WRRC
Water Resources Research Center
University of Hawaii at Manoa
March 2005 Bulletin

L. Stephen Lau Water Research Endowed Scholarship Fund

We are happy to announce that on December 31, 2004 WRRC's former director (1971-1990), Dr. L. Stephen Lau, and his wife, Virginia Lau, generously established the *L. Stephen Lau Water Research Endowed Scholarship Fund.* After many years of teaching and research Dr. Lau continues to serve as an emeritus professor of Civil Engineering at the University of Hawaii. There are many alumni of Dr. Lau's groundwater hydrology and other engineering classes working throughout the state.

Dr. and Mrs. Lau and their son Ronald at the signing of the MOU

Dr. Lau, his wife, and their son Ronald were recently on campus to sign a memorandum of understanding (MOU) which sets up the endowment with the University.

The scholarship will be made available to upper division undergraduate or graduate students in "any discipline related to water resources at the University of Hawaii." Applicants must meet GPA requirements and will need to submit an essay or research proposal. Full- or part-time students are eligible for the award.

WRRC will administer the awards process. Recipients will be selected from the applicants by a multidisciplinary committee appointed by the current Director of the Center, Dr. James Moncur. We hope to develop publicity and make the initial award available in time for fall semester 2005.

The Laus' scholarship is an "open" one, meaning that subsequent contributions may be added to the initial endowment. If you would like to participate in this worthy initiative we would be happy to add your contribution to the principal. Please contact the Center at 808-956-7847 to find out more.

Analytical Groundwater Flow and Transport Modeling for the Estimation of Sustainable Yield of the Pearl Harbor Aquifer

Principal Investigator

Clark C.K. Liu, Ph. D., UH Water Resources Research Center and Civil and Environmental Engineering Department

Funding Agency

Hawaii State Water Commission, Dept. of Land and Natural Resources

Project Period

05/01/04-04/30/05

Background

The single most pressing water resources problem in Hawaii, as identified in the Five-Year Hawaii Water Research Agenda 1982-1987, is to provide for an adequate freshwater supply, especially on Oahu and the leeward parts of Maui, Hawaii, and Molokai. The Pearl Harbor aquifer is the most important source of freshwater for the island of Oahu and the most exploited in the state. The aquifer has been extensively studied to determine its sustainable yield. The sustainable yield of an aquifer is defined by the State Water Commission (1979) as the water supply that may normally be withdrawn from a source at the maximum rate which will not "unduly impair source utility". Since the beginning of groundwater extraction in the Pearl Harbor aquifer in the early 1880s, head levels have steadily fallen (Figure 1, page 3), giving rise to concerns about the sustainability of supply from the aquifer.

Dr. Clark Liu

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Integrated Water Management Policies for Oahu

By Basharat Pitafi and James Roumasset, WRRC Researchers

Economists have frequently observed that water prices in Hawaii (as elsewhere) are far less than the full marginal cost of providing water and that such under-pricing results in substantial waste. The status quo pricing system ignores the costs that depletion imposes on future users as well as the differential costs of transporting water to different elevations.

Efficient water management combines existing hydrological, engineering, and economic knowledge. This includes determining efficient water usage, examining welfare effects of efficient usage, and designing pricing schemes for achieving efficient use in a politically feasible manner. More broadly, water management must be integrated with efficient watershed conservation.

To this end, the following studies have been conducted for various components of the water resource system in Oahu's Central Corridor.

> ***"The status quo pricing system ignores the costs that depletion imposes on future users... ."***

Efficiency Pricing over Space and Time

Efficient water usage can be achieved through quantity controls or price controls. In the case of price controls, water needs to be priced at marginal cost of providing water, including the marginal cost of extraction and distribution and the marginal future cost or the effect of present extraction on future costs of water provision. This results in higher prices now but more water being available in the aquifers for a longer period of time. By switching to efficiency pricing, in accordance with sustainable management, current users would be slightly worse off but future consumers would be much better off. The present value of the losses for the Honolulu case is about $34 million while that of the gains is about $441 million. Thus, the pricing reform is economically feasible. The problem of political feasibility, however, is one that has hindered previous reform efforts.

Political Feasibility

Current users are the decision makers of today whereas future users have no political power. As a result, resistance by current users can block reform even though the gains are much larger than the losses. To avoid this problem, benefit taxation can be applied to make pricing reform a win-win proposition. This can be done by fully compensating users who lose welfare due to the pricing reform. The compensation would be financed through proportional reduction out of future welfare gains. Because of the small size of the losses in comparison with the gains, the required compensation burden is only about 7% of the gains.

> ***"...resistance by the current users can block reform even though the gains are much larger than the losses."***

Since the full marginal cost, including opportunity cost, is greater than the average cost, standard marginal cost pricing creates a revenue surplus. This can be returned to users through the device of pricing an intra-marginal block at zero. This intra-marginal "free lunch" can be further adjusted to finance the compensation scheme just described. Roughly, future consumers would get slightly smaller free blocks, and current consumers would get larger blocks.

For further details, visit
http://www2.hawaii.edu/~basharat/HTMLobj-288/Pareto-Improving_Water_Management_over_Space_and_Time.pdf

Sequencing Watershed Conservation and Pricing Reforms

Groundwater aquifers are recharged by inflow from watersheds. If watersheds are damaged due to factors such as fires or invasive species, recharge may fall. For this reason, watershed conservation may be considered as an alternative to the pricing reform, especially since the latter is thought to be politically infeasible.

To understand the relative advantages of substituting one reform for another or having one reform delayed by another, we considered the gains from different sequences of watershed conservation and pricing reform. Numerical analysis shows that watershed conservation is more beneficial if pricing reform is not delayed. In the case of the Pearl Harbor aquifer and the Koolau watershed, a conservation plan that can prevent a 1% loss of recharge provides a benefit of about $43 million in present value terms, if implemented without the pricing reform. The benefit of the conservation increases to about $72 million if pricing reform is undertaken simultaneously. In addition, adoption of watershed conservation may cause a delay in the pricing reform even if the latter is ultimately adopted. An immediate pricing reform (along with watershed conservation) provides a present value benefit of about $950 million. A 10-year delay in the pricing reform brings the benefits down by 24% to $720 million, and a 20-year delay results in 44% lower benefits at $536 million.

(For further details, visit
http://www2.hawaii.edu/~basharat/HTMLobj289/Watershed_Conservation_and_Efficient_Groundwater_Pricing.pdf)

Uncertainty

Ex ante, we cannot say when and to what extent various risks to watersheds will be realized. However, without watershed conservation, there is a probability that the watershed will be damaged after a certain period of negligence and, as a result, the recharge to the aquifers will be reduced. If, without the conservation, there is a 10% probability of watershed damage after 20 years and this damage reduces the aquifer recharge by 15%, the expected present value of the benefits of conservation comes out to

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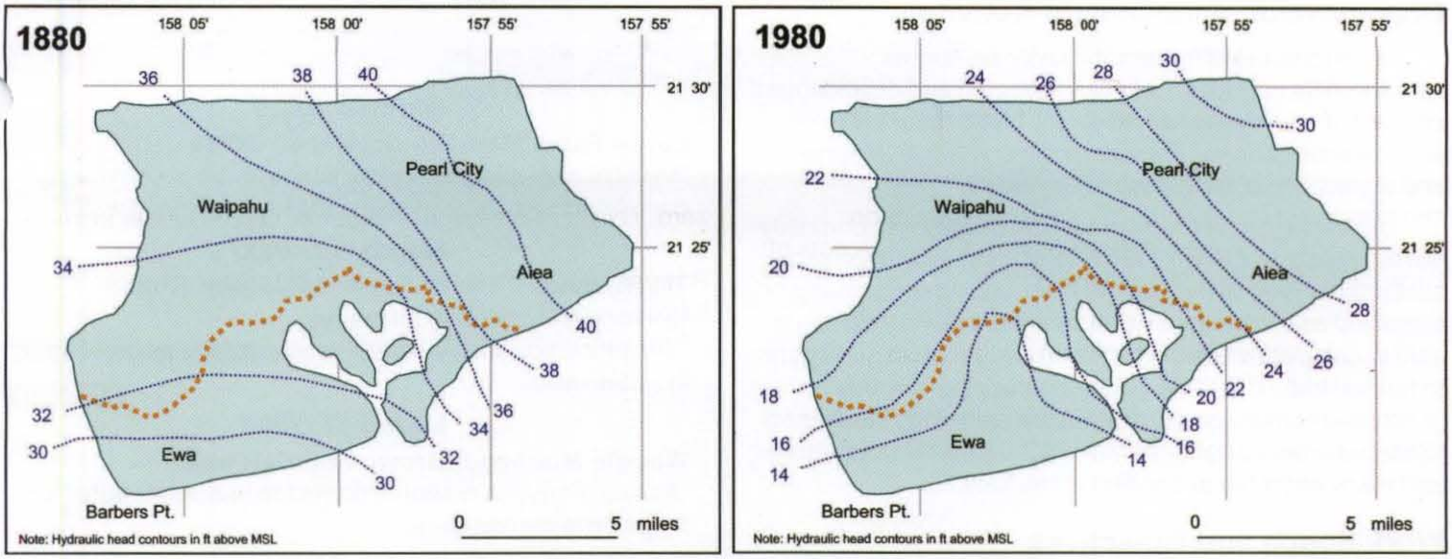

Figure 1 decline of groundwater heads in the Pearl Harbor aquifer, 1880-1980

Hydrogeologic features of Oahu, Hawaii

The Pearl Harbor aquifer is a basal fresh water body which floats atop seawater (Figure 2). For a homogeneous basal water-body in hydrostatic equilibrium, freshwater and the underlying seawater are separated by a relatively sharp interface. According to the classical Ghyben-Herzberg relation, the sharp interface of a basal water-body will be found below mean sea level at a depth of about 40 times the hydraulic head. Under natural conditions however, a transition zone exists in which salinity decreases gradually from that of seawater to that of fresh water. The thickness of the transition zone depends on transport processes of salt advection and dispersion, which are caused by tidal fluctuation, atmospheric pressure variation, and recharge. For a preliminary investigation of a basal aquifer resource, the sharp interface assumption is acceptable and the 50% salinity contour in the transition zone can be taken as the approximate

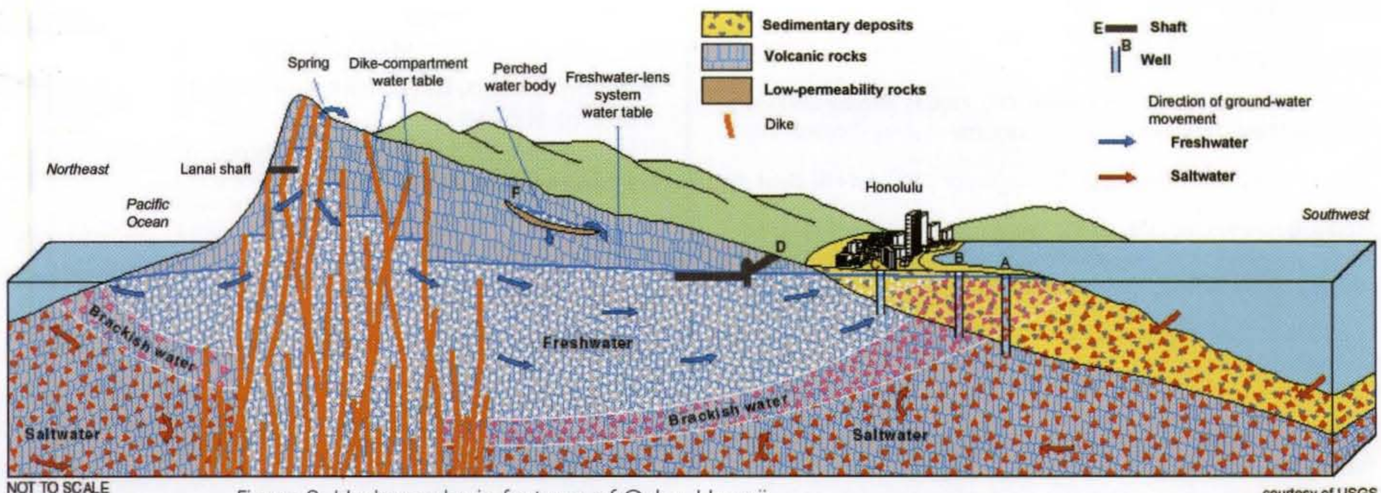

Figure 2 Hydrogeologic features of Oahu, Hawaii

location of the Ghyben-Herzberg sharp interface. However, for the formulation of coastal groundwater development plans, expansion of the transition zone or saltwater intrusion should be taken into account (Alley, Reilly, and Franke, 2001).

Over the last twenty years, numerous modeling efforts have been made to simulate the flow and salt transport processes in the Pearl Harbor aquifer (Liu, Lau, and Mink, 1983; Liu, Ewart, and Huang, 1991; and Izuka and Oki, 2001). Figure 1 shows the 1980 freshwater head distribution of the Pearl Harbor aquifer, which was simulated by a two-dimensional flow model of Pearl Harbor Aquifer (Liu, Lau, and Mink, 1983). Three-dimensional flow and salt transport simulation of the Pearl Harbor aquifer is currently being conducted by the Hawaii District of the US Geological Survey Water Resources Division.

These modeling exercises have enhanced our understanding of the aquifer. However, most of these models are too complicated; adequate calibration and verification of these models requires extensive field data which are not currently available.

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Groundwater Management Activities

To support existing groundwater resources management activities in Hawaii, research and development efforts in the following two areas are being made: (1) extensive field survey and monitoring and (2) development and application of simple modeling tools.

A simple robust analytical model (RAM) was originally developed by John Mink (1981) for the determination of the sustainable yield of the Pearl Harbor aquifer. With many simplified assumptions in its derivation, the RAM model is able to calculate variations of basal aquifer head in response to forced draft. The RAM model, as the most popular groundwater management tool in the state, has been used to estimate the sustainable yield of the Pearl Harbor aquifer and many other basal aquifers in the sate.

Work Scope and Objectives

In this project, the RAM model will be modified by including transport processes of salt advection and dispersion. After modification, the model will consist of a flow sub-model, basically in the form of Mink's RAM model, and a transport sub-model, which is in the form of an analytical two-dimensional steady-state advection-dispersion equation. The mathematical structure of the modified model remains simple such that it can be solved analytically. The usefulness of this modified RAM model as a viable management tool will be demonstrated by applying it to an evaluation of the sustainable yield of the Pearl Harbor aquifer.

REFERENCES CITED:

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2. Bear, J. (1979). Hydraulics of Groundwater, McGraw-Hill Book Co.
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6. Mink, J.F. (1981). Determination of Sustainable Yields in Basal Aquifer, in: Groundwater in Hawaii-A Century of Progress, Book published by the Water Resources Research Center, University of Hawaii at Manoa, pp.101-116.
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WRRC Spring 2005 Seminar Series

March 3, 2005

Lorrin Pang, Maui District Health Office
"Medical and epidemiological assessment of community complaints following additives to Maui's drinking water"

March 10, 2005

Till Rubbert, Chair of Applied Geology, Ruhr-University Bochum (Germany)
"The efficiency of clay-cement-suspensions as grout seals in water wells"

March 17, 2005

Woodie Muirhead, Brown and Caldwell
"Assessment of a research project to use wastewater for irrigation in central Oahu"

April 7, 2005

Ken Kawahara et al., City and County of Honolulu
"Update on sludge treatment and sludge reuse issues and implementation of a new sludge treatment technology for Sand Island Wastewater Reclamation Treatment Facility"

April 21, 2005

Ross Tanimoto, Vic Moreland, Hans Krock, City and County of Honolulu and Univ. of Hawaii
"Update on issues related to ocean discharge of sewage and evaluation of CCH decision to disinfect Sand Island primary treated sewage effluent using ultra-violet (UV) technology"

May 5, 2005

Watson Okubo, Department of Health, State of Hawaii
"Update on beach monitoring program for fecal indicator bacteria in Hawaii"

There may be additional special seminars this semester. Please consult the WRRC website for up-to-date information on seminars.

http://www.wrrc.hawaii.edu/seminars.html

HWEA 2005 Conference Student Poster Contest Winners

WRRC students did well in the student poster contest at the 2005 HWEA conference held this month at the Hawaii Convention Center. The following prizes were awarded to our students:

First Prize: Atiim Senthill "Performance of a "CBT" on-site wastewater treatment system" - $150

Tied for 2nd:

Kathleen Brostrom "Fecal Sterols: A possible alternative "chemical" indicator of human waste contamination for Hawaii"- $75

Huaiqun Chen "Prediction of permeate flux decline in crossflow membrane filtration: A RBF neural network approach" - $75

WRRC Researcher Wins NSF Grant

Dr. Albert Kim, Civil Engineering professor and WRRC researcher, has recently been awarded a National Science Foundation Career grant. According to NSF's website, "The Faculty Early Career Development (CAREER) Program offers the National Science Foundation's most prestigious awards for new faculty. The CAREER program recognizes and supports the early career development activities of those faculty members who are most likely to become the academic leaders of the 21st century. CAREER awardees will be selected on the basis of creative, integrative, and effective research and education career development plans that build a firm foundation for a lifetime of integrated contributions to research and education".

Dr. Albert Kim

Alert readers will remember that there was an article about Dr. Kim's WRRC-sponsored research into water purification membrane fouling in an earlier issue of the WRRC bulletin. Dr. Kim's CAREER award project builds upon that research.

The CAREER grant is slated for research into "Aggregate-Enhanced Membrane Filtration" for water purification. Microfiltration (MF) and ultrafiltration (UF) are extensively used to remove particulate materials, suspended solids, bacteria, and various microorganisms. The rejected materials (generally termed 'particles' including colloids and biocolloids) typically form a dense and thick deposit layer on the membrane surface which significantly reduces the efficiency of the filtration process.

Prior to the advent of filtration membranes, coagulation and flocculation (aggregation processes) were employed to quickly generate heavy collections of particles and settle them to the bottom of the process tanks. Combining filtration and aggregation holds great potential for reducing membrane fouling, thereby enhancing water permeation. However, none of fundamental research necessary to optimize this combination treatment process has been conducted.

Toward this end, Professor Kim's research group will investigate the role of particle pre-aggregation in colloidal filtrations employing MF/UF membranes through simulations and theoretical determinations. The results will enable more meticulous simulations, including hydrodynamic, physical, and chemical interactions between particles, and so provide a holistic understanding of the micro-scale phenomena on the membrane surface at the most fundamental level. An educational component of the project will involve development of a research-education program, in which undergraduate and graduate students can effectively collaborate.

Large-Capacity Cesspools Must Go by April 5!

The U.S. Environmental Protection Agency (EPA) promulgated Underground Injection Control (UIC) regulations on December 7, 1999, which prohibit the construction of new large-capacity cesspools (LCCs) nationwide, effective April 5, 2000. **In addition, existing large capacity cesspools must be replaced by an alternative wastewater system and closed by April 5, 2005.** The regulations do not contain any provisions for an extension to the deadline.

States with delegated UIC programs are responsible for implementation of these regulations. In states where the program has not been delegated, such as Hawaii, EPA is implementing the regulations.

EPA Region 9 and the Hawaii State Department of Health (DOH) are working together as partners to ensure effective implementation. **Cesspools are more widely used in Hawaii than in any other state in the country.** This situation is cause for concern due to the State's heavy dependence upon groundwater as the principal source of drinking water and the threat posed to our aquifers by cesspools.

Number of Cesspools and Septic Tanks in Hawaii (1999)

Island	Cesspools	Septic Tanks
Hawaii	33,351	1,697
Kauai	11,326	868
Maui	15,537	968
Oahu	158,277	1,027

EPA estimates that there are 2,000 LCCs in Hawaii to be closed by the April 2005 deadline. Determinations on the applicability of the regulations to a cesspool are made by EPA. The DOH has rules on the wastewater systems and injection wells that are used throughout the State. Further information on this program can be found at

http://www.epa.gov/region9/water/groundwater/uic-hicesspools.html.

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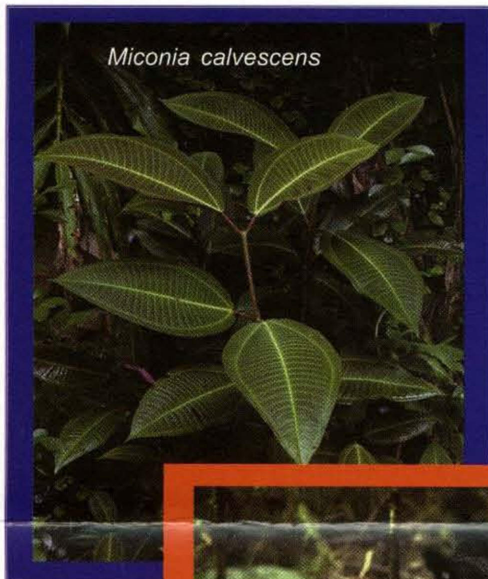
about $89 million. Recent research has indicated that the costs of successful conservation may be as high as $45 million. Only in cases where both the probability of the damage and the effect of the damage are very low (e.g., if, without the conservation, there is a 5% probability of a 5% loss in recharge), do the estimates of expected benefits fall below $45 million. Thus, watershed conservation in itself is a valuable management practice, though it becomes much more valuable when combined with the pricing reform.

(For further details, visit http://www2.hawaii.edu/~basharat/HTMLobj-293/Pitafi-Conservation.pdf)

Invasive Species

Invasive species such as *Miconia calvescens* are a particular threat to watershed resources. Entry of an invasive can be delayed by interdiction or control at the source. When prevention fails, an introduction of the invasive population occurs that grows, causes damage, and can be controlled at some cost. There may be a critical population level, above which the population cannot be appreciably altered by further introduction such that further prevention is not required.


Miconia calvescens


wild pig - *Sus scrofa*

Optimal post-introduction management of an invasive requires choosing control (removal) over time such that it minimizes the control costs and the damages from the remaining invasive. Depending on the initial population level, the cost of control, and the damages from the invasive, the optimal control may entail: a) doing nothing (zero control level) and letting the population grow to its carrying capacity, b) eradicating the population completely (zero population level) and commencing prevention expenditures again, or c) achieving a steady positive level of population with continued positive control. If the steady-state population is less than the critical level, then one also needs to take into account the possibility of further introductions. If the invasive is highly damaging, the optimal steady-state population level is small and vice versa. Also, the optimal population decreases as the removal cost decreases or the interest rate increases.

> Watershed/recharge protection activities (such as optimal control of Miconia and culling of wild pig populations) may result in considerable future economic benefits.

Optimal pre-introduction management of an invasive requires choosing prevention such that it minimizes the expected present value of the prevention costs and the minimized control and damage costs in case the prevention fails. If these control and damage costs are large, optimal prevention expenditures would also be large. The optimal prevention expenditures would also be bigger, the smaller the interest rate is and the more sensitive the probability of introduction is to prevention expenditures.

(For details, see http://www2.hawaii.edu/~basharat/id43.htm and http://homepage.mac.com/ondinebak/)

Directions for Further Research

Although useful insights can be obtained by analyzing one aquifer at a time, groundwater aquifers on Oahu are interconnected. Water flows naturally across adjacent aquifers depending, among other things, on the head level gradient between aquifers. In addition to these natural transfers, consumers located in one aquifer area can be supplied with water extracted and transported from another aquifer if this results in cost savings over local extraction. Incorporating such inter-district transport as well as natural subsurface flows would allow for an island-wide optimal management framework.

Another possible extension is to consider how the results will be modified if water users consider sewage charges as part of the effective water price. Inasmuch as official water prices are too low but effective water charges include sewage fees, this may be a case of two wrongs making a right.

Finally, the usual assumption of a sharp interface between freshwater and the underlying saltwater results in head level constraints in order to prevent extraction of saltwater. These constraints can be too tight or too lax, depending on the assumed depth of the sharp interface. We plan to generalize by modeling a transition zone in which salt concentration gradually increases as head level falls. Brackish water extracted from a well can then be mixed with freshwater from other wells or desalination to bring it to the drinking water standards of the State.

For further information, contact James Roumasset (jimr@hawaii.edu) or Basharat Pitafi (basharat@hawaii.edu).

Upcoming Conferences

3rd Conference on Watershed Management to Meet Water Quality Standards and Emerging TMDL
March 5-9, 2005, Sheraton Atlanta, Atlanta, GA
http://www.asae.org/meetings/TMDL2005/

5th Annual Conference on Safe Supply Of Drinking Water: Practical Strategies and Best Practices to Meet High Standards in Drinking Water Supply
The Sutton Place Hotel, Toronto, ON
Monday, March 7, 2005 to Tuesday, March 8, 2005
http://www.canadianinstitute.com/

The Association for Environmental Health and Sciences (AEHS): 15th Annual West Coast Conference on Soils, Sediments and Water
March 14-17, 2005, Marriott Mission Valley, San Diego, CA
http://www.aehs.com/conferences/westcoast/index.htm

Battelle In Situ and On-Site Bioremediation - Eighth International Symposium
June 6-9, 2005, Baltimore, MD
http://www.battelle.org/environment/er/conferences/biosymp/default.stm

AWWA 124th Annual Conference and Exposition
June 12–16, 2005, Moscone Center, San Francisco, CA
http://www.awwa.org/ace2005/

ASCE – EWRI 2005 Watershed Management Conference, "Managing Watersheds for Human and Natural Impacts: Engineering, Ecological, and Economic Challenges"
July 19-22, 2005, Williamsburg, VA
http://www.asce.org/conferences/watershedmanagement2005/

Soil and Water Conservation Society's 2005 Annual Conference
30 July 30, 2005, Rochester, NY
http://www.swcs.org/

ISES 2005 Solar World Congress - Bringing Water to the World
August 6-12, 2005, Orlando, FL
http://www.swc2005.org/

WEF Specialty ConferencesTechnology 2005
2nd Joint Specialty Conference for Sustainable Management of Water Quality Systems for the 21st Century - Working to Protect Public Health
August 28–31, 2005, Palace Hotel, San Francisco, CA
http://www.wef.org/conferences/

University of Massachusetts, 21st Annual International Conference on Soils, Sediments and Water
October 17-20, 2005, Amherst, MA
http://www.umasssoils.com/papers.htm

WEFTEC 05, Water Environment Federation, 78th Annual Technical Exhibition and Conference
October 29 – November 2, 2005, Washington, DC
http://www.weftec.org/news/

American Society of Agricultural Engineers, International Conference on Hydrology and Management of Forested Wetlands
April 8-12, 2006, New Bern, NC
http://www.asae.org/meetings/Forest2006/

3rd International Conference on Remediation of Contaminated Sediments
January 24-27, 2005, New Orleans, LA
http://www.battelle.org/environment/er/conferences/sedimentscon/default.stm

Hawaii Water Resources Research Institute Program Grants Recipients 2005

Under the USGS Water Resources Research Institute Program, WRRC makes small seed grants to support research that aids in the resolution of state and regional water problems and provides for the training of scientists and engineers through their participation in research. This year's recipients are:

- Kaeo Duarte, UH Botany/WRRC, "Dynamic Effects of Native Versus Non-Native Vegetation on the Ecohydrology of a Hawaiian Rainforest"
- Aly El-Kadi, UH Geology & Geophysics/WRRC, "Development of New Technique for Use of Dissolved Helium as Environmental Groundwater Tracer"
- Albert Kim, UH Civil Engineering/WRRC, "Diffusive Tortuosity of Reactive Porous Media: Application to Colloidal and Biofouling During Membrane Filtration"
- James Roumasset, UH Economics, "Integrated Management of Multiple Aquifers with Subsurface Flows and Inter-District Water Transport"

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AWRA 2005 Summer Specialty Conference

Institutions for Sustainable Watershed Management: Reconciling Physical and Management Ecology in Asia-Pacific

June 27-29, 2005, Hyatt Regency Waikiki, Honolulu, HI

http://www.awra.org/meetings/Hawaii2005/

This conference will investigate how traditional practices in the Asia-Pacific can be blended into effective management that achieves the sustainable use of watersheds for future generations. Traditional cultures tend to view water resources systems more broadly than modern society, by accounting for social and environmental issues. Traditional water resources management refers to the adaptation of culture and behavior to long-term natural cycles. By understanding how population and industrialization have disrupted watershed systems, we can propose sustainable solutions.