



A Brief Overview of Research Conducted at Hawai'i's Water Resources Research Center (1964-2013)

The Water Resources Research Center draws upon the expertise of the University faculty to conduct research that addresses to the problems and concerns of water and wastewater management in Hawai'i and the Pacific. The purpose of this document is to familiarize the reader with the long, varied, and extremely productive history of research at the Center.

Establishment of the Water Resources Research Center:

In 1964 the US Congress, realizing that water shortages were a looming issue for the country, reasoned that it would be useful to bring to bear the resources of the nation's universities to help address the problem. To facilitate this Congress passed, and President Lyndon B. Johnson signed, the Water Resources Research Act (WRRRA) of 1964 (Public Law 88- 379, 17 July 1964).

Johnson described the act in the following public statement:

"The Water Resources Research Act of 1964, which I have approved today, fills a vital need. Abundant, good water is essential to continued economic growth and progress. The Congress has found that we have entered a period in which acute water shortages are hampering our industries, our agriculture, our recreation, and our individual health and happiness. Assuming a continuation of current practices, by the year 2000 there will not be enough usable water to meet the water requirements of parts of the states of Arizona, California, Colorado, Delaware, Idaho, Illinois, Indiana, Iowa, Kansas, Louisiana, Michigan, Minnesota, Montana, Nebraska, Nevada, New Jersey, New Mexico, New York, North Dakota, Ohio, Oklahoma, Oregon, Pennsylvania, South Dakota, Texas, Utah, Wisconsin and Wyoming. This legislation will help us solve this problem. It will create local centers of water research. It will enlist the intellectual power of universities and research institutes in a nationwide effort to conserve and utilize our water resources for the common benefit. The new centers will be concerned with municipal and regional, as well as with national water problems. Their ready accessibility to state and local officials will permit each problem to be attacked on an individual basis..."



Congress' forward thinking in passing the WRRRA paved the way for university researchers to help mitigate the effects of our diminishing water resources in many ways. The program's early focus on water shortages has broadened to include all aspects of water in the United States. The WRRRA established a network of centers at land-grant universities in each state, Guam/FSM, Puerto Rico, the US Virgin Islands and the District of Columbia. The WRRRA has been amended several times since 1964 but the centers' primary mission continues to be to conduct research on regional water-related issues.

In 1964, UH Professors Doak C. Cox (Geology) and L. Stephen Lau (Engineering) proposed the establishment of the University of Hawai'i Water Resources Research Center (WRRC). In September that year, the UH Board of Regents formally established the Center as an "organized research unit". Cox and Lau were appointed director and associate director, respectively. A memorandum of agreement dated 7 May 1965 designated WRRC as Hawai'i's node in the national network and state funds were allocated to the Center.

Over more than four decades of effort WRRC has produced a wealth of research results and more than 500 reports and peer-reviewed publications. The research

conducted at WRRRC has been extremely broad and varied in scope. Most of the Center's research has been directed at addressing the evolving needs and problems of the local agencies responsible for managing Hawai'i's waters. WRRRC has helped these agencies respond to water-related crises, such as the discovery of chemical contamination in Oahu's potable wells in 1983, flooding of Manoa Stream in 2004, and the Ala Wai Canal sewage spill of 2006. The agencies concerned turned to WRRRC for guidance and scientific perspective in responding. The Center has also served local agencies by helping them comply with federal mandates related to pollution monitoring and reduction. Agencies historically served by the Center include the state Department of Land and Natural Resources, the City of Honolulu's Department of Environmental Services, the Honolulu Board of Water Supply, drinking water utilities on other islands, and the state Departments of Health, Transportation, and Agriculture. In addition to the sponsorship of Hawai'i-based agencies, the Center scientists have received many grants from federal agencies such as the National Science Foundation, the US Environmental Protection Agency, the US Geological Survey, and the US Department of Agriculture.

The center promotes cooperation among academic disciplines concerned with water issues and facilitates the transfer of research results to policy bodies and operational agencies. WRRRC also promotes advanced education in water-related disciplines through the involvement of students and early career faculty in research projects. Many WRRRC alumni have gone on to become leaders in the agencies that manage water resources in the State and beyond. At the time of preparing this document, the Manager and Chief Engineer of the Honolulu Board of Water Supply, and the Hydrologic Program Manager at the State Commission on Water Resource Management are WRRRC alumni. Other alumni currently occupy

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important positions at local, national, and international environmental consulting firms. The Center administers a small federally-funded grant-making program which supports regionally relevant research projects that involve the participation of many students.

How WRRRC Has Met Hawai'i's Water Research Needs Since 1964

The following describes some of the research categories on which WRRRC has focused significant efforts, and to which it has made important contributions. The breadth of the scope of the research described reflects the comprehensive nature and responsiveness of the research that has been conducted at WRRRC.

WRRRC Research Focus #1 - Groundwater Characterization Assessment and Modeling: >80 Studies

Around 1880, vast quantities of excellent quality groundwater were discovered on the island of Oahu. Groundwater soon became the principal source on the island; today providing more than 98% of the municipal supply. Oahu's abundant groundwater made intensive agriculture possible in the past and makes it possible for the island to support large populations of residents and tourists today. The other Hawai'ian Islands are not blessed with as much groundwater as Oahu; however, it is a critically important resource on all islands and as such has been the focus of much attention and study at WRRRC. The emphasis on water supply implied in the WRRRC was also a key in setting the Center's early focus on groundwater studies.

WRRRC scientists have contributed greatly to the body of groundwater data in Hawai'i through monitoring activities over the years. WRRRC efforts have included the establishment of deep monitoring stations in the Pearl Harbor aquifer, evaluation of seismic, electromagnetic and radio sounding techniques, tracing studies, remote sensing of coastal spring discharges, tritium analysis, geophysical analysis, tidal analysis, and pumping tests.

The difficulties inherent in characterizing the subterranean environment and groundwater resources in Hawai'i are obvious. Empirical observation is only possible at a limited number of points (wells, springs, seeps). Hydrologists have developed a



Monitoring a production well in South Kona

variety of modeling techniques to help understand and quantify what is occurring in the subsurface; how water moves, how it interacts with surface water, how it is affected by tides, and how much is available for us to use. Such models are necessarily extremely simplified versions of the very complex real conditions, with many assumptions being necessary. Despite this limitation, modeling is a principal tool that managers turn to in making decisions on water policy. WRRC hydrologists have conducted many modeling studies from the Center's earliest days. Models developed at the Center have been especially derived to address Hawai'i's unique hydrogeology and the water management issues that stem from it and have been extensively used by the State and Counties in their planning.

WRRC Research Focus #2 - Groundwater Contamination, Drinking Water Supply Protection >65 Studies

WRRC researchers have conducted numerous projects focusing on the protection of groundwater from contamination. Indeed almost all of the studies by Center researchers that concern wastewater reuse, non-point source pollution, chemical contamination, streams and lakes, etc., have the underlying objective of protecting drinking water sources as well as meeting federal regulations. For example, the 1996 amendments to the federal Safe Drinking Water Act (SDWA) required states to develop and implement source water assessment programs (SWAP) aimed at protecting sources of public water supply from contamination the Health Department turned to WRRC

researchers to conduct the research to develop this program for Hawai'i.

Many WRRC research projects have been concerned

with protecting groundwater from contamination more indirectly. Until recently, a large part of Hawai'i's land was used for agriculture. Center scientists have conducted much research on assessing the threat posed by various agricultural chemicals to groundwater. Studies have examined the transport of pesticides and endocrine disruptors in wastewater irrigation. When pesticides (DBCP, EDB) used by pineapple growers were discovered in production wells on Oahu WRRC, researchers embarked on a project that involved deep boring, laboratory testing,

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Installing lysimeters for pesticide leaching study in Kunia

and predictive-transport modeling funded by special appropriations from the Hawai'i State legislature, the Office of Environmental Quality Control, and the Department of Health. Modeling studies were conducted at the Center to predict the transport of these contaminants over the long term. When the Honolulu Board of Water Supply deployed activated

carbon contactors to remove these chemicals from drinking water, they encountered problems with early breakthrough and exhaustion of the carbon. WRRC researchers rose to the challenge of optimizing the operation of these systems, including identifying ways to extend the useful life of the carbon. WRRC researchers examine the potential for new agricultural chemicals to leach to groundwater prior to being approved for use in the state. Other studies have assessed the threat that landfill leachate and fuel/chemical spills pose to groundwater supplies so that these threats can be mitigated.

WRRC Research Focus #3 – Recreational/Microbial Water Quality, Microbial Methods: >40 Studies

Today, Hawai'i's economy depends primarily on tourism. A critically important factor in attracting tourists to Hawai'i, and in maintaining the lifestyle enjoyed by residents, is the safety of our recreational waters – our beaches. The federal Clean Water Act sets out national bacterial standards for recreational waters based on studies of the incidence of illness among swimmers at beaches on the US mainland done in the 1970s. Monitoring indicates that beach water in Hawai'i sometimes exceeds the EPA



Sampling ocean water for microbial analysis, Kailua

standards despite there being no apparent sources of sewage. Research conducted by scientists at WRRC revealed that the standard bacteria in fact grow and reproduce in soil under the tropical conditions found in Hawai'i even in the absence of sewage. This discovery suggested that federally-mandated standards (promulgated to protect swimmers' health) were not applicable in our state. This significant finding led state regulators to adopt other, more appropriate indicators of fecal pollution such as the bacterium *Clostridium perfringens*. The impact of the research conducted at WRRC extended to other states, first in other tropical places—Guam, Puerto Rico, South Florida, and later in temperate regions—California and the Great Lakes, where it was found that the prescribed indicators did not reflect sewage contamination either. WRRC researchers have emerged as national leaders in this avenue of research, and have been strong advocates for the adoption of better standards. The initial findings in Hawai'i have led other scientists to conduct many subsequent studies examining the prevalence of indicator organisms in the environment and their appropriateness as indicators of sewage contamination in recreational waters.

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WRRC Research Focus #4 - Wastewater Treatment Technology >50 Studies

Every day Oahu's sanitary sewer system collects, treats and disposes of about 105 million gallons of sewage. Wastewater utilities on Hawai'i's other islands perform the same functions there. Ever-tightening federal regulation of effluent quality has meant that the wastewater utilities in the state have had to continually work to improve their treatment systems to stay in compliance with the tighter standards.

As the population grows, it becomes more important to ensure that the greater quantities of sewage generated



Sampling sewage effluent at the Honouliuli

are adequately treated. WRRC scientists and engineers have done extensive research to help with this effort. There are some unique challenges to sewage treatment in Hawai'i. The sewage collection system in Honolulu experiences inflow of seawater near the coast which affects the performance of biological treatment, there are many individual household systems that are unregulated and often poorly constructed/maintained, landfill space to receive solids/sludge is limited, use of disinfectants can damage delicate reef ecosystems near the discharge pipes, small quantities of nutrients in effluent can result in ocean algal blooms, etc.

WRRC Research Focus #5 - Wastewater Reuse/Disposal >35 Studies

Most of the sewage effluent from Hawai'i's treatment plants is disposed of through ocean outfalls or injection wells. This represents a waste of fresh water and nutrients and a source of pollution to nearshore waters. The use of processed sewage for irrigation is increasingly being adopted around the country as a key strategy in sustainably managing water resources. Recycled water can replace high-quality groundwater that is currently often used for irrigation in Hawai'i. Water reuse allows us to capture the nutrients in wastewater, reducing the need for crop fertilization. Ocean sewage disposal has significant implications for recreational water quality. Water reuse is an environmentally preferred method of disposing of effluent compared to the traditional ocean outfalls and injection wells. With increasing demand for water and diminishing rainfall Hawai'i is poised to greatly increase its use of recycled water for irrigation. There are concerns however about the potential for contaminants in the reused water to reach drinking water aquifers. Wastewater reuse has been one of WRRC's most active areas of research over the years.

WRRC Research Focus #6 - Watershed/Non-Point/Runoff >40 Studies

Perhaps more important to nearshore water quality than sewage discharges are the many non-point sources of pollution in the state. Hawai'i's streams are generally very small, short and extremely responsive to rainfall. Heavy rainfall often results in significant erosion that carries much sediment and pollutants such as pesticides and fertilizers into nearshore waters, with serious impacts to reef ecosystems. Loss of native vegetation has resulted in altered patterns of stream discharge. Hawai'i's large



Installing an automatic sampler for polluted runoff study.

populations of feral pigs and goats destroy vegetation and churn up soil. Storm drains carrying debris, street pollutants and garden chemicals

empty into streams. Many streams in urban areas are essentially open storm drains into which much trash blows or is thrown. The EPA, recognizing the serious impacts of non-point pollution on the nation's waters, has mandated that the states identify water bodies impaired by pollution, take steps to find its sources, and formulate watershed plans to reduce pollution and restore the impaired water bodies. WRRC researchers have undertaken around 40 studies that characterize the hydrology of streams, pollutant loading, and impact to nearshore waters. Other Center studies have helped agencies in Hawai'i comply with EPA's requirements.

WRRC Research Focus #7 - Ocean Outfall Biomonitoring – more than 100 Studies

Because of the importance of recreational water quality in Hawai'i, understanding the impacts that effluent inputs to the ocean may have on nearshore waters is crucial. Prior to the mid-1970s, most of Honolulu's minimally treated sewage was disposed of at shallow depths, close to shore near Sand Island. Today, this would be an unacceptable practice in recreational waters. Honolulu responded by upgrading treatment facilities and constructing long outfalls at the two largest plants that discharge the effluent in deep water far offshore.

In the early 1970s, the USEPA mandated advanced treatment at publicly-owned sewage treatment plants. For decades, Hawai'i's two largest treatment

plants operated under USEPA approved waivers from this requirement. The waivers were granted based on the enormous dilution afforded by the deep ocean waters and currents where the outfalls

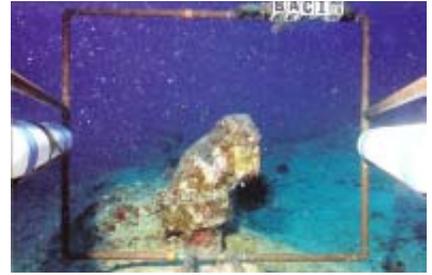


Photo transect on Waianae wastewater outfall.

discharge and on a lack of demonstrable impact to public health and the environment.

As a condition of obtaining the waivers, the City of Honolulu was obliged to conduct

monitoring of the ecosystems around the plant outfall pipes. WRRC assembled a team of experts at the University to conduct this research for the City. The team has continued to assess the health of, and changes to communities of organisms (fish and sand-dwelling worms, crustaceans, and mollusks) around the outfalls at Sand Island, Barbers Point, Mokapu, and Waianae for more than twenty years. This is the Center's longest running project. The methodology developed by the team in Hawai'i has been applied in other tropical locations by these researchers. The dataset collected by this project is unparalleled in terms of time extent, and project researchers have discovered a number of new species in the course of the work.



Outfall diffuser port, Waianae ocean sewer outfall for ocean outfall biomonitoring study.

WRRC Research Focus #8 - General Marine Water Quality >35 Studies

In addition to the numerous studies related to sewage effluent discharge and non-point source pollution mentioned above, researchers at WRRC have conducted many other types of studies pertaining to ocean water quality. These cover a wide range of topics from a broad multidisciplinary project in the 1970s designed to "...identify, develop, and evaluate the critical physical, biological, and rational parameters needed in formulating effective policies, institutions, and systems for protecting the quality of coastal waters in Hawai'i", to much more focused projects such as examining the quality of water in restored coastal fishponds and investigating the levels of chemical pollution in the waters of Pearl Harbor.

WRRC Research Focus #9 - Economics/Policy/Law >55 Studies

WRRC's research over the decades has extended into the world of social science as well. There have been many social scientists on the faculty of WRRC including the Center's director from 1999-2010 and Professor of Economics, Dr. James Moncur. Water, politics, economics, and law are inextricably

interconnected. Since the islands do not have recourse to importation of water it is important that the water is used wisely and without waste, however the meaning of “wisely” is subjective. The history of water in Hawai‘i is tied to several large corporations with their origins in the sugar trade of the late 1800s and early 1900s. Water, land, labor, transportation, and finance continue to be controlled largely by the descendants of these corporations. As water resources have become diminished in recent decades due to burgeoning population, an expanding tourism sector, and decreasing rainfall, conflicts over who has the rights to the water have emerged. The courts have ruled that water is publicly owned, but in some areas the former sugar plantations turned land developers continue to manage and distribute the water. There is mixed opinion of whether water should go to support tourist development and thereby increase Hawai‘i’s economic solvency, or to restore water to highly degraded stream ecosystems and to small farmers. These issues make Hawai‘i a very interesting laboratory for legal and economic scholars. Economic analyses of pricing conducted at WRRC have helped water supply agencies in Hawai‘i develop policies aimed at efficiently allocating water.

**WRRC Research Focus #10 -
Climate/Atmosphere/Precipitation/
Evaporation/Flooding >30 Studies**

WRRC researchers have also looked into the more fundamental matters of climate science as an important determinant of water availability, the incidence of severe storms and the occurrence of flooding and drought. Hawai‘i’s climate is extremely varied over very short distances and each island comprises several different climate areas characterized by significantly different rainfall, temperature, sunlight, and wind. The Islands’ unique topography and moisture-laden prevailing winds are major factors. Storms can be severe with torrential downpours. Due to the rapid and large response of Hawai‘i’s short streams to rainfall, flooding is a



Woodlawn Bridge in Manoa Valley after Oct. 2004 flood.

perennial problem. Conversely the islands sometimes suffer from protracted periods of drought. All of these problems associated with adverse

climatic events are predicted to be exacerbated by climate change in coming decades. WRRC researchers have worked to characterize the climate in Hawai‘i and to provide data and predictions that aid local agencies in developing strategies to mitigate the potential damage of climate change. Studies of flooding in Hawai‘i have helped to guide the State’s strategy for monitoring storms and the resulting flooding. Center researchers continue working to better understand the possible impacts that increasing climate variability may have on Hawai‘i’s water future.

**WRRC Research Focus #11 -
Rainwater Catchment >10 Studies**

Some areas of Hawai‘i and other Pacific Islands are not served by water distribution systems and rely to some extent on collecting rainwater from roofs and other surfaces. This is the case in the Tantalus neighborhood in Honolulu, and many small communities on the neighbor islands. The hydrogeology of many smaller islands often precludes the development of groundwater resources and therefore the inhabitants rely heavily on collected rainfall for drinking water and shallow wells for non-potable uses. There are sanitary, climatic, social, and engineering issues surrounding the use of rainwater and shallow groundwater which WRRC researchers have addressed in a number of studies both in Hawai‘i and on western Pacific islands.



Photograph by J.D. Griggs

**WRRC Research Focus #12 -
Pacific Islands >15 Studies**

Over the years, WRRC has worked to assist Hawai‘i’s neighbors on other Pacific islands with their water problems. Hawai‘i is unusually blessed by nature with relatively abundant fresh water resources owing to our unique hydrogeology and climate. As part of a developed nation, Hawai‘i has relatively good wastewater and sanitation infrastructure. Many of our Pacific neighbors, and indeed islands in other parts of the world, are not as lucky. They lack our easy access to



Photo- Island Research & Education Initiative (IREI), Micronesia.

Shallow well in Micronesia.

clean water and sanitation, resulting in a good deal of hardship and illness for the inhabitants.

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WRRC's work has included investigations of the hydrology of some of the lower islands in the Western Pacific to help identify sources of clean water, and the examination of rainwater collection and storage, and sanitary practices on other islands with the goal of improving the health status and standard of living of the islands' inhabitants. A recent study is assessing the sustainability of water resources on Tutuila, American Samoa, under climate change.

WRRC Research Focus #13 - Streams/Lakes >15 Studies

There are a number of factors that make the study of Hawai'i's streams and lakes compelling from both the social and physical science perspectives: streams are generally short and have unpredictable, but generally low, flow rates; historically the sugar plantations used stream water for irrigation, diverting up to 100% of the flow to the detriment of people who relied on that water for subsistence agriculture, drinking and other domestic use, and to support fish and wildlife that evolved to live in and around these streams. The protection of Hawai'i's native species and cultural practices are matters of high priority. Another high priority issue is flooding of streams - a perennial problem that causes much property damage in the state. WRRC researchers have conducted studies related to all of these issues.



Overgrowth of *Salvinia Molesta* on Lake Wilson, Central Oahu.

Miscellaneous Studies >65 Studies

In addition to the above categories, Center scientists have conducted research on a wide variety of topics ranging from desalination, to spill remediation, to development of a prototype swine waste treatment plant for the tropics. Considerable work has been done developing and exploring the use of innovative technologies such as using radio sounding to determine the location of the groundwater table, the applicability of electric well logging in Hawai'i, the use of helium and tritium as groundwater tracers, and the development of an advanced surface tensiometer for measuring water quality.



CT scanning of soil core for determination of preferential flow channels.



Visit to Indian village women's agricultural cooperative by Conservation Agriculture Practices project team. Orissa, India.



Wind-powered desalination project, Coconut Island.

Additional information regarding Hawai'i's WRRC and full text PDF versions of many of the Center's publications can be accessed via the WRRC website at <http://www.wrrc.hawaii.edu>.