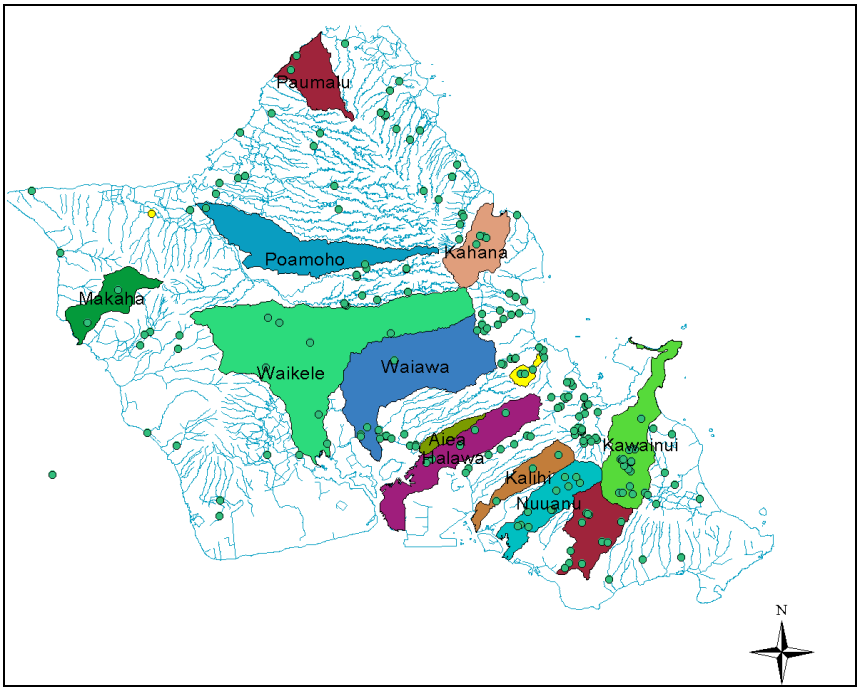

Figure 1. Watershed areas on Oahu selected for model development and testing

The IUH parameters N and K (or Q_p and t_p) were determined, based on historical rainfall and runoff data, as shown in Table 1.

Table 1. Parameters of the Instantaneous Unit Hydrographs of Selected Hawaii Watersheds

Watershed	Area (ha)	N	K	T_p (min)	Q_p (cfs)
Puekele	303	2.73	43.00	74.44	307
Makaha	589	1.77	117.20	90.55	314
Kalihi	653	2.33	42.56	56.64	407
Kahana	548	1.35	109.00	38.42	727
Waiahole	985	2.30	57.13	57.13	837
Halawa	1,175	1.30	52.00	15.00	2,034
Manoa	1,279	2.06	29.67	31.38	2,807
Waimea	3,159	3.77	48.00	133.00	2,332
Waikele	11,399	2.87	41.22	77.10	11,985

The IUH of the Wahiawa reservoir station can then be obtained as follows:

$$\text{IUH} = 3{,}557.13\left(\frac{t}{12.16}\right)^{2.5775} \exp\left(\frac{\Delta t}{12.16}\right) \qquad (6)$$

The IUHs derived by this study and by another researcher (I-Pai Wu, 1969, Hydrograph Study and Peak Discharge Determination of Hawaiian Small Watersheds: Island of Oahu, Technical Report No. 30, Water Resources Research Center, University of Hawaii, Honolulu) were applied in a modeling analysis to predict the runoff generated a storm on October 24-25, 2005. Modeling results are shown in Figure 2.

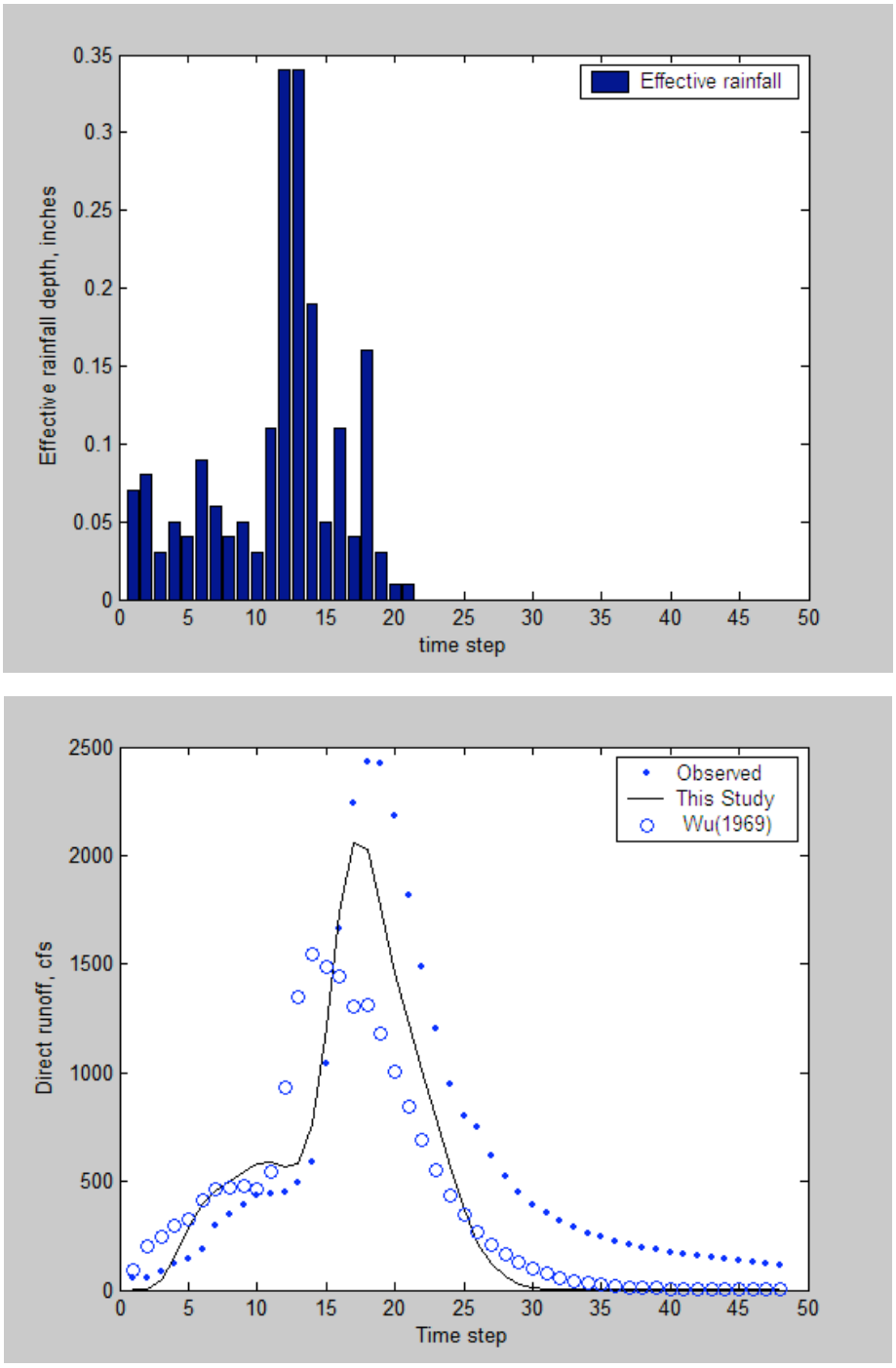

Figure 2. Prediction of storm runoff of Wahiawa Stream at USGS gaging station 10268000, October 29-30, 2005

Methods derived from this project will be used by a different project to conduct a survey and modeling analysis of Highway MS4 storm runoff on Oahu. In addition, a workshop to train the technical staff of city and state agencies engaged in storm water quality control is planned. A journal paper, entitled "Infiltration and Effective Rainfall in Flood Hydrograph Analysis of Hawaiian watershed" is in preparation (to be submitted by the end of summer). Two additional journal papers are contemplated.

Identification and control of membrane bioreactor biofouling organisms using genetic fingerprinting

Basic Information

Title:	Identification and control of membrane bioreactor biofouling organisms using genetic fingerprinting
Project Number:	2006HI159B
Start Date:	3/1/2006
End Date:	2/29/2008
Funding Source:	104B
Congressional District:	1
Research Category:	Engineering
Focus Category:	Water Supply, Treatment, Economics
Descriptors:	
Principal Investigators:	Roger Babcock

Publication

1. Babcock, R.W., Jr.; T. Huang; Y. Chanthawornsawat, 2006, Characterizing biofouling in membrane bioreactors, in Proceedings of the 21st Annual WateReuse Symposium, Hollywood, California.

Problem and Research Objectives

Recycling of wastewater receiving primary treatment could be greatly expanded, saving conventional groundwater for potable uses, if costs of treatment could be reduced. Membrane bioreactors (MBRs) are a relatively new wastewater treatment technology that promises exceptional treatment efficiency and a reduced footprint compared to conventional treatment process trains. However, MBRs are susceptible to biofouling. Biofouling is not well understood but does increase operating pressure, reduce maximum flux (water passed through the membrane), increase recovery cleaning requirements, and possibly reduce total membrane life.

The overall goal of this research is to obtain a better understanding of biofouling in MBRs and methods to control said fouling in order to improve the economics of water recycling. Genetic fingerprinting methods will be developed to identify organisms responsible for biofouling.

Methodology

This study involves long-term operation of two different bench-scale MBRs. One MBR uses flat sheet membrane technology provided by Enviroquip Inc.; it utilizes Kubota membranes with a 0.4 μm pore size. A second MBR uses hollow fiber technology provided by Ionics Corp.; it utilizes Mitsubishi membranes with a 0.4 μm pore size. These bench-scale MBRs have been operated using raw sewage pretreated only by a 3-mm fine screen since the start of the project in March 2006. Operating parameters that have been and will be varied include flux rate (flow per unit area of membrane; 10 and 15 GFD), solids retention time (10 and 20 days so far, and 5 and 40 days to be completed), organic/nutrient loading (raw sewage with/without supplemental organics), and state of oxygenation (high, low, anoxic). Under each set of conditions, steady state is achieved before proceeding to the next set of conditions. Operating and water quality parameters monitored include TMP (continuous on-line measurement), biofilm/cake layer thickness, SMP/EPS carbohydrate and protein fractions (carbohydrates, proteins), viscosity, PSD, soluble COD, and colloidal TOC.

Microbial consortium samples from both mixed liquor and attached biofilms (cake layers) will be collected from the bench-scale MBRs under various conditions. Samples of microbial populations in full-scale conventional activated sludge systems and pilot-scale MBR systems will be collected for comparison. The dominant microbial species will be determined by DNA sequencing of genetic material taken from denaturing gradient gel electrophoresis (DGGE) bands. The sequenced DGGE bands will be compared with information in the GeneBANK database to identify the bacteria responsible for biofouling.

Principal Findings and Significance

We collected a great number of sludge and biofilm samples. A large percentage of these have been processed to extract community DNA, amplified by PCR, and then run through DGGE to determine the species diversity in each sample. We have data that show changes in bacterial speciation over time during different runs and under different fouling conditions. We also have data that show the species in the attached biofilm are different and less diverse than those in the bulk mixed sludge. We are in the process of having a number of the DGGE bands sequenced to determine bacterial types. We are also beginning to try to correlate certain dominant bacteria with operating and fouling conditions as well as water quality parameters. We will collect samples from conventional activated sludge systems for comparison. We will try to determine relationships between dominant microorganisms and water quality parameters as they relate to membrane biofouling.

In the second year of this project (currently under way), we plan to operate the bench reactors, mostly under high-fouling conditions, to get more data on speciation under these conditions. Also, we will monitor pilot- and full-scale MBRs to determine if diversity and speciation are similar or different and look for trends in terms of fouling rates. We will further determine relationships between dominant microorganisms and water quality parameters as they relate to membrane biofouling. We will begin to investigate the morphology and physiology of the identified dominant microorganisms to see if there are biological controls that could be effective to either select for desired organisms or inhibit undesirables. We will develop a chart correlating sets of conditions under which differing degrees of biofouling are expected

(and what microbes will dominate). Finally, we will develop life-cycle costs associated with different degrees of biofouling.

A presentation of project findings, entitled “Understanding and controlling fouling in MBRs,” by R.W. Babcock, Jr. and T. Huang, was made in February 2007, at the 29th Annual Hawaii Water Environment Association Conference, Honolulu, Hawaii.

Information Transfer Program

Each year, a small amount of the 104(b) funds is allocated to Technology Transfer activities. This typically (as in this reporting period) covers the costs of a periodic *Bulletin* describing WRRC projects, project results and personnel. This project also contributes to the costs of sponsored conferences as well as preparation for and attendance at meetings in the State and nationally.

Technology Transfer

Basic Information

Title:	Technology Transfer
Project Number:	2006HI170B
Start Date:	3/1/2006
End Date:	2/28/2007
Funding Source:	104B
Congressional District:	01
Research Category:	Not Applicable
Focus Category:	Education, None, None
Descriptors:	
Principal Investigators:	Philip Moravcik

Publication

1. Water Resources Research Center *Bulletin*, October 2006

Information Transfer Program

WRRC's Technology Transfer program activities for the report period included: organization of a seminar series, production of project bulletins and newsletters, participation in conferences, and providing information to consultants, students of all levels, and the public. The program P.I. also participated in school science fairs, research projects having an informational component, and refinement of the Center's web site. During the current reporting period the Technology Transfer program produced one newsletter describing research projects, Center activities and news.

During this reporting period the Technology Transfer Office has made extensive use of the Center's large-format printer/plotter, producing posters for display at meetings and conferences locally, nationally, and internationally. A number of these posters illustrating the work of graduate student researchers have won awards at conferences.

The Information Transfer Program organizes a biweekly seminar series designed to foster communication amongst WRRC researchers, students, and target audience of government agencies, private sector personnel and members of the public with an interest in water resource issues. A WRRC faculty member is appointed each semester to organize the seminar and recruit speakers from University faculty, visiting scientists, government agencies and private sector firms. Topics thus vary depending on the interests of the coordinator and availability of speakers. Typically the seminars include reports on WRRC projects and discussions by government officials of emerging water-related issues. The seminars are generally well attended and provide one of the few public forums for the discussion of water issues in the state. The following is a list of the 23 seminars presented during the reporting period.

Spring 2006, Seminar Coordinator: John Cusick

03/02/2006	John T. Harrison, Ph.D., Coordinator, UH Environmental Center, "Thoughts on Sustainability: Past, Present and Future"
03/16/2006	John Gutrich, Environmental Science Program, Hawaii Pacific University, "Watershed Partnerships to Conserve and Better Manage Upland Forested Watersheds in Hawaii"
04/06/2006	Peter Rappa, UH Hawaii Sea Grant College Program, "Management of Hawaii's Watersheds"
05/04/2006	Deanna Donovan, Programme Officer, World Water Assessment Programme, UNESCO, Paris, "UN world water Assessment Programme: Moving Toward a Better Understanding of the World Water Crisis."
05/30/2006	Henning Prommer, CSIRO Land and Water, Australia, "Modeling Spatially and Temporally Varying Redox Zonation and its impact on the fate of micro pollutants in aquifers"

Fall 2006, Seminar Coordinator: Roger Fujioka

09/07/2006	Ross Tanimoto, City & County of Honolulu, Environmental Services, "The City & County of Honolulu's Response to the Sewage Spills During Record Rain Event of 2006 and the City's Program to Mitigate These Problems with Special Reference to the Ala Wai Sewage Spill Event"
09/12/2006	Dr. Denie Augustijn, Visiting Professor at the Watershed Hydrology Lab NREM-CTAHR, "Water Management in the Netherlands"
09/14/2006	Steve Markstrom, USGS Denver Colorado, "GSFLOW - A Basin-scale Model for Coupled Simulation of Ground-water and Surface-water Flow"
09/21/2006	Watson Okubo, State Department of Health, "The DOH Program to Monitor Sewage Spill Events and to Close and Open Beaches for the Purpose of Protecting the Public Health with Special Reference to the Ala Wai Sewage Spill Event"
10/05/2006	Roger Fujioka, Researcher, UH WRRC, "Application of Alternative Fecal Indicators and Molecular Methods to Assess the Quality of Water and Sand at Beaches During the Ala Wai Sewage Spill Event"
10/19/2006	Francis Pien, Straub Clinic and Hospital, "Vibrio Infections and Disease Symptoms Associated with Marine Water Exposure with Special Reference to the Ala Wai Sewage Spill Event"
11/02/2006	Dolan Eversole, DLNR State of Hawaii and Sea Grant UH, "Program to Replenish Sand at Kuhio Beach and Discolored Sand Sediments with Special Reference to Ala Wai Sewage Spill Event"
11/16/2006	Gerald Kato & Thomas Kelleher, UH School of Communications, "Impact of Media (newspaper, TV, radio) on the Development of Public Opinion, Public Perception and Public Action with Special Reference to Ala Wai Sewage Spill Event"
11/17/2006	Siqing Xia, Professor & Vice Dean, College of Environmental Science and Engineering Tongji University, Shanghai, PR China, "Environmental Science and Engineering Teaching and Research at Tongji University and a UNEP Platform"
11/27/2006	Douglas F Moore, Director Public Health Laboratory, Orange County Health Care Agency, "Comparison of Molecular Amplification Techniques and Culture for Enterococcus Water Quality Measurements"
12/14/2006	Walter McLeod, President of Clean Beaches Council Washington DC, "National Perspective on Quality of Water and Sand at Beaches: A Call to Action!"
12/22/2006	Daniel Y. C. Fung, Ph.D., Professor of Food Science, Dept of Animal Sciences & Industry, Kansas State University, "Innovative Detection Methods to Address the National Research Council's Revaluation of Indicators for Waterborne pathogens"

Spring 2007, Seminar Coordinator: Clark Liu

01/03/2007	Dr. In Mei Sou, Department of Civil & Environmental Engineering, Oregon State University, “An Experimental Study of Surf and Swash Zone Hydrodynamics Using a Particle Image Velocimetry Technique and the Other Applications of Imaging-Based Measurement Techniques”
01/18/2007	Dr. Clark C. K. Liu, Professor, UH Civil & Environmental Engineering & WRRC, “Estimating Sustainable Yields of Hawaiian Basal Aquifers by the Modified Robust Analytical Model (RAM2)”
01/26/2007	Kapildev Sharma, Director, National Institute of Hydrology, Roorkee, India, “The National Institute of Hydrology, Roorkee, India”
02/06/2007	Bart Bibler, Chief, Bureau of Water Programs for Florida Department of Health, “Florida Healthy Beaches Monitoring Program”
02/15/2007	Roger Babcock, UH Civil & Environmental Engineering, “Pilot Test Comparison of Six Different Membrane Bioreactors”

Student Support

Student Support					
Category	**Section 104 Base Grant**	**Section 104 NCGP Award**	**NIWR-USGS Internship**	**Supplemental Awards**	**Total**
Undergraduate	0	0	0	2	2
Masters	5	1	0	1	7
Ph.D.	7	0	0	1	8
Post-Doc.	0	0	0	0	0
Total	12	1	0	4	17

Notable Awards and Achievements

The University of Hawaii Board of Regents awarded the 2006 Regents' Medal for Excellence in Research to **Albert S. Kim**, Associate Professor of Civil and Environmental Engineering, and P.I. on several recent 104(b) projects. His research includes identifying effects of particle interactions on membrane filtration performance. Since 2002, ten of Dr. Kim's scientific papers have been published or accepted in significant journals. He also received the National Science Foundation's competitive and prestigious five-year CAREER award, on the basis of a proposal to extend work begun under WRRIP projects.

The American Academy of Water Resources Engineers has conferred its Diplomate, Water Resources Engineer (D.WRE) or Honorary Diplomate, Water Resources Engineer (Hon.D.WRE) credential on a total of 291 individuals over the years. This year, **Clark C.K. Liu**, University of Hawaii Professor of Civil and Environmental Engineering and WRRC Researcher, was elected to this elite group.

Three WRRC graduate research assistants received first, second and third prizes for their poster presentations at the Hawaii Water Environment Association 28th Annual Conference and Expositon, February 8 - 10, 2007. All three are students of WRRC Researcher Dr. Roger S. Fujioka. The students and their presentations are:

- **Sherilyn Hashiro**, MS student in Microbiology, "Assessing the Quality of Sand at Kuhio Beach Before and After DLNR Sand Replenishment Project, Using Multiple Sewage-Borne Microorganisms," (1st Place)
- **Timothy Lum Yee**, undergraduate student in Civil and Environmental Engineering, Adsorption of the MS-2 Bacteriophage to Tropical Soils of Hawaii," (2nd place)
- **Jing Hu**, MS student in Civil and Environmental Engineering, "Pilot-Scale Fine-Pore Aeration Testing to Determine Alpha Factor," (3rd place)

Publications from Prior Projects

1. 2005HI114B ("Diffusive Tortuosity of Reactive Porous Media: Application to Colloidal Fouling and Biofouling During Membrane Filtration") - Articles in Refereed Scientific Journals - Chen, Huaiqun; Albert S. Kim, 2006, Prediction of permeate flux decline in crossflow membrane filtration of colloidal suspension: A radial basis function neural network approach, Desalination, 192, 415428.
2. 2005HI114B ("Diffusive Tortuosity of Reactive Porous Media: Application to Colloidal Fouling and Biofouling During Membrane Filtration") - Articles in Refereed Scientific Journals - Kim, Albert S; Huaiqun Chen, 2006, Diffusive tortuosity factor of solid and saft cake layers: A random walk simulation approach, Journal of Membrane Science, 279, 129139.
3. 2001HI701B ("Removal of Nitrogenous Aquaculture Wastes by a Wind-Powered Reverse Osmosis System") - Articles in Refereed Scientific Journals - Liu, C.C.K.; W. Xia; J.W. Park, 2007, A wind-driven reverse osmosis system for aquaculture wastewater reuse and nutrient recovery, Desalination, 202, 2430.
4. 2005HI114B ("Diffusive Tortuosity of Reactive Porous Media: Application to Colloidal Fouling and Biofouling During Membrane Filtration") - Articles in Refereed Scientific Journals - Kim, Albert S.; Aileen N.L. Ng, 2007, Hydraulic permeability of polydispersed cake layers: An analytic approach, Desalination, 207, 144152.
5. 2003HI27B ("An Evaluation of Factors Affecting the Transport of Pharmaceutical Compounds and Pathogens in Selected Hawaii Soils for Land Application of Wastewater") - Dissertations - Mohanty, Sanjay K., 2006, Fate and Transport of Selected Endocrine Disrupting Chemicals in Recycled Water Through a Tropical Soil, MS Thesis, Department of Civil and Environmental Engineering, University of Hawaii at Manoa, Honolulu, Hawaii, 143 pages.
6. 2003HI27B ("An Evaluation of Factors Affecting the Transport of Pharmaceutical Compounds and Pathogens in Selected Hawaii Soils for Land Application of Wastewater") - Conference Proceedings - Mohanty, S.K.; C. Ray, 2006, Fate and transport of selected endocrine disrupting chemicals (EDCs) in recycled water, in Proceedings, 5th Int. Conf. on Pharmaceuticals and Endocrine Disrupting Chemicals in Water, National Ground Water Assn., Costa Mesa, California, March 1315, 2006.
7. 2002HI2B ("A win-win approach to water pricing and watershed conservation") - Articles in Refereed Scientific Journals - Pitafi, Basharat A., and James A. Roumasset. "Pareto-improving water management over space and time: the Honolulu Case," American Journal of Agricultural Economics (under review).
8. 2002HI2B ("A win-win approach to water pricing and watershed conservation") - Other Publications - Pitafi, Basharat A., and James A. Roumasset. 2005. "Integrated water management policies for Oahu," University of Hawaii at Manoa Water Resources Research Center *Bulletin* (March).