

**Water Resources Research Center
Annual Technical Report
FY 2011**

Introduction

Among the problems driven by global climate change, none is more important for long-term sustainability than the potential impacts on water resources. Water is essential for sustaining life and economies. Closely following and deeply intertwined with the need for water is the need for secure and sustainable energy resources and the efficient use of available energy.

Scientists at the University of Hawaii at Manoa (UHM) Water Resources Research Center (WRRC) address those water- and energy-related issues in common with other United States locales and those specific to the islands of the State of Hawaii.

UHM WRRC serves as the focal point for organizing UHM faculty expertise to study the adequacy, integrity, and purity of Hawaii's offshore recreational waters and onshore potable-water resources. WRRC researchers address issues regarding efficient water usage, enhancing groundwater availability, efficient wastewater management and re-use, and related energy-efficiency concerns. Going beyond various monitoring studies, WRRC projects continue to push forward the frontiers of scientific knowledge on island hydrology, generate watershed-assessment and watershed-improvement plans, advance knowledge of energy-efficient desalination and other water-treatment processes, connect hydrologic and economic models of aquifer exploitation, and search for improved indicators of water quality, among other efforts.

The island of Oahu, more specifically the City and County of Honolulu, is truly the "canary in the coal mine" for many water- and energy-related issues that may face the population centers in the U.S. and the world.

Water shortages and energy crises are even more critical to the infrastructure of the Hawaiian Islands because of its geographic isolation and small land area. Therefore, the islands can serve as a microcosm of what may already be a reality for a third of the population in the western and/or southwestern U.S.—limited water shortage. Also, while water-pollution issues are an increasingly recognized problem, the energy crises has also been escalating over the last decade throughout the U.S.

The grants provided through the USGS Water Resources Research Institute Program sets the foundation upon which other activities of the UHM WRRC are structured.

Research Program Introduction

The Hawaii NIWR program for FY 2011 funded four new research projects, supported a multi-center conference on island water issues, and provided small amounts for technology transfer and administration. The funded research projects are:

Long-term aspects of high-elevation rainfall and climate change, Oahu.

The purpose of this research, conducted by Dr. David Beilman and his team, was to better understand long-term patterns of rainfall in Hawai'i by reconstructing the long-term ecohydrological changes that have occurred at mountain sites on the island of O'ahu from the examination of peat swamp sediments. The researchers focused on three study sites around O'ahu. They followed two main lines of enquiry: 1) fossil pollen abundances - reflecting changes in local vegetation over time and 2) stable isotope geochemistry of hydrogen, carbon, and nitrogen of bulk sediment and specific biomolecules (leaf waxes; n-alkanes). Their work concentrated on fossil pollen work for the last 8,000 years of sediments at one of the three sites. Stable isotope geochemistry work also focused on sediments at that site as the first priority.

Development of an advanced surface tensiometer for measuring water quality.

The goal of this project was to establish a broad-based, collaborative effort to promulgate new water quality regulations that will provide for greater community self-reliance in aquaculture production while sustaining environmental health. The four main objectives were to: (1) identify the different types of water quality standards revisions that could be proposed, including a survey of the practices in other jurisdictions; (2) document procedural roadmaps and scientific information needs for each type of revision identified; (3) analyze the potential for success in revising water quality standards for one or more coastal fishponds; and (4) estimate the resources needed to complete revisions on a wider scale.

Reshaping the regulatory framework for Hawaii aquaculture – water quality standards

The objective of this project was to develop an advanced surface tensiometer for measuring water quality. This tensiometer is based on the principle of drop shape analysis to detect contamination of water. Surface tension of water is a physical property highly sensitive to contamination. Trace amounts of pollutants (e.g., organic chemicals and microorganisms) can adsorb to the air-water interface, thus decreasing surface tension of pure water. Therefore, surface tension measurement can be used as a novel and sensitive physical method to detect water quality. Compared to other physical, chemical, and biological methods for assessing water quality, surface tension is relatively easy to measure and hence may be a useful control parameter for water quality and water-reuse systems. This method has the potential to be developed into a powerful screening tool for assessing water quality and other environmental impacts of water contaminants.

Addressing sewage contamination of Nawiliwili Stream and Kalapaki Beach

The first objective of this project was to train the Center's new microbiologist and familiarize him with Hawai'ian conditions following the 2009 retirement of Dr. R. Fujioka after completing 38 years of research for WRRC. The second objective was to confirm earlier findings that Nawiliwili watershed on the island of Kauai is being contaminated by the many cesspools in the area and whether this contamination compromises the quality of the water at Kalapaki Beach - one of the most popular beaches on Kauai.

WRRC researchers also continued, under no-cost extensions;

Hydraulic properties of the northern Guam lens aquifer system.

Research Program Introduction

The objective of this work was to estimate aquifer properties of the northern Guam aquifer. A three-dimensional ground-water flow and transport model will be developed in a subsequent study to evaluate the availability of Guam's groundwater resources under several recharge and withdrawal scenarios. This study helped to identify hydrologic parameters to constrain numbers that can be used as input for this model. Tidal-signal attenuation was used to estimate hydraulic properties, such as hydraulic conductivity and storage parameters for the northern Guam aquifer.

Application of radar imagery as input to a rainfall-runoff model for the Kawela watershed, Molokai, Hawaii

Under this study researchers have been compiling available radar-rainfall and raingage data for Molokai, Hawaii, comparing radar-inferred rainfall with observed rainfall from raingages, and providing radar- and gage-rainfall as input to a rainfall-runoff model for the Kawela watershed on Molokai. The project was addressed in three phases: 1) compilation of available radar-rainfall and raingage data for Molokai, 2) comparison of radar-inferred rainfall with observed rainfall from raingages, and 3) providing radar- and gage-rainfall as input to a rainfall-runoff model for the Kawela watershed, Molokai.

Numerical simulation of the effects of borehole flow on measured vertical salinity profiles from deep monitor wells, Pearl Harbor aquifer, O'ahu, Hawai'i

A previous numerical-modeling study of coastal wells in Israel indicated an upward displacement of the borehole salinity in wells located in the coastal-discharge area of the aquifer while in a steady-state condition. Responding to the influence of ocean tides the vertical flow in the borehole changes direction and the flow in the monitor well was three orders of magnitude larger than that in the aquifer. This indicates that the observed borehole salinity does not accurately represent the aquifer salinity. Therefore these monitor wells do not accurately monitor the actual freshwater-saltwater transition zone. The overall objective of this study is to provide information on how representative measured vertical salinity profiles from deep monitor wells are of conditions in the adjacent aquifer. A numerical modeling approach, incorporating the hydraulic characteristics and recharge data representative of the Pearl Harbor aquifer, is being used to evaluate the effects of borehole flow on measured salinity profiles from deep monitor wells.

Application of Radar Imagery as Input to a Rainfall-Runoff Model for the Kawela Watershed, Molokai

Basic Information

Title:	Application of Radar Imagery as Input to a Rainfall-Runoff Model for the Kawela Watershed, Molokai
Project Number:	2008HI282S
Start Date:	9/1/2008
End Date:	3/1/2011
Funding Source:	Supplemental
Congressional District:	Hawaii 1st
Research Category:	Climate and Hydrologic Processes
Focus Category:	Surface Water, Hydrology, Groundwater
Descriptors:	Radar-Raingage Rainfall, Rainfall-Runoff Model, Groundwater Recharge
Principal Investigators:	Aly I El-Kadi

Publication

1. Rotzoll, K.: Estimating bias of NEXRAD radar rainfall with raingages on Molokai, Hawaii, (in preparation for submission to Pacific Science)

FINAL REPORT

**Application of Radar Imagery as Input to a Rainfall-Runoff Model
for the Kawela Watershed, Molokai, Hawaii**

May 2012

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Water Resources Research Center
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Prepared for the U.S. Geological Survey
Pacific Islands Water Science Center

Project Number: 2008HI282S

Abstract

Spatial variability of rainfall is typically high and existing raingages usually are sparsely distributed on a watershed scale, which can lead to substantial over- and underestimation of total basin rainfall. Precipitation estimated from reflectivity measured by the NEXRAD radar promises spatially and temporally comprehensive coverage. Thus, hourly and daily radar rainfall was compared to raingage rainfall as potential input for a rainfall-runoff model in the Kawela watershed, Molokai, Hawaii. Rainfall rates from radar and raingages are log-normally distributed and correlate, although the relationship exhibits large scatter, especially at rainfall rates below 5 mm/day. Although radar rainfall is promising for the use in rainfall-runoff modeling, it is best to use radar rainfall to supplement areas without raingages or times without record as an addition to raingage data.

Introduction

Watershed-scale studies in Hawaii frequently require the integration of multiple aspects of basin-hydrology data including groundwater recharge, pollutant transport, sediment discharge, streambed erosion, and streamflow. Additionally the effects of rainfall variation or land-cover changes on any of these aspects may need to be assessed. As described by Field et al. (2007) for the Hanalei watershed, Kauai, multi-disciplinary analysis of terrestrial and marine ecosystems provides a broader understanding of the processes within a watershed. Multi-disciplinary analysis is particularly useful for watershed managers facing multiple concerns of improving coastal water quality, maintaining sustainable water supply, and restoring ecological integrity.

The primary factors controlling hydrologic processes in Hawaii watersheds are the temporal and spatial distribution of rainfall and runoff/infiltration characteristics. Existing watershed modeling studies in Hawaii include those on the Manoa-Palolo Stream, Oahu by Sahoo et al. (2006) and by El-Kadi and Yamashita (2007), on the Makaha Valley, Oahu (Mair et al. 2007), and on the Hanalei watershed, Kauai (Polyakov et al. 2007). Steep/mountainous terrain generates substantial and powerful runoff and streamflow is highly variable, often producing high peak flows in streams that have low base flows otherwise (Oki 2004). Rainfall in Hawaii is characterized by steep spatial gradients (Giambelluca et al. 2011). Existing networks of raingages are usually too sparse to reflect the full spatial variability of basin-scale areas. In this type of topography, time-series rainfall maps are generally more useful in identifying rainfall patterns than interpolation between the few existing raingages.

The National Weather Service's Weather Surveillance Radar-1988 Doppler Next Generation Weather Radar (NEXRAD) provides radar-inferred precipitation images (Smith and Krajewski 2002). Studies (e.g., Xie et al. 2006, Wang et al. 2008) have correlated these NEXRAD images with raingage data. The rainfall maps were made available in the form of

Geographic Information System-coverages (Gorokhovich and Villarini 2005, Xie et al. 2005). Such maps have been used as input for rainfall-runoff modeling in flat terrain (Peters and Easton 1997), complex mountainous terrain (Yates et al. 2000), and urban watersheds (Smith et al. 2007). Kalinga and Gan (2006) show that simulations with NEXRAD data accurately predict runoff hydrographs for convective storms but are less accurate for stratified storms. NEXRAD III images for Hawaii are available with a spatial resolution of ~1 km every 6 minutes from 2001 to the present day. However, the applicability of these images for Hawaii for use in hydrologic modeling has yet to be tested.

The Kawela watershed, a medium-size watershed on Molokai covering an area of 13.7 km², may provide a valuable and valid testing location. Average annual rainfall across the Kawela watershed is ca. 1,500 mm. Annual rainfall changes gradually from 3,300 mm at the top of the ridge to 330 mm at the coast (Giambelluca et al. 2011). Rainfall maps can be used to generate a rainfall-runoff model for the Kawela watershed to evaluate the accuracy of such a model for various climate and land-cover scenarios. The geographic/geologic/topographic patterns of the Kawela watershed are similar to those of many leeward Koolau watersheds on Oahu and similar areas on other Hawaiian islands. Therefore, a successful demonstration of this form of hydrologic modeling for the Kawela watershed would indicate applicability of this approach to other watersheds.

Problem and Research Objectives

The objective of this study is to compile available radar-rainfall and raingage data for Molokai, Hawaii, compare radar-inferred rainfall with observed rainfall from raingages, and provide radar- and gage-rainfall as input to a rainfall-runoff model for the Kawela watershed, Molokai. The rainfall-runoff modeling part is dropped from the scope in agreement with the U.S Geological Survey, because it is developed in a subsequent study by the U.S Geological Survey to evaluate the accuracy of such a model for various climate and land-cover scenarios on streamflow and groundwater recharge.

Methodology

The project was addressed in three phases: 1) compile available radar-rainfall and raingage data for Molokai, 2) compare radar-inferred rainfall with observed rainfall from raingages, and 3) provide radar- and gage-rainfall as input to a rainfall-runoff model for the Kawela watershed, Molokai.

1a) Data compilation of radar rainfall—The PHMO NEXRAD station on Molokai is located on top of West Molokai Mountain at an elevation of 415 m above sea level (Figure 1).

Radar rainfall is a function of radar reflectivity and rainfall rate. 1-hr accumulated precipitation (NIP) images for the period 5/5/2001–4/25/2010 were downloaded at <http://www.ncdc.noaa.gov/nexradinv/chooseday.jsp?id=phmo>. While the radar provides an image of 1-hr rainfall totals for every 5 to 6 min in irregular intervals, only the files at the full hour ± 3 min were considered. The binary radar image files were clipped to the geographic extent Molokai and converted to ESRI ASCII raster files with a rectangular grid-cell size of 70 m using the National Oceanic and Atmospheric Administration’s (NOAA) Weather and Climate Toolkit, version 2.4.2 (upgraded version available at <http://www.ncdc.noaa.gov/oa/wct/index.php>). The pixel (rainfall) values of the grid cell’s centroid closest to each raingage were extracted as 1-hr time series for the comparison with the gages. The 1-hr time series were also transferred as a cumulative function to daily rainfall values.

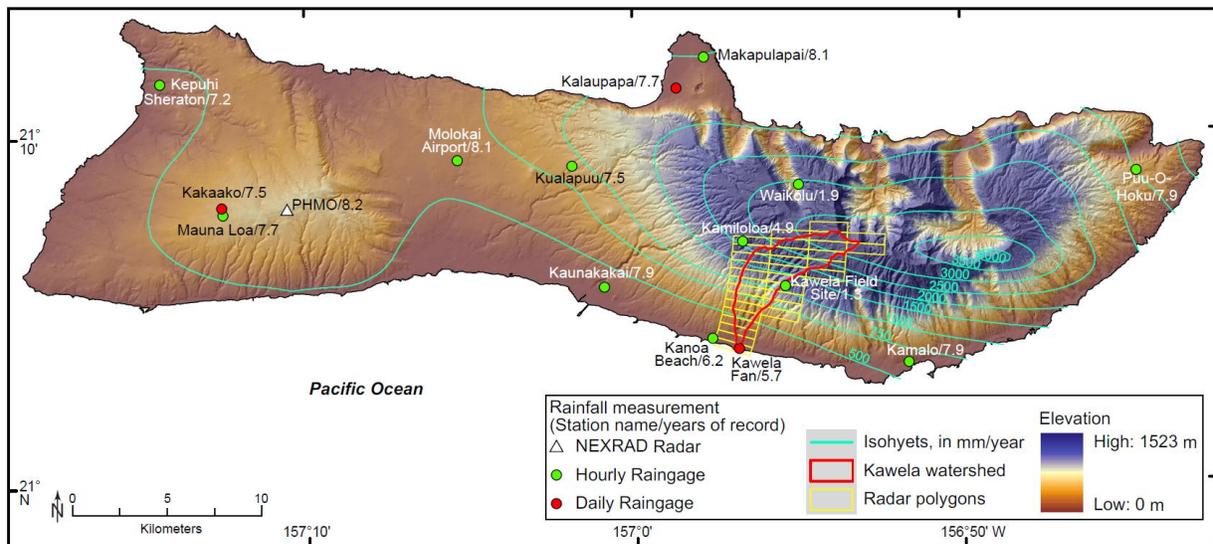


Figure 1. Map of elevation, isohyets (Giambelluca et al. 2011), location of radar and raingages, sampling interval, length of record available, and radar polygons intersecting Kawela watershed, Molokai, Hawaii.

1b) Data compilation of raingages—For the period of existing radar data, 15 raingages on Molokai have precipitation records available. Of these raingages, 12 have hourly or smaller temporal sample intervals (Figure 1). Data from Kamilolooa and Makapulapai were downloaded through the RAWs network of the Western Regional Climate Center, available at <http://www.raws.dri.edu/wraws/hiF.html>. Rainfall data at Molokai Airport was available from the NOAA National Climatic Data Center at <http://cdo.ncdc.noaa.gov/qclcd/QCLCD?prior=N>. Data from Kaunakakai and Kamalo were downloaded through the NOAA Hydronet, available at <http://www.prh.noaa.gov/hnl/hydro/hydronet/hydronet-data.php>. Precipitation data at Puu-O-Hoku, Kualaupuu, Kepuhi Sheraton, Mauna Loa, and Kalaupapa are available at the NOAA National Climatic Data Center <http://www4.ncdc.noaa.gov/cgi-win/wwcgi.dll?wwDI~StnsNear~20023492~25>. Rainfall data at Kakaako and Waikolu was collected by the USGS, available at <http://waterdata.usgs.gov/nwis/>. Rainfall data from the

Kawela Field Site was provided by Jonathan Stock, precipitation at the Kanoa Beach was collected by Dough Macmillan, and rainfall at Kawela Fan was recorded by Bill Feeter. Rainfall time series sampled at shorter intervals than 1 hour were aggregated as a cumulative function to 1-hr rainfall values and time series sampled at shorter intervals than 1 day were aggregated to daily rainfall values.

2) *Radar-gage comparison*— Distribution of rainfall data is tested for normal and log-normal distribution by plotting the data on a probability scale. The raingage rainfall was compared to the radar-inferred rainfall for hourly and daily records for every non-zero data pair to identify applicability of radar rainfall for Molokai.

3) *Gage- and radar-rainfall time series for Kawela*—Data files containing the hourly and daily rainfall rate at each raingage were provided to the U.S Geological Survey. The Kawela watershed intersects 33 radar polygons of ca. 2 x 0.5 km containing the averaged radar rainfall over that area (Figure 1). The coordinates and the pixel (rainfall) values at the radar-rainfall polygon’s centroid intersecting the Kawela watershed are exported to hourly and daily radar-rainfall time series and provided to the U.S Geological Survey. A subsequent study by the U.S Geological Survey will utilize both rainfall products as input to a rainfall-runoff model for the Kawela watershed, Molokai.

Results

Plotting hourly and daily rainfall rates from radar and raingages on a probability scale indicates that both data sets are log-normally distributed (Figure 2). Thus, the comparison of radar rainfall and raingage rainfall data is performed through logarithmic transformation.

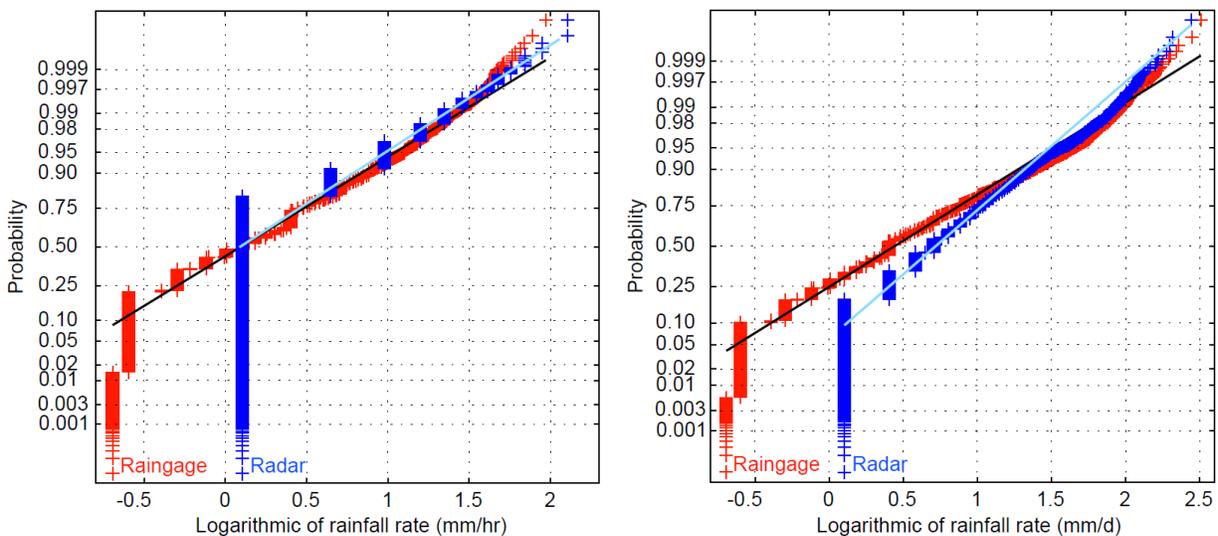


Figure 2. Normal probability plot of hourly and daily radar- and raingage rainfall 5/2001–4/2010 for Molokai.

Large scatter characterizes the relationship between radar- and gage-precipitation rates with better agreement at larger rainfall rates (Figure 3). Reasons for the disparity include the size of radar polygons, the binning of radar-inferred precipitation, and uncertainty in radar- and raingage rainfall. The radar polygons represent averaged rainfall over ca. 1 km², which might be too large to capture spatial differences. Further, the 1-hr radar-inferred rainfall is binned in 16 data levels with variable increments (0/2.5/6.4/12.7/19.1/25.4/32/38/45/51/64/75/100/150/200 mm), which might be too coarse to capture differences in rainfall. This is substantial at the light-rain level, indicated by the larger scatter below 5 mm of raingage rainfall (Figure 3).

Uncertainty in the estimated rainfall from the radar reflectivity is supplemented by uncertainty in the measured value at the raingage. Tipping buckets may miss heavy-rain events simply because the possible tip frequency is too low and water flushes through the gage without being quantified. Additional uncertainty stems from reporting errors; not all agencies collecting data impose the same quality assurance/quality control procedure on the rainfall measurements. Finally, the main purpose of radar rainfall is its use for flash-flood forecasting and it is not designed as a replacement of physical rainfall measurements in gages.

Correlation coefficients of the log-transformed values are 0.56 and 0.59 for the hourly and daily rainfall, respectively. Overall, the fit between radar rainfall and raingages is reasonable with higher confidence at larger rainfall rates. Although radar rainfall is promising for the use in rainfall-runoff modeling, it is best to use radar rainfall to supplement areas without raingages or times without record as an addition to raingage data.

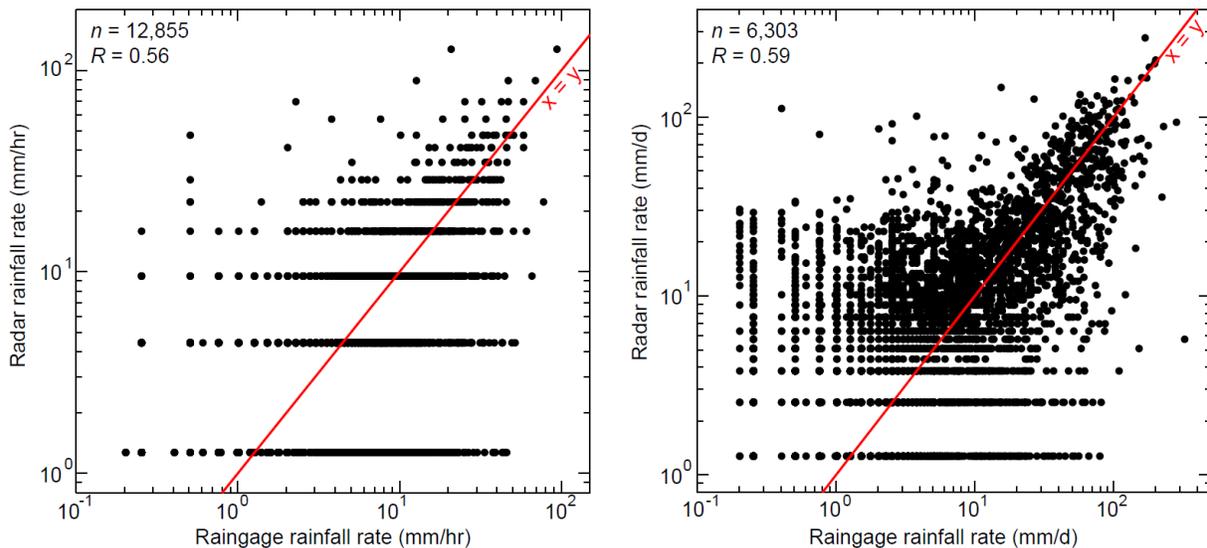


Figure 3. Comparison of hourly and daily radar- and raingage rainfall 5/2001–4/2010 for Molokai, n denotes the number of non-zero data pairs and R the correlation coefficient.

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Numerical Simulation of the Effects of Borehole Flow on Measured Vertical Salinity Profiles from Deep Monitor Wells, Pearl Harbor Aquifer, Oahu, Hawaii

Basic Information

Title:	Numerical Simulation of the Effects of Borehole Flow on Measured Vertical Salinity Profiles from Deep Monitor Wells, Pearl Harbor Aquifer, Oahu, Hawaii
Project Number:	2009HI284S
Start Date:	8/1/2009
End Date:	3/31/2011
Funding Source:	Other
Congressional District:	Hawaii 1st
Research Category:	Ground-water Flow and Transport
Focus Category:	Groundwater, Models, Water Quality
Descriptors:	Borehole Flow, Deep Monitor Wells, Salinity Profiles, SEAWAT Model
Principal Investigators:	Aly I El-Kadi

Publications

1. A final report will be published in the U.S. Geological Survey Scientific Investigations Report series.
2. Rotzoll, K., D.S. Oki, and A.I. El-Kadi, 2010, "Numerical simulation of borehole flow in deep monitor wells, Pearl Harbor aquifer, Oahu, Hawaii," Abstract H43A-1219, presented at 2010 Fall Meeting, AGU, San Francisco, CA, 13–17 Dec.
3. Rotzoll, K., Numerical simulation of borehole flow in deep monitor wells in a coastal freshwater lens, Pearl Harbor aquifer, Oahu, Hawaii, U.S. Geological Survey Scientific Investigations Report. (in review)
4. Rotzoll, K., D.S. Oki, and A.I. El-Kadi, 2010, "Numerical simulation of borehole flow in deep monitor wells, Pearl Harbor aquifer, Oahu, Hawaii," Abstract H43A-1219, presented at 2010 Fall Meeting, AGU, San Francisco, CA, 13–17 Dec.
5. Rotzoll, K., 2012: Numerical simulation of flow in deep open boreholes in a coastal freshwater lens, Pearl Harbor aquifer, Oahu, Hawaii. U.S. Geological Survey, Scientific Investigations Report 2012-5009, 39 p.
6. Rotzoll, K. and A.I. El-Kadi, 2011, Numerical simulation of borehole flow in deep monitor wells in a coastal freshwater lens, Pearl Harbor aquifer, Oahu, Hawaii, presented at WRRRC Water Resource Sustainability Issues on Tropical Islands Conference, Honolulu, HI, 14–16 Nov.

Problem and Research Objectives

A recent numerical-modeling study of coastal wells in Israel indicates an upward displacement of the borehole salinity in wells located in the coastal-discharge area of the aquifer while it is at a steady-state condition. Responding to the influence of ocean tides the vertical flow in the borehole changes direction and the flow in the monitor well is three orders of magnitude larger than that in the aquifer. This indicates that the observed borehole salinity does not accurately represent the aquifer salinity (Shalev et al. 2009). Therefore these monitor wells do not accurately monitor the actual freshwater-saltwater transition zone.

The overall objective of this study is to provide information on how representative measured vertical salinity profiles from deep monitor wells are of conditions in the adjacent aquifer. A numerical modeling approach, incorporating the hydraulic characteristics and recharge data representative of the Pearl Harbor aquifer, will be used to evaluate the effects of borehole flow on measured salinity profiles from deep monitor wells. Borehole flow caused by vertical hydraulic gradients associated with both the natural regional flow system and with local groundwater withdrawals will be simulated. Model results will be used to estimate differences between vertical salinity profiles in open boreholes and the adjacent aquifer in areas of downward, horizontal, and upward flows within the regional flow system—in areas both with and without nearby pumped wells. Results from this study will provide insights into the magnitude of the discrepancy between current vertical salinity profiles from deep monitor wells and the actual salinities of adjacent aquifers. Such data is critically needed for management and predictive modeling purposes.

Methodology

A three-dimensional numerical model, SEAWAT Version 4 (Langevin et al. 2007), capable of simulating density-dependent groundwater flow and solute transport will be used in this study. Although the model will mainly be conceptual in nature and incorporate a simplified geometry, previously published values for hydraulic characteristics and recharge representative of the Pearl Harbor aquifer will be tested. A steady-state condition that generally represents the distribution of measured water levels in the aquifer will be simulated and used as an initial condition for all other simulations.

Within the model, deep open boreholes will be introduced at selected sites within the natural regional flow system in areas of downward, horizontal, and upward flows. Flow within the borehole will be simulated with a suitable model for an open conduit. Simulated salinity profiles within the borehole will be compared to 1) the pre-existing distribution of salinity in the aquifer without the borehole and 2) the distribution of salinity in the aquifer with the borehole present.

Additionally within the model, pumped wells will be introduced at selected distances from the open boreholes to evaluate the immediate effects of groundwater withdrawals on salinity profiles and saltwater intrusion into the aquifer. The depths of simulated pumped wells will correspond to the depths of typical production wells in the Pearl Harbor aquifer. The effects of both vertical wells and horizontal shafts will be simulated. Pumped wells will be located about 100 and 3,000 ft from the open boreholes and groundwater-withdrawal rates of about 4 and 17 mgd will be simulated for each pumped well.

A sensitivity analysis, in which values of hydraulic characteristics are varied one at a time, will be conducted to evaluate how the magnitudes of well hydraulic conductivity and aquifer anisotropy ratios may affect borehole flow. In addition, two simulations incorporating low- and high-permeability layers within the aquifer will be simulated.

Principal Findings and Significance

Model results indicate that borehole-flow velocities caused by the natural groundwater-flow system without local groundwater withdrawals is five orders of magnitude greater than the vertical flow velocities in the homogeneous aquifer. The contrast is consistent with the larger vertical hydraulic conductivity in the well compared to the aquifer. Directions of borehole flow are consistent with the regional flow system: downward flow in inland recharge areas and upward flow in coastal discharge areas. Displacement of salinity inside the wells does not exceed 17 ft for an effective hydraulic conductivity of the well determined from measured flow velocities (K_{well}). However, using the theoretical well hydraulic conductivity for turbulent flow (K_{tur}), borehole-flow velocities under natural groundwater-flow conditions increase more than an order of magnitude, and upward displacement of the 2 percent salinity depth exceeds 220 ft in the coastal DMW-1. Using K_{well} , the average salinity difference from the midpoint (50 percent salinity depth) upwards is 0.65 percent seawater salinity in DMW-1, which indicates that salinity in the DMWs is largely unaffected by borehole flow from the regional groundwater flow field. Commonly, a 1 percent error in salinity is acceptable for numerical modeling studies.

Borehole flow and movement of salinity in the well that is caused by local groundwater withdrawals are greater than flow and displacements under natural flow conditions. Simulated groundwater withdrawals of 4.3 Mgal/d 100 ft from a DMW causes thirty times more borehole flow than borehole flow induced by the regional flow field. The 2 percent borehole salinity is displaced 33 ft or 231 ft, depending on the assumed hydraulic conductivity of the well. Peak borehole flow caused by local groundwater withdrawals near DMWs is directly proportional to the pumping rate in the nearby production well. The upward displacement of the 50 percent salinity depth in DMW-1 increases from 4.6 to 7.1 ft (using K_{well}) and from 19 to 83 ft (using K_{tur}). The average salinity difference increases from 0.85 to 11.4 percent seawater salinity (using K_{well}) and from 6.5 to 12.5 percent salinity (using K_{tur}) in DMW-1.

Simulated groundwater withdrawals 3,000 ft away from DMW-1 are less influential on borehole flow and salinity than the withdrawals nearby. For simulated withdrawal wells 3,000 ft from DMW-1, increasing the withdrawal rate from 4.3 to 16.7 Mgal/d causes borehole flow in DMW-1 to increase by only 50 percent. However, due to the closer location of withdrawals to DMW-2, borehole-flow velocities in DMW-2 increased by 70 percent with the higher withdrawal rates. Displacement of the 2 percent salinity depth in DMW-1 increases from 25 to 114 ft, and the 50 percent salinity depth shifts from 5.8 to 6.4 ft with the higher withdrawal rate.

Effects of groundwater withdrawals from a horizontal shaft and withdrawals from a vertical well in a homogeneous aquifer were generally similar, except that borehole-flow velocities in DMW-1 were greater and upward displacement of the 2 percent salinity depth was slightly greater (123 instead of 114 ft) for the scenario that simulated withdrawal from a shaft. Generally, the 50 percent salinity depths are less affected by borehole flow than the 2 percent

salinity depths. Hence, measured salinity profiles are useful for calibration of regional numerical models despite borehole-flow effects. Commonly, a 1 percent error in salinity is acceptable in numerical modeling studies.

Local withdrawals near a DMW alone cannot produce the large vertical steps observed in salinity profiles in southern Oahu when the entire well is in contact with a homogeneous aquifer. Over the length of such a step, the salinity remains constant because mixing of water in the borehole with water from the aquifer is limited. Thus, water inside the well can be more brackish than water in the aquifer under upward borehole-flow conditions. Thick zones of low hydraulic conductivity rock may limit exchange of water between aquifer and well and lead to a vertical step in the salinity profile. The heterogeneous basalt aquifer simulated in this study is one of many plausible aquifer representations. Nevertheless, simulated salinity profiles include observed vertical steps and simulated borehole flow is consistent with measured borehole flow from DMWs in southern Oahu. Due to limitations of model grid-cell size and lack of detailed information about heterogeneity in the subsurface, the inclusion of local-scale heterogeneities in regional models is not warranted.

Model results indicate that, with all other factors being equal, larger withdrawal rates, closer withdrawal locations, higher hydraulic conductivity of the well, and lower vertical aquifer hydraulic conductivity result in greater borehole flow and displacement of salinity in the well. Heterogeneity in the aquifer around the monitor well is necessary to produce vertical steps in salinity profiles in the model. Reliability in the model results can be improved by better borehole-flow measurements under different withdrawal conditions, incorporation of three-dimensional distribution of model parameters to extend the two-dimensional to a regional model, and enhanced representation of DMWs in the model.

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Hydraulic Properties of the Northern Guam Lens Aquifer System, Territory of Guam, USA

Basic Information

Title:	Hydraulic Properties of the Northern Guam Lens Aquifer System, Territory of Guam, USA
Project Number:	2010HI316S
Start Date:	6/30/2010
End Date:	12/31/2012
Funding Source:	104B
Congressional District:	Hawaii 1st
Research Category:	Ground-water Flow and Transport
Focus Category:	Groundwater, Hydrology, Water Supply
Descriptors:	Aquifer Parameter Estimation, Tidal Responses, Aquifer Test
Principal Investigators:	Aly I El-Kadi

Publications

1. Rotzoll, K., J. Jenson, and A.I. El-Kadi, 2011, Estimating hydraulic properties of the Northern Guam Aquifer by analysis of ocean-driven groundwater-level fluctuations, Abstract H34E 08, presented at 2011 Fall Meeting, AGU, San Francisco, CA, 5-9 Dec.
2. Rotzoll, K., S.B. Gingerich, J. Jenson, and A.I. El-Kadi, Estimating hydraulic properties from tidal attenuation in the Northern Guam Lens Aquifer, Territory of Guam, USA, (in preparation for submission to Hydrogeology Journal).

Problem and Research Objectives

Hydraulic parameters such as hydraulic conductivity and storage parameters are essential elements of models used to manage groundwater availability and quality. Uncertainty in these parameters can result in erroneous model estimates and potential mismanagement of drinking-water resources. The objective of this work is to estimate aquifer properties of the northern Guam aquifer.

A three-dimensional ground-water flow and transport model will be developed in a subsequent study to evaluate the availability of Guam's groundwater resources under several recharge and withdrawal scenarios. This study will identify hydrologic parameters to constrain numbers that can be used as input for this model.

Methodology

Tidal-signal attenuation is conveniently used to estimate hydraulic properties, such as hydraulic conductivity and storage parameters of coastal aquifers and to determine the distance of tidal influence into the aquifer (e.g., Rotzoll et al. 2008). Jacob (1950) provided a now classic analytical solution for water levels in a one-dimensional, homogeneous, isotropic, confined, and semi-infinite aquifer with a sharp boundary subject to oscillating forcing. Moreover, salinity time-series at discrete depths also are available to estimate aquifer properties (Presley 2010).

Principal Findings and Significance

Analyses of current and historical tidal-signal data in an array of wells widely distributed across the NGLA indicate that a lower-permeability limestone rim causes a significant tidal-damping effect at the boundary. Wells on the periphery consistently exhibit two orders of magnitude lower hydraulic conductivities than wells in the interior. For assigned specific yields of 0.01 to 0.1, hydraulic conductivity ranges from ~10 to 300 m/d for the former, and ~1,000 to 20,000 m/d for the latter. An argillaceous limestone unit exhibits intermediate conductivity.

The lower permeability of the peripheral rocks relative to the interior rocks may best be explained by the effects of karst evolution: (1) dissolutional enhancement of horizontal hydraulic conductivity in the interior; with (2) case-hardening and concurrent reduction of hydraulic conductivity in the cliffs and steeply inclined rocks of the periphery; and (3) the stronger influence of higher-conductivity regional-scale features in the interior relative to the periphery. The study demonstrates that applying simple techniques can be beneficial when characterizing regional aquifers.

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Long-term aspects of high-elevation rainfall and climate change, O'ahu

Basic Information

Title:	Long-term aspects of high-elevation rainfall and climate change, O'ahu
Project Number:	2011HI318B
Start Date:	3/1/2011
End Date:	2/28/2013
Funding Source:	104B
Congressional District:	HI-001
Research Category:	Climate and Hydrologic Processes
Focus Category:	Climatological Processes, Wetlands, Drought
Descriptors:	
Principal Investigators:	David Beilman

Publications

There are no publications.

Problem and Research Objectives

Climate and precipitation of the Hawaiian Islands is notoriously dynamic across geographic space (Giambelluca et al. 2011; Figure 1) and has long been recognized to vary over time with broad-scale atmospheric circulation (Chu 1995). Variation over time includes dynamics ranging from annual to decadal and longer, including ENSO- and PDO scale dynamics (Chu & Chen 2005). Mountain rain is the crucial component of groundwater recharge in Hawai'i (Giambelluca et al. 1993) and the ultimate source of water for the City and County of Honolulu. Water resource planning over the long term (several decades) requires a long-term understanding of the patterns and drivers of climate variation and change.

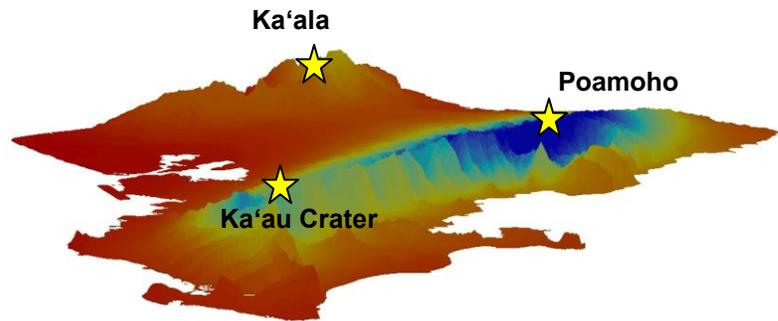


Figure 1. Three-dimensional rendering (base heights exaggerated) of O'ahu, Hawai'i viewed from the southeast showing our study sites. Coloring shows mean annual rainfall from 1978 to 2007 (Giambelluca et al. 2011).

In this study, we seek to better understand long-term patterns of rainfall by reconstructing from peat swamp sediments the long-term ecohydrological changes that have occurred at mountain sites on O'ahu. We have been focusing on three study sites laid out in our original proposal; Ka'au Crater, Poamoho Pond, and Mt. Ka'ala (Figure 1).

Methodology

We are employing two main lines of enquiry: 1) fossil pollen abundances reflecting changes in local vegetation over time and 2) stable isotope geochemistry of hydrogen, carbon, and nitrogen of bulk sediment and specific biomolecules (leaf waxes; *n*-alkanes). Owing to the considerable time investment needed to complete pollen analysis, fossil pollen work has concentrated on the last 8,000 years of sediments at Ka'au Crater. Stable isotope geochemistry work has also focused on Ka'au Crater sediments as the first priority (see principle findings). Sediments have been collected from Poamoho Pond (1m) and from Ka'ala (1.5m) and will also be included in geochemistry measurements.

The position of the water table is one of the critical links between rainfall/hydrology, plant growth and soil organic matter dynamics, and thus the accumulation of organic sediments and their geochemical character. In recognition of this importance, we added a

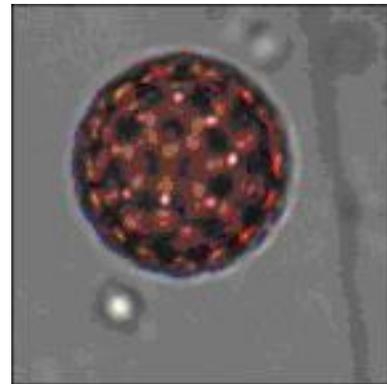


Figure 2. Light micrograph of a pollen grain of *Chenopodium* spp. (Hawaiian goosefoot) from Ka'au Crater sediments; an endemic dry-tolerant shrub which is found on all of the main Hawaiian Islands.

secondary component to this study to monitor the water table fluctuations with rainfall at Ka'au Crater and Poamoho Swamp. Water table loggers were installed at Ka'au Crater in July 2011 and at Poamoho in September 2011 (see principle findings).

Principal Findings and Significance

Fossil Pollen

Twelve samples from the Ka'au Crater sediment profile have been processed for fossil pollen analysis. This includes sieving together with acetolysis and hydrofluoric acid chemistry to remove material from the sediment, leaving the pollen unaffected, in order to identify pollen morphometrically using light microscopy. The pollen in six of the 12 levels has been drawn, photographed, described and counted, totaling over 1,000 grains and spores (Fig. 2). Pollen of approximately 34 different families of plants has been found thus far (Fig. 3). In total, more than 30 assemblages will be counted to show vegetation response over time to rainfall changes. Master's student Ms. Olivia Schubert is working on the pollen assemblages (see Student Support).

Stable isotope geochemistry

Nitrogen stable isotope values ($\delta^{15}\text{N}$) of bulk sediment from Ka'au Crater show surprisingly variable pattern over time, including enriched values in the oldest organic sediments (that have been subject to microbial decay for thousands of years) and those disturbed sediments at the surface. Additionally, a highly enriched departure is evident around 5000 years ago. Such an enrichment in ^{15}N is consistent with a greater degree of microbial processing of organic matter (trophic level enrichment of microbial biomass) and shows something other than just time or recent disturbance, and is consistent with a drop in water table around

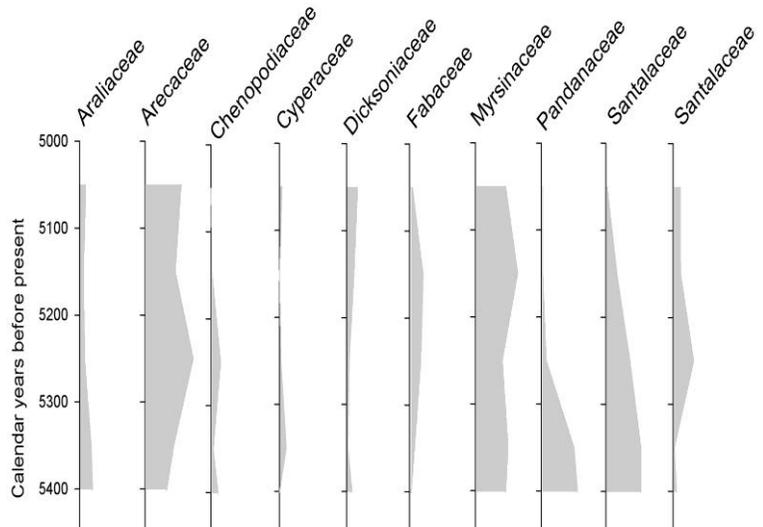


Figure 3. Selected fossil pollen abundance changes over time. Five levels dated between 5000 and 5500 years ago are shown for 10 of 34 different plant families, and indicate vegetation variability in the mountain environments of the southern Ko'oula, O'ahu.

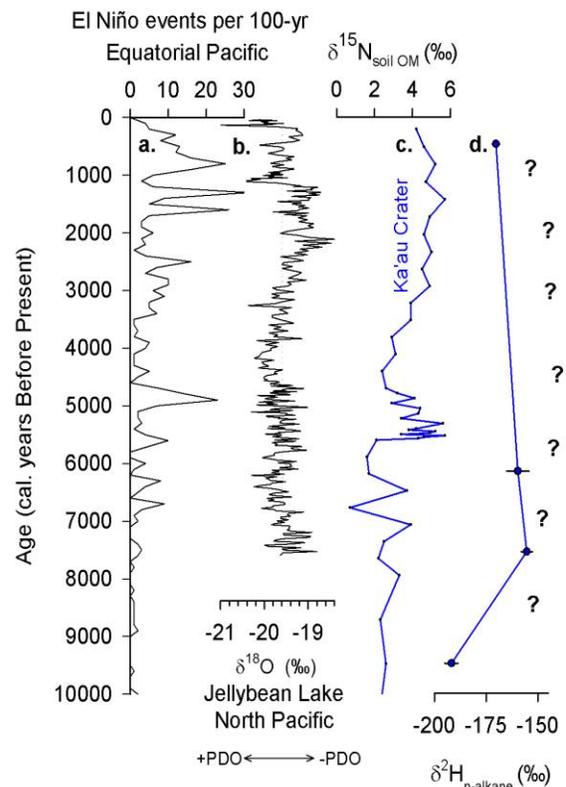


Figure 4. Long-term reconstructions of ENSO and PDO and isotope data from Ka'au Crater. **a.** El Niño events (Moy et al. 2002). **b.** PDO reconstruction (Anderson et al. 2005). **c.** $\delta^{15}\text{N}$ values of Ka'au Crater peatswamp sediment organic matter (OM). **d.** $\delta^2\text{H}$ values of leaf waxes from Ka'au Crater, which we are currently filling in at higher resolution. Note the dry anomaly (greater $\delta^{15}\text{N}_{\text{OM}}$) around 5,000 yrs ago.

5000 years ago, a period suggested by Uchikawa et al. (2010) to have had dominantly dry vegetation on O‘ahu’s leeward Ewa Plain, and during a period of prolonged negative-phase PDO and dominated by El Niño conditions (Fig. 4).

Our isotopic measurements of plant leaf waxes (*n*-alkanes) extracted from Ka‘au Crater sediments have yielded promising early results. *n*-alkane abundance has ranged from 234 $\mu\text{g g}^{-1}$ to below detectable limits for samples between 14 cm and 390 cm in the collected profile, with leaf wax composition (abundance of different chain lengths) and hydrogen isotope values surprisingly variable; ranging from -132 to -192 ‰ (Table 1). An overall depletion in mean $\delta^2\text{H}_{n\text{-alkane}}$ over the last 8000 years is consistent with an overall drying pattern over thousands of years, which is also suggested by Uchikawa et al. (2010) for leeward O‘ahu. Presently, we plan to extract and analyze leaf waxes at higher resolution to test the hypothesis that the overall drying of O‘ahu climate has been punctuated by multi-decadal or longer periods of drought (Fig. 4). Presently, we plan to extract total lipids in May 2012 and will run samples this summer in collaboration with the compound-specific stable isotope lab at the NASA Goddard Institute for Space Studies.

Table 1. Leaf wax abundance, chain length distribution, and mean $\delta^2\text{H}_{n\text{-alkane}}$ value of Ka‘au Crater sediments

Depth (cm)	Description	Total <i>n</i> -alkane ($\mu\text{g g}^{-1}$)	ACL (average chain length)	CPI (25-35)	Average $\delta^2\text{H}$ (\pm SD: ‰)
14-16	near-surface	100.8	27.8	12.6	-170.3 \pm 3.6
270-272	Approx. 6200 yr old	122.4	28.4	6.2	-159.7 \pm 10.7
308-310	Approx. 7500 yr old	233.9	29.3	5.5	-155.4 \pm 5.4
334-336	Approx 9200 yr old	86.8	23.4	1.6	-191.9 \pm 5.5
366-368	Approx. 12,000 yr old	22.10	24.8	1.5	
388-390	>12,000 yr old	11.51	27.7	4.3	-131.9 \pm 9.1

Rainfall and water table dynamics

At Ka‘au Crater and Poamoho Pond, basin water balance consists of inputs (rainfall, surface water, and groundwater) and outputs (evapotranspiration and runoff) that affect water table dynamics and processes that affect sedimentation as well as plant growth and soil decomposition. We observe that water table depth changes at Ka‘au Crater vary with rainfall changes (Figure 5), but also observe that prolonged rainfall does

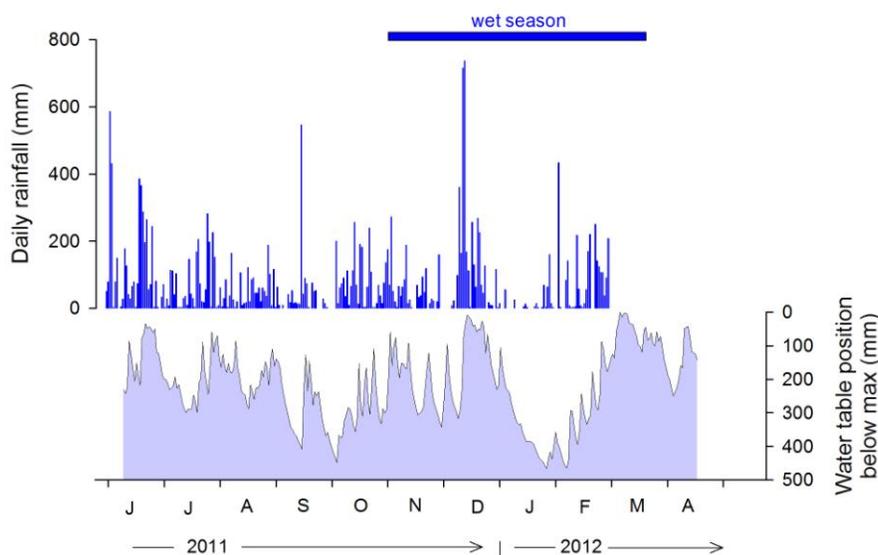


Figure 5. Rainfall in Palolo Valley (station GHCND:USC00517664) and changes in the position of the local water table in the center of the Ka‘au Crater peatwamp. The blue bar shows the duration of the wet season for the southern Ko‘olau Mountains showing the period of above-average daily precipitation, as defined and calculated by Grand and Gaidos (2010)

not result in storage (excess is lost to runoff) and that prolonged periods with little rainfall show a rapid response of water table drop (see Fig. 5; January and February 2012) rather than buffering from groundwater inputs or the water-holding capacity of the peatswamp. Water table dynamics (and the impact on ecohydrology and ecosystem processes) may be more sensitive to dry periods than wet periods. Continued monitoring over dry and wet seasons will help address the drivers of water table changes and impacts.

Future funding

Data, analysis, and hypotheses generated from this project were the seed for a subsequent proposal, which was submitted to the Pacific Islands Climate Change Cooperative and the Pacific Islands Climate Change Center on 2 April 2012 (\$267,107; status: pending).

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Development of an Advanced Surface Tensiometer for Measuring Water Quality

Basic Information

Title:	Development of an Advanced Surface Tensiometer for Measuring Water Quality
Project Number:	2011HI320B
Start Date:	3/1/2011
End Date:	2/28/2013
Funding Source:	104B
Congressional District:	HI-001
Research Category:	Water Quality
Focus Category:	Water Quantity, None, None
Descriptors:	
Principal Investigators:	Yi Zuo

Publications

There are no publications.

Problem and Research Objectives

Characterizing the physical, chemical and biological properties of potable and recreational waters plays a vital role in assessing and controlling water quality. Direct measurements of water quality mainly rely on (1) Physical assessment, such as pH, temperature, turbidity, and total dissolved solids; (2) Chemical assessment, such as salinity, dissolved oxygen, biochemical oxygen demand; and (3) Biological assessment, such as presence and abundance of microorganisms and insects. Due to the high costs associated with direct measurements of water quality, ongoing monitoring programs are typically conducted by government agencies. Hawai'i has more than 400 public beaches stretching along nearly 300 miles of Pacific Ocean coastline. According to the 20th annual beachwater quality report released by the Natural Resources Defense Council (NRDC) on July 28, 2010, pollution continues to contaminate the water at America's beaches, causing 2,352 closing and advisory days in Hawai'i last year and 18,682 nationwide. *Therefore, there is an urgent need, especially for Hawai'i, to develop an inexpensive, easy-to-use, and highly sensitive technique for measuring water quality.*

Surface tension of water is a physical property highly sensitive to contamination. A trace amount of pollutants (e.g., organic chemicals and microorganisms) can adsorb to the air-water interface, thus decreasing surface tension of pure water. *Therefore, surface tension measurement can be used as a novel and sensitive physical method to detect water quality.* Dynamic surface tension measurement has long been recognized as a means of evaluating water quality.¹ The adhesion and growth of marine bacteria have been found to depend on surface tension, and therefore, potentially have a direct impact on development of some diseases.² Compared to other physical, chemical, and biological methods for assessing water quality, surface tension is relatively easy to measure and hence may be a useful control parameter for water quality and water-reuse systems.²

The **objective** of this project was to develop an advanced surface tensiometer for measuring water quality. This method has the potential to be developed into a powerful screening tool for assessing water quality and other environmental impacts of water contaminants.

Methodology

The surface tensiometer is developed based on the principle of drop shape analysis.³ That is, in equilibrium, the shape of a drop or a bubble is determined by the balance between gravity, which tends to deform the drop (elongate a pendant drop or flatten a sessile drop), and surface tension force, which tends to hold the drop spherical. The force balance is determined by the Laplace equation of capillarity. If the shape of a drop or bubble is known (e.g., by photographing or videotaping), it is possible to determine surface tension by solving the Laplace equation. The drop shape analysis offers a number of advantages as it requires less liquid sample, is applicable to both air-liquid and liquid-liquid interfaces, and is versatile and applicable to various situations.

Specifically, the proposed surface tensiometer is called the constrained drop surfactometer (CDS). As shown in **Fig. 1**, the CDS uses a small sessile drop ($\sim 10\text{-}20\ \mu\text{L}$) to measure the surface tension of liquid sample. Any surface active pollutant, such as ocean surfactant, is expected to adsorb at the air-water of the sessile drop to decrease surface tension of pure water. The specific physicochemical properties of the pollutant can be further characterized by measuring its surface rheological properties, in which the adsorbed film will be compressed and expended by withdrawing liquid from and injecting liquid into the droplet using a motorized syringe. A key design of the CDS is a carefully machined drop holder which uses a sharp knife-edge to prevent the droplet from spreading even at very low surface tension (i.e., high surface pressure). In this case, the excess line energy of the sharp edge outweighs the weak surface tension in maintaining the integrity of the sessile drop. In addition, due to its compact design, the CDS allows accurate surface tension measurements with a controlled environment using a drop chamber.

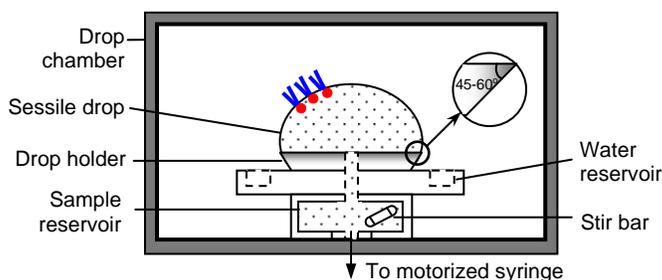


Figure 1. Schematic of the constrained drop surfactometer (CDS).

The surface tension of the liquid sample can be determined from the shape of the sessile drop using Axisymmetric Drop Shape Analysis (ADSA). ADSA is a patent-pending software package developed by the PI.⁴⁻⁶ ADSA features an optimized computational algorithm and an automatic image analysis scheme, thus permitting real-time and dynamic surface tension measurements.⁴ In addition to surface tension, ADSA simultaneously outputs surface area, drop volume, and curvature at the drop apex. All this information is valuable for characterizing properties of water samples. ADSA is superior to all existing commercial software packages in terms of rapid and highly accurate calculation, which is a key requirement for high-throughput screening. Meanwhile, ADSA features a user-friendly PC interface which allows surface tension measurement on one-click without the need of pre-training and knowledge of surface science. The applicability and accuracy of ADSA for measuring dynamic surface tension have been clearly demonstrated.⁴⁻⁶

Principal Findings and Significance

1. Prototype Development

During the past 12-month period, we successfully developed the prototype of the CDS. As shown in **Fig. 2**, the prototypes consist of three primary modules: the optical module, the liquid handling module, and the environmental control module. The optical module, which consists of a high resolution CMOS camera and a high-performance LED backlight, was developed with a separate grant. The liquid handling and the environmental control modules were developed in this project.

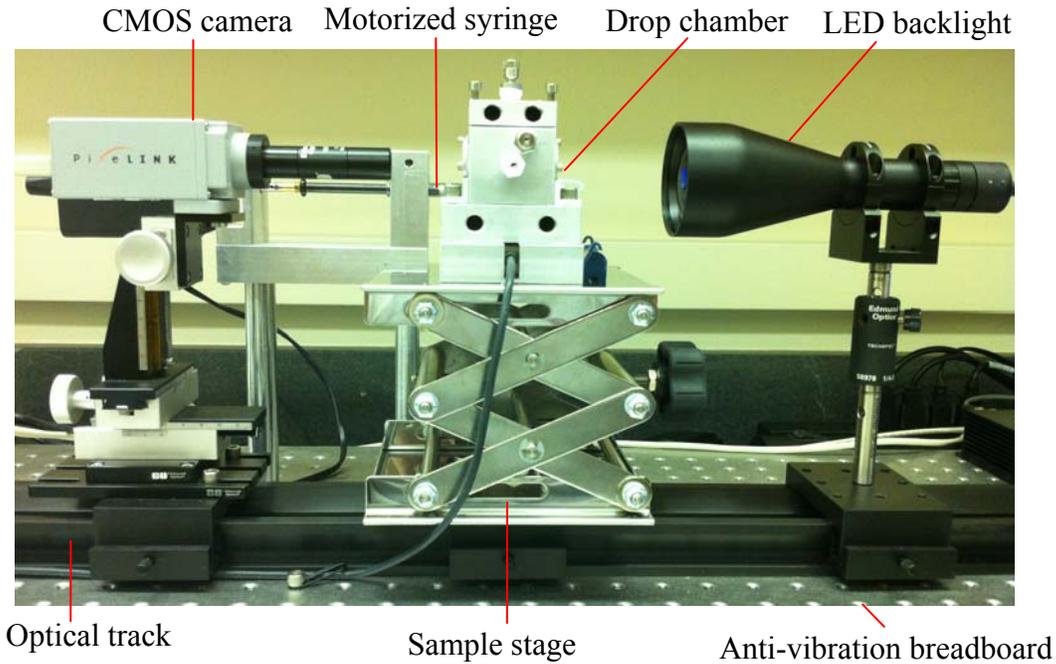


Figure 2. Prototype overview of the constrained drop surfactometer (CDS).

1.1. Liquid Handling Module

The liquid handling module was developed based on a motorized syringe. As shown in **Fig. 3**, the syringe (2.5 mL, Gastight, Hamilton) was controlled by a precision motorized actuator (LTA-HS, Newport, Irvine, CA). The motor has a resolution of 0.1 μm , a maximum travel distance of 50 mm and a maximum rate of 5 mm/s.

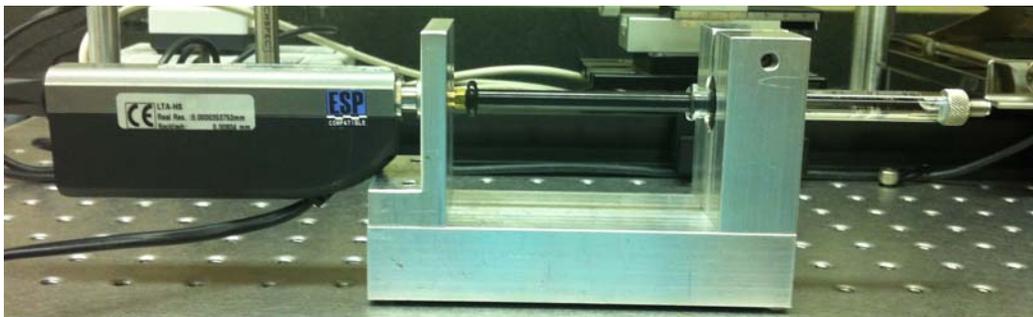


Figure 3. Motorized syringe.

We developed a LabVIEW program (**Fig. 4**) to precisely control movement of the motor, including the travel distance, rate, and fashion of movement (forward, backward, and cycling). This will allow us to automatically pump the liquid sample, form the droplet, and study the rheological properties of the liquid sample.

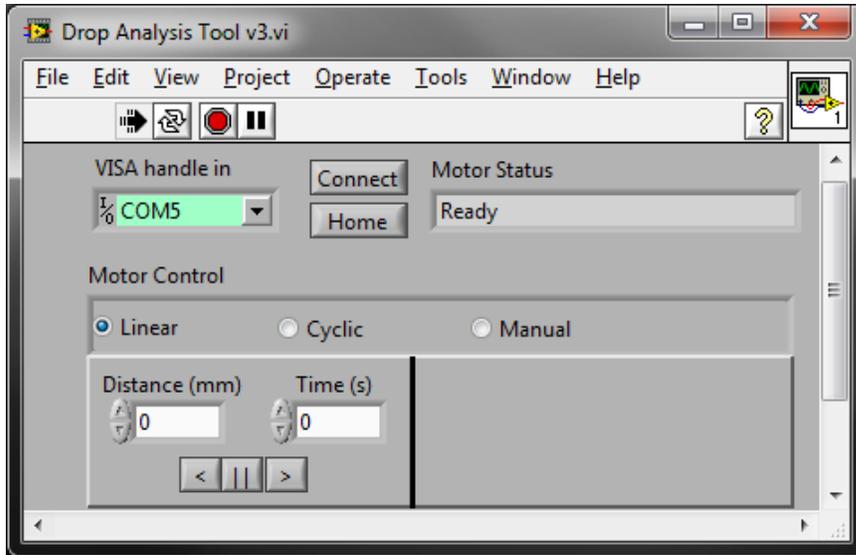


Figure 4. LabVIEW program to control the motorized syringe.

1.2. Environmental Control module

The environmental control module was developed based on a drop chamber (**Fig. 5**), designed and machined in the machine shop of the Department of Mechanical & Industrial Engineering at the University of Toronto. The temperature is controlled within ± 1 °C externally by a circulating water bath (4100R20, Fisher).

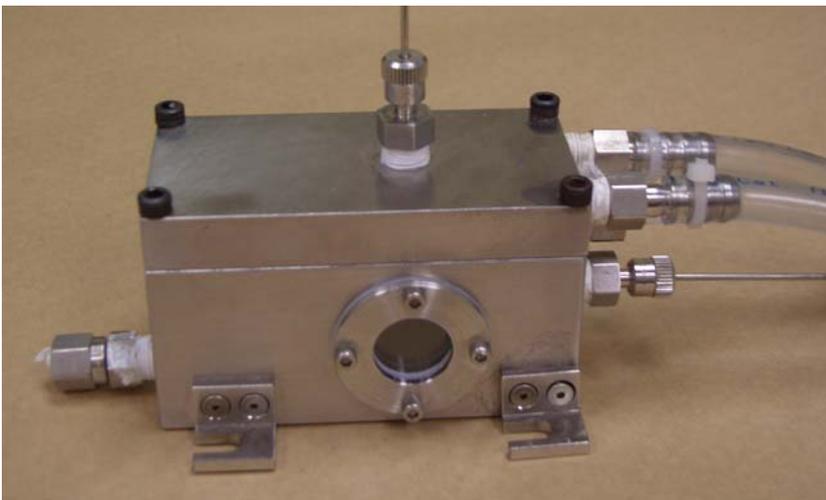


Figure 5. Drop chamber of the constrained drop surfactometer (CDS).

2. Test Results

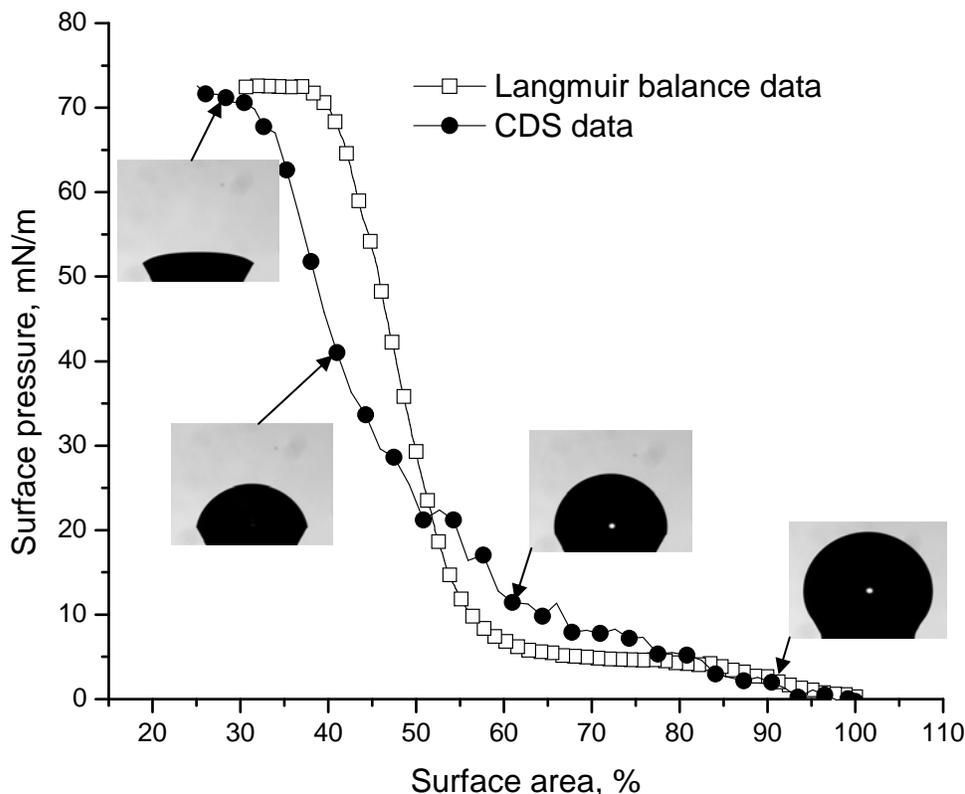


Figure 6. Surface pressure - surface area isotherms of DPPC monolayers measured with the CDS prototype and the Langmuir balance.

To test the CDS prototype, we measured the surface pressure - surface area isotherms of dipalmitoyl phosphatidylcholine (DPPC) monolayers at the room temperature. Surface pressure is defined to be the difference between the surface tension of pure water (~ 72 mN/m at room temperature) and the surface tension of film-covered (i.e., contaminated) water surface. Therefore, increasing surface pressure corresponds to decreasing surface tension. To verify our measurement, we compared the isotherm obtained from the CDS prototype to that obtained from the traditional Langmuir balance.⁷ As shown in **Fig. 6**, the isotherm measured by the CDS demonstrates a good agreement with that measured by the Langmuir balance.

The inserts in **Fig. 6** show the sessile drop at different surface pressures. One can see clearly that the sessile drop becomes flatter and flatter as increasing surface pressure (i.e., decreasing surface tension). These data demonstrate the feasibility of the CDS in measuring dynamic and very low surface tensions (i.e., very high surface pressures).

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Reshaping the Regulatory Framework for Hawaii Aquaculture - Water Quality Standards, Coastal Fishponds, and Shellfish Grounds

Basic Information

Title:	Reshaping the Regulatory Framework for Hawaii Aquaculture - Water Quality Standards, Coastal Fishponds, and Shellfish Grounds
Project Number:	2011HI323B
Start Date:	3/1/2011
End Date:	2/28/2013
Funding Source:	104B
Congressional District:	HI-001
Research Category:	Water Quality
Focus Category:	Water Quality, Law, Institutions, and Policy, Management and Planning
Descriptors:	
Principal Investigators:	David C. Penn

Publications

There are no publications.

Problem and Research Objectives

The goal of our seed grant project is to establish a broad-based, collaborative effort to promulgate new water quality regulations that will provide for greater community self-reliance in aquaculture production while sustaining environmental health. Due to personnel changes that were beyond our control, the timeline for achieving our four main objectives is now one year later than originally proposed:

- (1) identify the different types of water quality standards revisions that could be proposed, including a survey of the practices in other jurisdictions (March-June 2012);
- (2) document procedural roadmaps and scientific information needs for each type of revision identified (June-September, 2012);
- (3) analyze the potential for success in revising water quality standards for one or more coastal fishponds (September- November, 2012); and
- (4) estimate the resources needed to complete revisions on a wider scale (October-December 2012).

Methodology

We are conducting technically-based policy analyses utilizing all readily available scientific data and historical/contemporary regulatory information. We will use the results of these analyses to develop a comprehensive inventory of potential regulatory approaches and compliance practices. The suitability of these approaches and practices for local implementation will be assessed through participatory research with project collaborators and other interest groups.

Principal Findings and Significance

We initiated collaboration with the Pacific Aquaculture & Coastal Resources Center (PACRC), University of Hawaii at Hilo, which enabled us to identify the membership and strategic approach of the Hawaii Shellfish Working Group (HSWG). The HSWG includes representatives from Hui Malama Loko I'a (a consortium of thirty non-profit organizations focused on the restoration of fishponds originally built by native Hawaiians), the State of Hawaii Aquaculture Development Program, NOAA's Pacific Regional Aquaculture Program, shellfish producers and management consultants, and scientists from the University of Hawaii and Oregon State University. The PI joined the Hawaii Aquaculture & Aquaponics Association, which provides another avenue for connecting with potential collaborators and vetting our research results with the affected community.

During the last year, the U.S. Department of Agriculture evaluated state laboratories, trained state regulatory staff on sanitary surveys and growing area classification, and visited and sampled potential grow-out sites. *See* Department of Health (2011). The water quality sampling results indicated that several of the sites tested are suitable for USDA "conditional approval" of

commercial shellfish harvest. However, it is difficult for Hawaii to meet the federal operating requirements operating for conditionally-approved sites because the sanitation branch staff charged with the implementation of the state's shellfish sanitation program do not have the necessary law enforcement powers. If these enforcement issues are not resolved, it will become increasingly important to plan and develop relay procedures and depuration facilities for transporting shellfish from grow-out areas to "fully approved" harvest areas. Maria Haws, PACRC, personal communication, March 20, 2012.

Publications Cited in Synopsis

Department of Health, Statewide Classification Program for Shellfish Growing Areas, Report to the Twenty-Sixth Legislature, State of Hawaii, 2012 (2011). *Available at* [http://co.doh.hawaii.gov/sites/LegRpt/2012/Reports/1/Shellfish Growing Areas Report - FY 2011 _2_.pdf](http://co.doh.hawaii.gov/sites/LegRpt/2012/Reports/1/Shellfish%20Growing%20Areas%20Report%20-%20FY%202011%20_2_.pdf).

Addressing Sewage Contamination of Nawiliwili Streams and Kalapaki Beach

Basic Information

Title:	Addressing Sewage Contamination of Nawiliwili Streams and Kalapaki Beach
Project Number:	2011HI328B
Start Date:	3/1/2011
End Date:	2/28/2013
Funding Source:	104B
Congressional District:	1
Research Category:	Water Quality
Focus Category:	Water Quality, Surface Water, Non Point Pollution
Descriptors:	
Principal Investigators:	Marek Kirs, Joseph J. Lichwa, Philip Moravcik

Publications

There are no publications.

I. Problem and Research Objectives

Identification of the Problem. EPA requires every state to use EPA approved methods to assay water samples to determine whether the water used will meet drinking water or recreational water quality standards. When these water quality standards are exceeded, EPA directives conclude that the water samples are contaminated with sewage. However, previous studies conducted by Hawaii's Water Resources Research Center (WRRC) and confirmed by research microbiologists throughout the nation, have shown that the EPA standards results in data that are suggestive of but do not confirm the presence of sewage contamination. This problem is most apparent in Hawaii because of the islands tropical environment which is characterized by relatively warm temperatures and high humidity. These same conditions allow bacteria to grow more readily in tropical environments (e.g. soil) than in temperate environments. In this regard, studies conducted by WRRC have shown that the EPA fecal indicator bacteria (total coliform, *Escherichia coli*, enterococci), which are used to establish water quality standards, will grow naturally in the soil environments of Hawaii and are washed into all streams in Hawaii at concentrations that exceed EPA standards. The WRRC studies have concluded that the presence of fecal indicator bacteria in Hawaii's environmental waters is more likely due to soil contamination than sewage contamination. Additional studies by WRRC laboratories have shown that analyses of drinking and recreational water samples for other human sewage microorganisms called "alternative fecal indicators" such as *Clostridium perfringens*, a bacterium and coliphages or viruses that infect fecal bacteria provide more reliable data for determining the presence and absence of sewage contamination.

Dr. Roger Fujioka of WRRC completed a water quality research project for the Nawiliwili watershed on the island of Kauai where cesspools are extensively used. The conclusions of that study were as follows: 1) Many of the microbial water monitoring data obtained from the island of Kauai were similar to data previously obtained from the island of Oahu. 2) FIB (fecal coliforms, *E. coli*, enterococci) are naturally present in high concentrations in soil and represent a major environmental, non-sewage source of FIB. 3) Under ambient conditions, concentrations of FIB in streams routinely exceed current water quality standards and the predominating source of FIB is soil rather than sewage. 4) FIB are unreliable indicators of fecal contamination for streams and coastal waters receiving land based discharges on the islands of Kauai and Oahu. 5) Monitoring for F+ coliphages provided reliable data to detect subsurface contamination of streams by cesspool waste because the small size of these viruses enabled their movement through soil. 6) Although *Clostridium perfringens* was previously shown to be a good indicator of surface sources of sewage pollution on the island of Oahu, this fecal bacteria was not a good indicator for subsurface contamination of streams by cesspool waste because the large size of this bacterium prevented their movement through soil. 7) Identifying and genotyping FRNA coliphages recovered from environmental water samples provided additional data to show that human sewage was a source of contamination in the Nawiliwili watershed. 8) The detection of elevated levels of FRNA coliphages of human sources (genotypes II, III) in streams on Kauai indicate that these streams are contaminated with cesspool waste and are likely to be contaminated with human sewage-borne viruses.

Project Objectives. The first objective was to train the new WRRC microbiologist because Dr. R. Fujioka of WRRC retired in 2009 after completing 38 years of research for WRRC. Dr. Marek Kirs was recently hired to replace Dr. Fujioka. For this training objective, Dr. Fujioka participated in the training of Dr. Kirs in the use of established methods at WRRC and to introduce Dr. Kirs to the leaders of Hawaii's water agencies to include the Hawaii Department of

Health, the City and County of Honolulu, Environmental Services and the Honolulu Board of Water Supply. The second proposed research objectives were to confirm previous findings that Nawiliwili watershed is being contaminated by use of cesspools and whether this contamination compromises the quality of the water at Kalapaki Beach which is one of the most popular beaches on Kauai.

II. Methodology and Experimental Design

To implement the stated objectives of this study, the following experimental designs were completed: 1) Dr. Gayatri Vithanage, who completed the first WRRC study for the Nawiliwili watershed was hired as a post-doctoral researcher to complete most of the water quality assays. 2) Arrangements were made with the Hawaii State Department of Health (HDOH) to participate in this study. 3) Mr. Gary Ueunten of HDOH, who works on the island of Kauai was consulted to establish the sampling sites at the Nawiliwili Watershed (see Figure 1). An agreement was made with Gary Ueunten to collect water samples, to assay the quality of water for selected parameters (temperature, turbidity, pH, salinity) at the time of collection and to send the water samples from Kauai to Oahu. 4) Dr. Vithanage was assigned to pick up the water samples at the airport and proceeded to assay the samples within 6 hours of collection. 5) Dr. Fujioka supervised the training of Dr. Kirs and introduced Dr. Kirs to the all the leaders of the agencies (Hawaii Department of Health, City and County of Honolulu, Honolulu Board of Water Supply, Other researchers at the University of Hawaii as well as researchers from other universities. 6) After Dr. Kirs was sufficiently trained, he was authorized to become the Principle Investigator for this project and assumed responsibilities to implement the research objectives of this study, 7) Dr. Kirs completed the writing of this final report.

To implement the water monitoring design of this study, culture based methods were used to assay for *E. coli*, enterococci, *C. perfringens*, somatic coliphages and male (F+) coliphages. Selected subsamples were assayed for Human enteric viruses (enteroviruses, adenoviruses, noroviruses,) using molecular based method (PCR method).

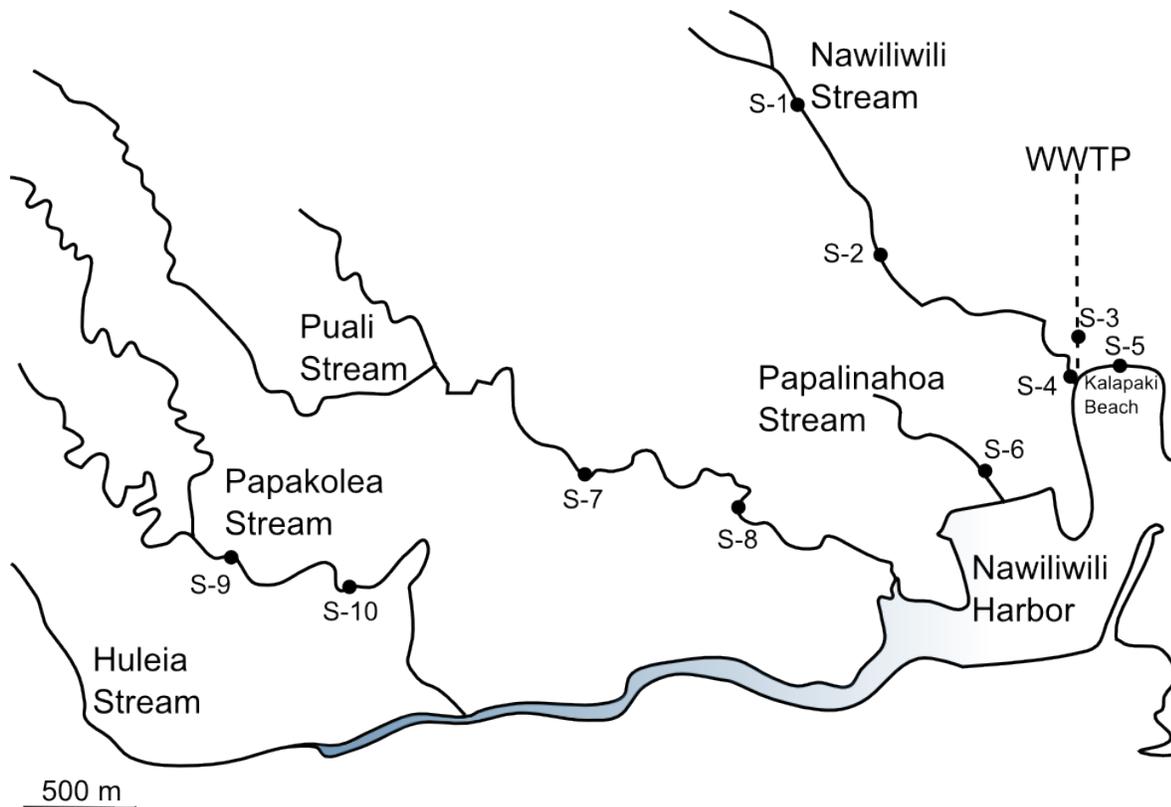


Figure 1. Nawiliwili watershed sample sites. S-1 Upper Nawiliwili Stream, S-2 Lower Nawiliwili Stream, S-3 Mariott Culvert, S-4 Pine Trees, S-5 Kalapaki Beach, S-6 Papalinahoa Stream, S-7 Upper Puai Stream, S-8 Lower Puai Stream, S-9 Upper Papakolea Stream, S-10 Lower Papakolea Stream.

A total of 117 water samples were collected by Mr Gary Ueunten (Kauai Branch of Hawaii State Department of Health) from ten sites at the Nawiliwili watershed and Kalapaki Beach located at the eastern section of Kauai Island (Fig. 1), as well as from one additional relatively pristine control site at the Lawai Stream located in the middle section of Kauai Island. Samples were collected roughly fortnightly from June to December 2011. After collection, samples were cooled on ice and shipped by air to the microbiology laboratory at the WRRC, University of Hawaii at Mānoa. All samples were analyzed within 6-9 hours after sample collection for fecal indicator bacteria (enterococci, *E. coli*) and alternative fecal indicators (*C. perfringens*, coliphages). During every second sampling, a subsample was provided for Dr. Yuanan Lu in the Department of Public Health Sciences laboratory at the University of Hawaii 'i at Mānoa for the analyses of noro- entero- and adenoviruses by polymerase chain reaction (PCR) method, a molecular assay that detects for the presence of specific gene of a microorganism but does not determine the infectivity of that microorganism. .

Concentrations of enterococci and *E. coli* were determined using USEPA approved membrane filtration based methods 1106.1 [1] and 1103.1 [2] respectively. In the case of enterococci, the samples were filtered through glass fiber filters (Pall Corporations, Ann Arbor, MI), the filters were placed on mE agar plates and incubated at 41°C for 48 h. After incubation the filters were transferred to pre-warmed EIA plates and incubated for an additional 20 minutes. Colonies with black or reddish brown precipitate on the underside of the membrane were counted as enterococci. In the case of *E. coli* the samples were filtered through glass fiber filters

(Pall Corporations, Ann Arbor, MI), filters were placed on mTEC agar plates and incubated first at 35°C for 2 h and then in a waterbath at 44.5°C for another 22-24 h. After incubation the membranes were transferred to absorbent pads saturated with Urea Substrate Medium for 15-20 minutes. Yellow, yellow-brown and yellow-green colonies were counted as *E. coli*.

Presence of human viruses (adeno-, entero- and noroviruses) was determined by Dr. Lu using endpoint polymerase chain reaction (PCR) technology and group specific primers. PCR products were visualized on agarose gel after electrophoresis. Appropriate negative and positive controls were used during each PCR run.

Water samples to assay for *C. perfringens* spores were pretreated by heating 100ml subsamples for 15 min at 60°C to kill the vegetative cells. Concentrations of *C. perfringens* were assayed for using the SFP media-based Fung double tube (FDT) test [3] during the initial sampling events. Due to the high background signal originating from other species of *Clostridia* in freshwater samples, the conventional mCP agar-based method [4] was used for the rest of samples. After incubation in an anaerobic chamber at 45°C for 24 h, the membranes were exposed to ammonium hydroxide fumes for 20 seconds and pink colonies were counted as *C. perfringens*. Concentrations of somatic and male (F⁺) specific coliphages were identified in 5ml sample portions using UEPA approved Method 1601 [5] using *E. coli* CN-13 and *E. coli* F_{amp} as hosts respectively. Negative samples were assayed by enrichment using 100 ml sample portions following day.

Somatic and F⁺ specific coliphages were quantified by assaying five ml sample portions by the double agar layer methodology as in Vithanage et al. [6] using *E.coli* CN13 and *E. coli* F_{amp} as hosts correspondingly. Samples which were negative by the quantitation assay were then assayed by the sensitive presence absence method by assaying 100ml water samples using the initial 24 h at 37°C enrichment method with tryptone broth and appropriate host. After the enrichment procedure, samples were centrifuged (10,000 g for 4 min) and ten µl of supernatant was spotted on fresh bacterial lawn prepared using double agar methodology. Formation of plaques on the lawns of the bacterial cells indicated the presence of coliphages in that tested water sample.

Concentration of total phosphorus (PO₄³⁻) was determined using acid persulfate digestion (method 8190) on a Chemical Oxygen Demand reactor (Hach, Loveland, CO). Temperature, pH, salinity and weather conditions were recorded in the field by HDOH staff.

III. Principal Findings and Significance

All freshwater sites, this includes all sites studied except Kalapaki beach (which was a marine site, salinity: 29 - 34 ppm), were characterized by high concentrations of conventional indicator bacteria (*E.coli* and enterococci) throughout the study period. Concentrations of *E. coli* varied from <4 to 7920 CFU per 100 ml with a geometric mean varying from 196 to 1260 CFU per 100ml between sites. Concentrations of enterococci varied from 41 to 6040 CFU per 100 ml with a geometric mean varying from 76 to 1928 CFU per 100 ml between sites, hence concentrations of indicator bacteria were elevated, except for the marine site (S-5 Kalapaki Beach) where concentrations of enterococci were relatively low (4-26 CFU per 100 ml, with a geometric mean of 9 CFU per 100ml) (Table 1). These results are comparable to the earlier study by Vithanage et al. [6], and confirmed again that cesspools and the freshwater streams were the major source for all fecal microbial indicators. The comparative concentrations of these fecal microbial indicators were relatively lower at the harbor sites where the salinity indicated a mixture of freshwater and marine waters. The concentrations of all microbial indicators were

much lower at Kalapaki Beach which was characterized as a marine water based on high salinity and being contaminated with low volumes of fresh stream waters.

Current Hawaii recreational freshwater water quality standards are based on enterococci and state explicitly that no sample should exceed 89 CFU of enterococci per 100ml and the geometric mean of samples collected over 25-30 days should not exceed 33 CFU of enterococci per 100 ml [7]. All samples collected, including the control sample from the pristine environment, exceeded the standard based on the geometric mean throughout the study period. The standard based on the single sample maximum was also exceeded in all freshwater samples, except for one sample collected from Puali Stream and three out of four samples collected at the pristine control site (Lawai Stream). These findings collectively indicate that **current water quality standards are not suitable for Hawaii due to high environmental background of indicator bacteria**, ergo have little relevance to the actual health risk posed by recreational exposure to these waters.

Current Hawaii recreational marine water quality standards are based on enterococci and state explicitly that no sample should exceed 104 CFU of enterococci per 100ml and the geometric mean of samples collected over 25-30 days should not exceed 35 CFU of enterococci per 100 ml [7]. Samples collected at the Kalapaki Beach did not exceed the standards during the study.

Tests for human enteric viruses were conducted at five sites (S-2, S-3, S-4, S-6, S-8, and S-10) only (Table 2). Human norovirus genogroup 1, genogroup 2, enteroviruses, and adenoviruses were detected at all sites, except the norovirus genogroup 2 which was not detected at site S-4 and S-10 (Table 2). While human adenoviruses were detected in all samples tested, PCR signal (group specific DNA fragment) from other groups was inconsistent indicating fluctuating levels of sewage input. It is not clear whether the PCR signal originated from viable viruses and what the associated health risk is, although detection of molecular signal originating from human viruses is a clear indication that **human sewage, likely from adjacent cesspools, is reaching the watershed.**

C. perfringens concentrations were low during the study at all sites. No sample exceeded 50 CFU per 100 ml limit, except for one sample collected at Papalinaloa Stream after wet weather. No spores of *C. perfringens* were found at the marine site (Kalapaki Beach). *C. perfringens* concentrations were low likely due to the prevailing dry weather, although the relatively large size of the spores compared to pathogenic viruses can further hamper transport of this bacterium through the soils [6]. While obligate anaerobe *C. perfringens* is a solid indicator of sewage contamination, the viral contamination component might remain undetected using bacterial targets and **monitoring for bacterial and viral indicators simultaneously is warranted.** This is in agreement with earlier studies which indicate that current bacteriological water quality standards do not reflect viral contamination component [8].

Concentrations of somatic coliphages (geometric mean 2-289 PFU per 100ml) were comparable to estimates made in an earlier study [6] with the highest concentrations detected at the Papalinaloa Stream and Pine Tree site (2620 PFU and 2680 PFU per 100ml respectively). Also somatic coliphages were more frequently recovered and at higher concentrations compared male (F⁺) specific coliphages. Somatic coliphages have been proposed as indicators of fecal contamination as they are removed during treatment processes at comparable rates to enteroviruses as well as appear to exhibit similar seasonal variation [9, 10]. Due to their high concentrations in sewage, stability and because they are viruses, somatic coliphages have potential as indicators of fecal contamination, including virus contamination. Furthermore, while

possible replication of somatic coliphages in the environment has been indicated in earlier studies [11, 12], most recent studies have been suggesting that the replication in the natural environment is very unlikely [13, 14]. The results of this study show that the monitoring for somatic coliphages could indicate presence of fecal contamination in the watershed and support PCR based findings for presence of human enteric viruses.

Male (F⁺) specific coliphages were detected in the watershed at lower levels (geometric mean 1-11 PFU per 100 ml) when compared to earlier report [6]. These phages were detected also at low frequency, with only 30% of the samples analyzed being positive for this phage group. These coliphages cannot replicate in the environment as F⁺ pili are not formed below 25°C [15] and therefore, in theory, they could also be good indicators of fecal contamination (animal and/or human). It should be noted that only a small percentage of humans and animals carry this group of phages, hence a leaking cesspool from a single family household or input from a small population of animals could remain undetected. Since male (F⁺) specific coliphages are similar in size to human enteric viruses and smaller than somatic coliphages (25-30 nm vs. (25)80-400 nm) these viruses have been proposed as more specific to human enteric viruses and can be expected to be transported through the soil column. However, recent studies have indicated that they can be accumulated over 100 times more in clayey sediments [16] because the hydrophobic protein coat [17, 18] of these viruses may be favorable for the adsorption to clay particles. In this regard, soils in Hawaii are known to contain high levels of clay. This property of male (F⁺) specific coliphages may prevent these viruses from being easily transported through soils with high clay contents and may explain the lower detection levels of these viruses in the Nawiliwili watershed. In summary, the concentrations of certain groups of male (F⁺) specific coliphages in environmental waters are believed to be more specific indicator for human sewage than somatic coliphages. However, a recognized limitation in monitoring for male (F⁺) coliphages is their lower numbers as compared to somatic coliphages.

A significance of this project was the introduction of Dr. Kirs to many collaborators to include Mr. Joseph Lichwa and Mr. Philip Moravcik of WRRC, University of Hawaii at Mānoa. Also with Dr. Yuanan Lu (Department of Public Health Sciences, University of Hawaii at Mānoa). In addition Dr. Kirs was introduced to Mr. Watson Okubo (Section Chief, Clean Water Branch, HDOH), Mr. Ross Tanimoto (Deputy Director, Department of Environmental Services, CCH), Mr. Ken Tenno (Laboratory Director, Lab. Branch, Department of Environmental Services, CCH) and Mr. Owen Narikawa of Honolulu Board of Water Supply. As a result Dr. Kirs have discussed future collaborative projects with these scientists. Finally, USEPA recently reported that they will continue to use the same recreational water quality standards based on monitoring for standard FIB for the next five years (2012 to 2017). WRRC has already determined that these EPA standards are not reliable in Hawaii and other tropical climates because these FIB can grow in soil environments. One solution proposed by USEPA is to initiate microbial source tracking (MST) methods to confirm for the presence and absence of human sewage versus animal wastes. The need for verification of the usefulness of MST methods is greater in tropical environments such as Hawaii than in other US states. Therefore a new proposal seeking to evaluate current and alternative indicator bacteria using microbial source tracking tools was submitted for funding under the WRIP program for 2012-2013.

Table 1. Nawiliwili watershed sampling sites and their geometric means of *E. coli*, enterococci and alternative indicators at each site.

Site	<i>E. coli</i> CFU/100 ml	Enterococci CFU/ 100ml	<i>C. perfringens</i> CFU/100 ml	Somatic coliphages PFU/100 ml	Male (F ⁺) coliphages PFU/100 ml
S-1	286 (4-1560)	255 (120-480)	3 (<1-25)	32 (<1-240)	2 (<1-40)
S-2	1151 (640-2040)	900 (480-1880)	4 (<1-30)	108 (20-440)	8 (<1-260)
S-3	239 (<4-7280)	780(284-2880)	4 (<1-15)	123 (20-1040)	7 (<1-160)
S-4	409 (<4-1440)	520 (256-1040)	4 (<1-10)	272 (80-2680)	11 (<1-260)
S-5	7 (<4-106)	9 (4-26)	3 (<1-15)	2 (<1-40)	1 (<1)
S-6	1050 (144-7920)	1928 (1000-3640)	6 (<1-56)	289 (<1-2620)	2 (<1-500)
S-7	475 (92-5440)	204 (88-480)	2 (<1-25)	87 (20-800)	2 (<1-140)
S-8	1260 (560-3920)	1113 (332-6040)	4 (<1-15)	78 (<1-800)	1 (<1-20)
S-9	352 (40-1120)	348 (128-2040)	3 (<1-35)	214 (60-600)	11 (<1-140)
S-10	741 (280-5600)	524 (240-1040)	4 (<1-15)	101 (<1-360)	4 (<1-40)
Lawai Stream (Control)	196 (99-305)	76 (41-140)	1 (<1-2)	18 (<1-140)	9 (<1-260)

Table 2. Detection of human enteric viruses in the Nawiliwili watershed (number of positive samples / number of samples tested).

Site	Noroviruses Genogroup I	Noroviruses Genogroup II	Enteroviruses	Adenoviruses
S-2	2/3	1/3	3/3	3/3
S-3	3/3	1/3	2/3	3/3
S-4	2/3	0/3	2/3	3/3
S-6	3/3	1/3	3/3	3/3
S-8	3/3	1/3	3/3	3/3
S-10	2/3	0/3	1/3	3/3

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Information Transfer Program Introduction

Introduction to Information Transfer Program

Hawaii and other Pacific Islands face a unique set of environmental and cultural issues in the management of water resources. Fresh water resources are under threat on many islands both from overuse and contamination. In Hawaii most of our surface waters are not much utilized because of their small size, intermittent flow and ecological sensitivity. As such we are extremely dependent on groundwater. Groundwater resources are inherently more difficult to quantify and evaluate than surface water. We can only surmise subterranean conditions. The models we have are fairly crude instruments. Despite many years of study, to a large extent we still have not characterized the hydrogeology of our islands. Even sophisticated models fail to paint an accurate picture of the complex situation that exists. In the face of this uncertainty there are increasing demands being made upon this difficult to quantify resource. We can only be sure that with increasing withdrawals and reduction and alteration of recharge areas there will be some negative impact on our drinking water assets. Quantifying this impact is problematic.

As population and income grows, and consumer preferences turn toward greater water use, pressure on island water resources grows even more. It becomes ever more critical that those agencies tasked with protecting and managing water resources have accurate, up to date information about their condition to make as sound decisions as possible. The mission of the Water Resources Research Center is to study all aspects of water in the islands and to communicate our findings to agencies responsible for water management.

Our direct audience includes the State Health Department, the State Department of Land and Natural Resources, the county water supply boards, as well as national regulatory and planning agencies. Furthermore as decision makers are strongly influenced by popular opinion, we try to educate the general public about water issues. A good deal of misinformation circulates about water resources, much of it generated by persons or groups advancing self-interested agendas. In order for our research to fulfill its potential to assist in water management it is important for the results to reach the people who can use it. That is the goal of the technology transfer effort at our Center.

In 2011 in recognition of the similarity of problems facing islands in water management we undertook to organize a conference in collaboration with all of the directors of the other island centers in the NIWR network; Guam, Puerto Rico, and the U.S. Virgin Islands. This conference was held Nov. 14-16 in Honolulu and was well attended by people from around the Pacific, the United States, and other island states.

Technology Transfer

Basic Information

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Principal Investigators:	Philip Moravcik

Publications

1. Moravcik, Philip, 2011, WRRRC Bulletin, 8/26/11 2 pages
2. Moravcik, Philip, 2011, WRRRC Bulletin,9/16/11 3 pages
3. Moravcik, Philip, 2011, WRRRC Bulletin,10/21/2011 4 pages
4. Moravcik, Philip, 2011, WRRRC Bulletin,1/20/12 4 pages

Hawaii and other Pacific Islands face a unique set of environmental and cultural issues in the management of water resources. Fresh water resources are under threat on many islands both from overuse and contamination. In Hawaii most of our surface waters are not much utilized because of their small size, intermittent flow and ecological sensitivity. As such we are extremely dependent on groundwater. Groundwater resources are inherently more difficult to quantify and evaluate than surface water. We can only surmise subterranean conditions. The models we have are fairly crude instruments. Despite many years of study, to a large extent we still have not characterized the hydrogeology of our islands. Even sophisticated models fail to paint an accurate picture of the complex situation that exists. In the face of this uncertainty there are increasing demands being made upon this difficult-to-quantify-resource. We can only be sure that with increasing withdrawals and reduction and alteration of recharge areas there will be some negative impact on our drinking water assets. Quantifying this impact is problematic.

As population and income grows, and consumer preferences turn toward greater water use, pressure on island water resources grows even more. It becomes ever more critical that those agencies tasked with protecting and managing water resources have accurate, up to date information about their condition to make as sound decisions as possible. The mission of the Water Resources Research Center is to study all aspects of water in the islands and to communicate our findings to agencies responsible for water management.

Our direct audience includes the State Health Department, the State Department of Land and Natural Resources, the county water supply boards, as well as national regulatory and planning agencies. Furthermore as decision makers are strongly influenced by popular opinion, we try to educate the general public about water issues. A good deal of misinformation circulates about water resources, much of it generated by persons or groups advancing self-interested agendas. In order for our research to fulfill its potential to assist in water management it is important for the results to reach the people who can use it. That is the goal of the technology transfer effort at our Center.

Technology Transfer

Technology Problem and Research Objectives

The mandate of the Water Resources Research Center (WRRC) includes an obligation to broadly disseminate the results of its research activities to audiences of local water and wastewater agencies, environmental engineering consultants, other academic researchers, and interested members of the public.

Methodology

The Technology Transfer Office employs a range of media to disseminate the results of research done at the Center. WRRC bulletins; other publications; web site; workshops, meetings, and conferences; and regular biweekly seminars all served to aid the center in transferring to its multiple audiences timely and critical information concerning water-resource research and issues.

Technology Transfer Program

WRRC's Technology Transfer Program activities for the report period included: organization of multiple seminars; production of project bulletins and newsletters; participation in meetings and conferences; and providing water-resources-research information to consultants, students of all levels, and the general public. The program PI also participated in classroom presentations, school science fairs, WRRC research projects, research report writing, and refinement and updating of the center's web site. During this reporting period the Technology Transfer Program produced four newsletters describing research projects and center activities and news. Extensive use was made of the center's large-format printer/plotter, producing posters for display at local, national, and international meetings and conferences. Several of these posters, illustrating the work of graduate student researchers, won awards at meetings. As it has done for more than twenty years the Technology Transfer Program continues to organize biweekly seminars designed to foster communication among WRRC researchers, students, and the organizational target audience of government agencies, private-sector researchers, and members of the general public with an interest in water-resource issues. Each semester one WRRC faculty member is appointed to organize the seminars with the assistance of the Technology Transfer office, 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 on emerging water-related issues. The seminars are generally well attended and provide one of the few public forums in the state for the discussion of water issues. The following is a list of the twenty-one seminars presented during the reporting period.

Spring Semester 2011

Feb. 4, 2011	<i>Effects of rainfall variability and groundwater pumping on streamflow in upper Mākaha valley, Oahu</i>	Alan Mair, Postdoctoral Fellow, University of Hawaii Geology & Geophysics & WRRC
Feb. 25, 2011	<i>Subsurface Colloidal Fines and their Role in Groundwater Contamination</i>	Dr. Tushar Kanti Sen, Lecturer in Chemical Engineering at Curtin University, Perth, Western Australia
Jul. 12, 2011	<i>Spatial & Temporal Modeling Using Artificial Intelligence/Pattern Recognition Technique (An Emerging Approach</i>	Debasmita Misra, Associate Professor Geological Engineering, University of Alaska Fairbanks

Fall Semester 2011, Seminar Coordinator: Dr. Roger Fujioka

Sept. 1, 2011	<i>Development of New Recreational Water Quality Criteria: Current Directions</i>	John E. Ravenscroft, Jr. (USEPA, Office of Water of Science and Technology, Washington, DC) <i>(Doak and Richard Cox WRRC Invited Speaker)</i>
Sept. 15, 2011	<i>Clean Water Act; Compliance and Frustration</i>	Ross Tanimoto (Deputy Director, City and County of Honolulu, Environmental Services)
Sept. 29, 2011	<i>Best Health Practices for Koi Dealers and Importers – A Tale of Woe or a Rising Phoenix?</i>	Dr. Tim Miller-Morgan, College of Veterinary Medicine, Laboratory Animal Veterinarian for Aquatics, and Aquatic Section Head at the Veterinary Diagnostic Laboratory - Oregon State Univ., Corvallis, OR.
Oct. 6, 2011	<i>Where Science and Public Policy Collide – Water Quality Standards and the Department of Health.</i>	Gary Gill, Deputy Director of the State of Hawaii Department of Health
Oct. 11, 2011	<i>Assessing Vulnerability of Groundwater Systems to Contamination: Geochemical & Modeling Approaches</i>	Frank Chapelle, USGS Research Hydrologist from South Carolina
Oct. 20, 2011	<i>Pathogenic Vibrios: Prevalence, Public Health Significance and the Lack of Water Quality Standards</i>	Dr. Gayatri Vithanage, Post-Doctoral Researcher, Water Resources Research Center, University of Hawaii
Nov 3, 2011	<i>Human Enteric Viruses – An Alternative Indicator for Recreational Water Quality Monitoring?</i>	Yuanan Lu, PhD, Professor, Director of Environmental Health Laboratory, Dept. of Public Health Sciences, University of Hawaii
Nov. 10, 2011	<i>Science, Economics, and Policy of the Department of Land and Natural Resources' Watershed Protection and Restoration Initiative</i>	Guy Kaulukukui, Ph.D, Hawaii DLNR First Deputy and Emma Yuen, DLNR Planner
Nov. 17, 2011	<i>Leptospirosis in Hawaii, 1999-2008</i>	Alan Katz, MD, MPH, Professor and Graduate Chair, Dept. of Public Health Sciences, University of Hawaii
Dec. 1, 2011	<i>Microbial Source Tracking (MST), a New Technological Approach to Measure for Sources and Risks of Fecal Contamination</i>	Marek Kirs, PhD, University of Hawaii, WRRC
Dec. 13, 2011	<i>Investigating Water Flow and Solute Transport in Soil by Non-Invasive Visualization Methods</i>	Michal Snehota, Czech Technical University, Prague, Czech Republic

Spring Semester 2012, Seminar Coordinator: Dr. Roger Babcock

Feb. 1, 2012	<i>Green Roof Technology: Opportunities and Barriers for Hawaii</i>	Andy Kaufman, ASLA, MLA, Ph.D. Associate Prof./Landscape Specialist, Dept. of Tropical Plant and Soil Sciences, College of Tropical Ag & Human Resources, University of Hawaii at Manoa
Feb. 15, 2012	<i>Green Roofs</i>	Mark Ambler (Weston Solutions)
Feb. 22, 2012	<i>A Strategy for Accelerating the Development of Hydrological Models: Societal Needs, Observational Requirements and Public Communication</i>	Jay Famiglietti, Birdsall-Dreiss Distinguished Lecturer, UC Center for Hydrologic Modeling , Department of Earth System Science, University of California, Irvine
Feb. 23, 2012	<i>Physical Controls of Soil Moisture Across Space and Time Scales – Current Understanding and Future Opportunities!</i>	Binayak P Mohanty, Ph.D., Professor (Focus: Soil Hydrology) Biological and Agricultural Engineering Texas A&M University, College Station, TX
Mar. 7, 2012	<i>Digging a Little Deeper – Designing Green Roofs</i>	Dawn Easterday, ASLA, GRP, LEED AP Senior Landscape Architect, Belt Collins Hawaii LLC
Mar. 14, 2012	<i>Can Interdisciplinary Centers work? The University of Minnesota Institute on the Environment as Object Lesson</i>	Dr. Deborah L. Swackhamer, Professor, Hubert H. Humphrey School of Public Affairs, U. of Minn.; Co-Director, Minnesota Water Resources Center; Professor, Environmental Health Sciences, U. of Minn.
Mar. 21, 2012	<i>The Landscape Inventory, cross-disciplinary uses of a mapping project for water resource management on campus</i>	Austin Stankus, University of Hawaii Department of Zoology
Apr. 4, 2012	<i>Turfgrass Management</i>	Jordan K. Abe, Superintendent - Ala Wai Golf Course, Dept. of Enterprise Services
Apr. 18, 2012	<i>Exploring subsurface fluid flow and solute transport by HYDRUS 1, 2/3D</i>	Seo Jin Ki, Researcher, Water Resources Research Center, University of Hawaii
May 2, 2012	<i>Halo-respiration, a natural process</i>	Paige Novak, Professor of Civil and Environmental Engineering, University of Minnesota

WRRC Website

The Center's website (www.wrrc.hawaii.edu) is continually updated with new information about WRRC researchers' activities, seminars, reports, meetings, grant announcements, scholarship opportunities, etc. The site provides information about center facilities and personnel as well as a database of WRRC publications. A search function provides easy access to the available information. There is a link on the Center's home page that leads to an archive of full-text PDF files of reports written by WRRC researchers since the early days of the Center. This permits extremely easy access to our reports for our clientele. Following a decision by our past director WRRC no longer publishes reports in-house and our researchers submit their reports as articles directly to journals which generally restrict access to these articles. WRRC continues to post the abstracts and publication information about these articles on our website.

Conference

The Water Center organized a conference on November 14 – 16, 2011 at the Ala Moana Hotel in Honolulu in cooperation with the NIWR Water Centers in the Virgin Islands, Puerto Rico, and Guam on the general theme of water and wastewater sustainability issues in island environments. The conference was entitled “Water Resource Sustainability Issues on Tropical Islands” and was attended by around 150 people from around the world. The ITTO office participated in the planning, arranging the facilities, and otherwise making the conference possible.

Poster Production

The Technology Transfer Program PI assisted numerous center faculty and graduate research assistants in the design and production of posters illustrating research projects for display at meetings and conferences. Several graduate-research-assistant posters were recognized by conference awards during the reporting period. Media Contact During the reporting period the Technology Transfer project P.I. responded on several occasions to inquiries from reporters about water and environmental issues. In addition the Technology Transfer Office submitted news releases regarding the research activities of Center faculty to local and national media through the University of Hawaii's media office.

Legislative Testimony

During the reporting period the Technology Transfer project P.I. submitted testimony at the State legislature on several issues pertaining to water and wastewater issues

Media Contact

During the reporting period the Technology Transfer project P.I. provided interviews for local periodicals on issues pertaining to water and center projects.

Island Director's workshop/conference

Basic Information

Title:	Island Director's workshop/conference
Project Number:	2011HI330B
Start Date:	3/1/2011
End Date:	2/28/2013
Funding Source:	104B
Congressional District:	1
Research Category:	Not Applicable
Focus Category:	None, None, None
Descriptors:	
Principal Investigators:	Chittaranjan Ray, Philip Moravcik

Publications

There are no publications.

Problem and Research Objectives

Island states are faced with a unique set of environmental and cultural issues pertinent to the management of water resources. Fresh water resources are under threat on many islands from both overuse and contamination. Ocean waters in these tropical regions are ecologically sensitive and valuable, and similarly threatened by overuse and pollution. On some islands, climate-induced sea level rise and associated increases in storm surge magnitude are degrading groundwater resources. Many island states have been experiencing climate-change based alterations of precipitation patterns resulting in floods and droughts. Sustainable management and protection of island water supplies is even more critical than it is on the continents, as island communities have no recourse to importation in the event of a failure of their water supplies. Island states are heavily dependent on imports such as food, fuel, and manufactured goods to satisfy their resource needs. On most of these islands, population growth is putting increasing pressure on water resources. It is imperative that these threats to the welfare of island communities be addressed by sound scientific research before they reach crisis proportions. Those tasked with resource protection and management need access to scientifically sound research that is specific to island environments.

The above issues are universal to island states yet researchers in these far-flung and isolated places seldom have opportunity to share knowledge and experience with one another. They work largely in isolation. The great distances that separate most island states from larger centers of academia and government means that there is less frequent exchange between the islands' researchers and their colleagues in the major population centers. It is believed that enhanced communication and collaboration between island researchers can provide a vital, synergistic link, which will strengthen all the researchers programs. It is true that the greatest scientific advances usually result from the collaboration of groups of researchers working together.

There are four island-based research centers within the NIWR consortium: Water Resources Research Center (WRRC) in Honolulu, Water and Environmental Research Institute (WERI) of the Western Pacific in Mangilao, Puerto Rico Water Resources and Environmental Research Institute (WRERI) in Mayaguez, and Virgin Islands Water Resources Research Institute (WRRI) in St. Thomas. Each Center addresses similar issues within its region and yet communication between the Centers is infrequent and difficult due to physical and temporal distance. In addition to the four US Centers, there are other water research institutes on non-US islands, such as Samoa, Fiji, Tonga, and Palau, which face similar water problems and issues.

We proposed to organize an intensive three-day meeting of the directors and other faculty members from the island research centers, both US and non-US, in Honolulu as an opportunity to share information about research we are conducting, research needs that we perceive, and collaboration in future research that will address common problems and issues. Grant monies we used to invite recognized experts in water research fields pertinent to the issues faced by island states.

Methodology

The workshop was hosted by the University of Hawai'i at the Ala Moana Hotel in Honolulu and was attended by about 150 participants. Hawai'i's WRRC was the primary sponsor and the water centers from Guam, Puerto Rico, and US Virgin Islands were co-sponsors. The program was covered in 2.5 days. A field trip was organized in the last day after the end of the sessions. A book of abstracts was prepared for distribution at the conference. The staff at WRRC prepared the necessary informational materials and handled conference logistics. Details about the program, speakers, conference organization, and others information can be found in the web site:

<https://sites.google.com/site/wrrconference2011/>

The following committees planned and actively managed the conference.

Regional Organizing Committee

Dr. Chittaranjan Ray

Interim Director, Water Resources Research Center, University of Hawai‘i at Mānoa

Dr. Gary Denton

Director, Water and Environmental Research Institute of the Western Pacific, Guam

Dr. Jorge Rivera-Santos

Director, Puerto Rico Water Resources and Environmental Research Institute

Dr. Henry H. Smith

Director, Virgin Islands Water Resources Research Institute

Local Organizing Committee

Conference Chair

Dr. Aly El-Kadi

Associate Director, Water Resources Research Center, and Professor, Department of Geology and Geophysics, University of Hawai‘i at Mānoa

Conference Co-Chairs

Dr. Roger Fujioka

Former Director, Water Resources Research Center, University of Hawai‘i at Mānoa

Philip Moravcik

Technology Transfer Specialist, Water Resources Research Center, University of Hawai‘i at Mānoa

Dr. Tetsuzan Benny Ron

UH Aquaculture Program Coordinator (OVCRGE) and Affiliate Faculty, Water Resources Research Center, University of Hawai‘i at Mānoa

Technical Advisory Committee

Dr. Roger Babcock

Associate Professor, Civil and Environmental Engineering and Associate Researcher, Water Resources Research Center, University of Hawai‘i at Mānoa

Dr. Clark Liu

Professor, Civil and Environmental Engineering and Researcher, Water Resources Research Center, University of Hawai‘i at Mānoa

Dr. Delwyn Oki

Hydrologist, US Geological Survey, Pacific Islands Water Science Center, Honolulu, Hawai‘i

Dr. Kolja Rotzoll

US Geological Survey, Pacific Islands Water Science Center, Honolulu, Hawai‘i

Keynote Speakers were Gary Gill, who spoke on "Role of Hawai‘i’s Department of Health in Water Protection as a Sustainable Resource", and Takashi Asano, who spoke on "The Role of Water Reuse in Water Resources Management", and Jennifer Orme-Zavaleta, who spoke on "Building a Research Program to Ensure Safe and Sustainable Water Resources". The respective titles and affiliations were, Deputy Director for the Environment, Hawai‘i Department of Health, Professor Emeritus, University of California at Davis, and Interim National Program Director, Safe and Sustainable Water Resources Program, US Environmental Protection Agency.

The following is the full list of talks presented at the conference (invited presenters are marked by *).

Session 1. Wastewater

1. *Wojciech M. Jadwisienczak, The Current and Future Developments in Deep UV Solid State Technology for Water Purification
2. Douglas R. Tait, Dirk V. Erlen, Andrew Dakers, Leigh Davidson and Badley D. Eyre, The ecoTrench: A Low Cost, Low Technology On-Site Treatment System for Removing Nutrient in South Pacific Nations
3. Jessie Liu, Noémi D'Ozouville, Josselin Guyot-Tephany and Delio Sarango, Water Management and Practices: Fecal Contamination of Household Water and Health Outcomes in Santa Cruz Island, Galápagos
4. Mohammad H. Golabi and Manuel Duguies, Vetiver Grass System (VGS)—A Green and Low Cost Technology for Small Island's Waste Water Treatment Needs
5. Marek Kirs and Roger S. Fujioka, Application of Microbial Source Tracking Technologies in Recreational Waters Can Reliably Identify Risk from Sewage-Borne Pathogens in Tropical Regions
6. Robert M. Kerns, Lt. Lyle Setwyn, and Danielle Mauga, Bacteriological Contamination of Wells in American Samoa
7. Ginamary Negrón-Talavera and Luis A. Ríos-Hernández, Monitoring the Population Dynamics of Enterococci in Recreational Waters: A 24 Hour Odyssey

Session 2. Flooding

1. *Edward Teixeira, Impact of Disasters in Hawai'i on Surface Water Systems
2. Paul Hinds and Vincent Cooper, Development of a Surface Runoff Prediction Model for Unplanned Hillside Developments in Trinidad
3. Russell Yost, Aly El-Kadi and John Yanagida, A Water Resources Win-Win Scenario: Capturing Flood Waters from the Kaiaka-Waialua Watershed, North Shore, Oahu
4. Scot K. Izuka, Suspended-Sediment Transport in the Waikele Watershed, O'ahu, Hawai'i, During the Storm of December 11, 2008
5. Walter F. Silva-Araya and Federico García-Urbe, Modeling Mixed Flow Conditions in Surcharged Storm Systems

Session 3. Climate

1. *Thomas W. Giambelluca, Qi Chen, Abby G. Frazier, Jon P. Price, Yi-Leng Chen, Pao-Shin Chu and Jon K. Eischeid, Introducing the New Rainfall Atlas of Hawai'i
2. *Richard J. Wallsgrove, Maxine A. Burkett and David Penn, Hawai'i's Law & Policy Toolkit: Climate Change Adaptation and Water Resource Management
3. *Melissa L. Finucane, Integrating Physical and Social Sciences to Support Decision Making about Fresh Water Resources on Pacific Islands
4. *Mark Chappell, Potential Saline-Sodic Pedogenesis in Soils from Climate-Change Mediated Sea-Level Rise
5. H. Annamalai, The Current and Future Climate Conditions Over the Pacific Islands
6. Mark A. Lander, The Post World War II Observations of Climate in Micronesia: Sea Level Rise, Temperature Increases and Drying in the East
7. Pao-Shin Chu, Ying Ruan Chen and Thomas A. Schroeder, Trends in Precipitation Extremes and Return Levels in the Hawaiian Islands Under a Changing Climate

8. Steven R. Fassnacht, Sharla A. Stevenson and Graham Sexstone, Climate Change Near Kaloko-Honokohau National Historical Park and Implications for Water Resources Management

Session 4. Water Resources Availability and Management

1. *J. Sansalone, G. Ying and G. Garofalo, Myths, Models and Measurement of Particle Transport and Fate
2. Chester Lao, Role of Deep Monitor Wells in Island Hydrology
3. Delwyn S. Oki, Trends in Groundwater Availability in Hawai‘i
4. Lauren C. Roth Venu, Ecological Engineering: Building Sustainable Island Communities with Nature in Mind
5. Kolja Rotzoll and Aly El-Kadi, Numerical Simulation of Borehole Flow in Deep Monitor Wells in a Coastal Freshwater Lens, Pearl Harbor Aquifer, O‘ahu, Hawai‘i
6. Ryan T. Bailey and John W. Jenson, Analysis of Groundwater Resources of Atolls in the Federated States of Micronesia
7. *Martin Roush, The Path to Guam Waterworks Authority Overarching Sustainability: Building Leadership Capacity
8. Papacostas, Evolution of Island Water Rights in Hawai‘i
9. Juan C. Santamarta Cerezal and Jesica Rodriguez Martín, Advances in Exploitation of Underground Water Resources in Volcanic Islands Experiences and Methods in the Canary Islands, Spain, Europe
10. Shahram Khosrowpanah, The Impact of Guam’s Population Growth on Island Water Resources
11. James Roumasset and Christopher Wada, Planning for the Integrated Use of Groundwater, Recycled Wastewater, and Desalination
12. Shane Epting, Hawaiian Mythology and the Benefits of an Ecological Noble Lie: Water Resource Management, Sustainability, and the Curse of Pele

Session 5. Panel Discussion

1. *L. Stephen Lau, Learning About the Natural Waters in Humid Tropical Islands for Sustainable Communities Objectives
2. Travis W. Hylton, Guam Water Resources Management Study

Session 6. Groundwater Recharge

1. Adam G. Johnson, Water-Budget Model and Estimates of Groundwater Recharge for Guam
2. John W. Jenson, Mark A. Lander and Richard H. Randall, Vadose Fast Flow in the Northern Guam Lens Aquifer, Guam, Mariana Islands
3. Steve Parabolicoli, The County of Maui’s Water Reuse Program: A Key Component of Sustainable Water Resource Management in an Island Environment

Session 7. Surface Water Quality

1. John C. Hayes and Billy J. Barfield, Modeling Runoff, Sediment and Water Quality Practices in an Island Environment Using the model IDEAL
2. Shiang-Min-Chen, Yu-Min Wang and I Tsou, Using Artificial Neural Network Approach for Modeling Rainfall-Runoff

Session 8. Water for Energy

1. *Jan C. War, Economic Development Opportunities for Tropical Islands at the Natural Energy Laboratory of Hawai‘i Authority

2. Keith R. Olson, Historical Perspective of Environmental Monitoring at the Natural Energy Laboratory Hawai'i Authority
3. Shahram Khosrowpanah and Leroy Heitz, Predicting Hydropower Potential on Ungaged Streams in Kosrae Island, the Federated States of Micronesia
4. Deborah A. Solis, Scott Moncrief, Luis Vega, Philip A. Potter, Renee Kinchla, Tom Cook, Meghan Travers and Antti Koskelo, Assessing Hydroelectric Power Potential in the State of Hawai'i

Session 9. Submarine Groundwater Discharge

1. Christine A. Waters, Henrieta Dulaiova and Craig R. Glenn, Locating and Quantifying Coastal Groundwater Discharges Potentially Originating from a Wastewater Treatment Facility
2. Daniel Amato, Submarine Groundwater Discharge Increases Marine Macroalgal Photosynthesis
3. Jacque L. Kelly, Craig R. Glenn and Paul G. Lucey, Use of Thermal Infrared to Locate and Study Submarine Groundwater Discharge in the Hawaiian Islands
4. M. Bayani Cardenas, Peter B. Zamora, Kevin M. Befus, Fernando P. Siringan, Dirk V. Erler, Isaac R. Santos, Douglas Tait, Raymond S. Rodolfo and Mark R. Lopus, Off-Shore Electrical Resistivity Imaging for Multi-Scale Characterization of Near Shore Hydrogeologic Processes and Submarine Groundwater Discharge
5. Kevin M. Befus, M. Bayani Cardenas, Travis E. Swanson, Dirk Erler, Isaac Santos and Douglas Tait, Fluid and Heat Fluxes Across the Intertidal Zone
6. Joseph J. Kennedy, Craig R. Glenn and Henrieta Dulaiova, Evaluation of Anthropogenic Impacts on the Groundwater Flow from Two Coastal Springs, Maunalua Bay, South Shore, O'ahu

Session 10. Groundwater Quality

1. Alan Mair, Robert B. Whittier, Aly I. El-Kadi and Daniel Chang, Adapting Drinking Water Source Vulnerability Assessments for the Hawaiian Islands
2. Gary R.W. Denton and Carmen M. Sian-Denton, A Retrospective Analysis of Water Quality Data for Chemicals of Concern in Guam's Groundwater: Emerging Trends and Future Concerns
3. Joseph Fackrell and Craig R. Glenn, Geochemical Composition of Ground and Nearshore Marine Waters at Ka'anapali, Maui, Hawai'i

Poster presentations are listed below.

1. L. Stephen Lau and John F. Mink, Hydrology of the Hawaiian Islands
2. Joseph P. Morris, Alex Anderson, Wojciech M. Jadwisienczak and R. Guy Riefler, Water Disinfection of *Bacillus subtilis* Spores Using Ultraviolet Light Emitting Diodes
3. Alan Mair, Benjamin Hagedorn, Suzanne Tillery, Aly I. El-Kadi, Kyoochul Ha and Gi Won Koh, Estimating Groundwater Recharge Using a Water Balance Approach for Jeju Island, Korea
4. Brittany Anderson and Jiasong Fang, Assessing Effects of Environmental and Human Land Use Change in a Coastal Wetland Using Lipid Biomarkers and Stable Isotopes
5. Joseph D. Rouse, Goro Kobayashi and Hiroaki Fujii, High-Rate Biological Treatment Coupled with Sludge Reduction
6. Peter B. Zamora, M. Bayani Cardenas, Raymond S. Rodolfo, Hillel B. Cabria, Kevin M. Befus and Ma. Isabel Senal, Tidal
7. Response of the Subterranean Estuary Revealed by Electrical Resistivity Imaging and Hydraulic Monitoring

8. Juan C. Santamarta Cerezal and Jesica Rodriguez Martín, Traditional Systems for Water Harvesting and Soil Conservation in Volcanic Islands. Case Study: The Canary Islands, Spain, Europe
9. Yoko Yamamoto, Sharon LePage, Barbara McLain, Carlos Andrade and Tetsuzan Benny Ron, Sustainability Isn't A New Idea: Teaching Ancient Hawaiian Ahupua'a Using Virtual Reality
10. Seo Jin Ki, Bunnie S. Yoneyama, Philip Moravcik and Chittaranjan Ray, Use of Self-Organizing Map as an Advanced Bioassessment Tool: Assessment of Effect of Submarine Wastewater Outfall on Benthic Fauna Communities in Sand Island, Oahu
11. Vance Tomasu, Alvina Lutu, Toru Kumagai and David Hafner, University of Hawai'i Mānoa Drainage Project
12. Yu-Chieh Lin, Yu-Min Wang and I Tsou, Using ANN Approach to Recover the Missing Flow Records by the Data of Adjacent Stations in the Same Catchment
13. Seydou Traore and Yu-Min Wang, GIS Dot Density Mapping Interface for Analyzing Soil Water Holding Capacity Change Due to Organic Matter Amendment in Western African Regions
14. T.M. Gregg, J. Burns, A. Mokiau-Lee, K. Carlson and T. Takabayashi, The Effects of Community Structure and Water Quality on Coral Affliction Prevalence and Severity Around Hawai'i Island
15. Mara F. Cuebas-Irizarry, Valeria Semidei-Rodríguez, Ginamary Negrón-Talavera and Luis A. Ríos-Hernández, The Dominant Population of Enterococci in Puerto Rico's Waterways
16. Yasson Duque-Amaya and Jorge Rivera-Santos, Headwater Zone Delineation Using GIS: A Decision Making Tool for Sustainable Water Resources Management
17. Headquarters, Pacific Air Forces and Headquarters, Thirteenth Air Force, Joint Base Pearl Harbor-Hickam, Hawai'i: Operations PACIFIC ANGEL and PACIFIC UNITY

Principal Findings and Significance

The conference emphasized that the issue of sustainability is especially critical for islands due to resource limitation and water vulnerability to contamination. The ever-increasing and competing demands include water supply to urban and rural communities, tourist facilities, industry, and farm animals. Additional non-consumptive uses include hydropower generation, navigation, and recreation. Further, alternative energy sources, such as bio-energy, have added more strain on water resources. Demands are multiplying due to population growth and urbanization. In some cases, water supplies are unable to deliver water on a 24-hour basis due to high leakage and sometimes wastage. Issues related to the coordinated management of surface water and groundwater are of prime importance. Water resources are particularly sensitive to climate change due to islands' particular nature. Water scarcity and vulnerability to drought, flooding, and other natural disasters considerably increase as island size decreases. Major factors affecting water resources include physical island characteristics, such as size and topography, climate, and human impact. Climate change can lead to further degradation of water quality, which is already a major problem in many islands. Contamination originates from point and non-point sources. Pollution sources include discharges of untreated or partially treated wastewater and animals farms, inadequate solid waste disposal sites, agricultural chemicals, leakage of petroleum products and toxic chemicals, sediment erosion, and saltwater intrusion. The small size and steep slopes of catchments on high islands enable water and pollutants to move quickly to downstream areas. The highly permeable soils and shallow water tables on small coral islands facilitate the rapid migration of pollutants to the subsurface. The reversal of these negative impacts is difficult and time consuming. Pollution affects human health due to microbiological contamination and elevated chemical levels in water supplies.

High turbidity and suspended solids are experienced by consumers after periods of heavy rainfall. The effectiveness of water supply intakes and treatment systems is compromised by high-suspended sediment loads, leading to higher costs of providing clean, safe water supplies. Sedimentation in water supply reservoirs and rivers lead to disturbances in upstream catchments. Finally, sediments, bacteria, and chemicals are negatively affecting riverine and coastal environments. The conference presentations, addressing the issues outlined above, are grouped in sessions covering wastewater, flooding, climate, water supply and management, groundwater recharge, surface water and groundwater quality, water for energy, and submarine water discharge. Although most of the presentations are related to tropical islands, some method-oriented presentations were included that could be applied to these islands as well.

USGS Summer Intern Program

None.

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

Notable Awards and Achievements

Publications from Prior Years