Issue 1: Water Quality & Quantity

"In Hawaii, the most valuable product of the forest is water, rather than wood."
Ralph S. Hosmer, First Territorial Forester

Overview

Figure 1.1. Water is our most precious resource, and healthy forests are essential for maintaining water quality and quantity. Photocredit Chris Spears, Meteorologist; Waterfalls on Kauai.

Prior to the discovery of high “perched aquifers” in the late 1800’s all of the public water systems in Hawaii relied on surface water such as streams, springs and reservoirs for their source. The discovery of these groundwater sources came just in the nick of time. Between 1779 and the last half of 19th century, forests on all islands were nearly destroyed by wild cattle, sheep and goats that had been introduced by the early European explorers, and had been allowed to roam free. The intention was to allow wild animal populations to grow in order to provide game for the Hawaiian people into perpetuity. But the consequences of introducing these “feral ungulates” (hoofed grazing animals such as cattle, sheep, goats, deer and pigs living in the wild)
was disastrous for Hawaii’s forests. By 1890 everyone was experiencing the secondary effects from the destruction of the forests; rivers and springs began to disappear in the dry season. In the rainy season, flash floods carried rivers of mud out to sea, smothering reefs. Soon after the discovery of freshwater aquifers, the public water systems switched from surface water to groundwater as their source. At the same time, the Forest Reserve System was established to protect and restore the upland forests which are vital for recharge of groundwater aquifers. In addition, fog drip and irrigation water not lost to runoff or evapotranspiration are critical components of Hawaiian watersheds’ ability to retain rainwater. Fog condensation on trees high on forested mountains can increase rainfall collection and absorption by as much as thirty percent. Forests support infiltration of rainfall into the water table, where it percolates through permeable rock into groundwater aquifers formed by volcanic rocks.

Native Hawaiians recognized the important link between terrestrial and aquatic systems, and therefore designed land tenure systems within what is called “ahu`puu” - tracts of land capable of providing all that is needed to support the local families and populations living within. “Watershed” is the term used to describe the geographic area of land that drains water to a given destination such as a river or bay. This term is synonymous with ahu`puu, and includes not only the land from the mountains to the coast, but also the near shore marine resources. Since the first humans settled the Hawaiian Islands, people have recognized the importance of the links they share with the hydrologic systems. Watersheds are places, as geographer John Wesley Powell put it, “within which all living things are inextricably linked by their common water course and where, as humans settled, simple logic demands that they become part of a community.” Hawaii’s watersheds are rich in biological resources, unique ecosystems, and rare and endangered plant and animal species. Hawaii has 395 listed threatened and endangered species, the highest number in the nation. Of these species, 295 are plants. These rare plants live in varied habitats—from windward coastal sea cliffs to montane bogs; and from remnant dry forest to some of the wettest forests on earth. Native animal species within the watersheds include endemic birds, hoary bats, snails, and arthropods. The many small streams that drain these systems are home to diverse native aquatic insects, fishes, crustaceans, and mollusks.

Hawaii’s watersheds are also rich in cultural history. Native Hawaiians recognized the importance of forests in water production and water quality, as reflected in the saying, “Haihai ka ua i ka ulu la au” (The rain follows the forests). Native Hawaiians practiced wetland agriculture with taro in the fertile valleys, and other staple crops were intensively cultivated on many lower elevation windward slopes. On the leeward side of the islands, Native Hawaiians practiced dryland agriculture, in some cases transporting water for miles to crops in auwai (irrigation ditches or canals). Much later technological advances allowed for the development of complicated ditch & dam systems that even today support vast sugar and pineapple plantations.

Today, water quantity and quality remain critically important for all populations, and water is impacted significantly by human development and land use practices. Best management practices both in upland and coastal watersheds are needed to ensure groundwater recharge for drinking water, to protect habitat for threatened & endangered species, encourage native forest
carbon sequestration and support of all island and near shore hydrologic functions in general. In the urbanized areas, stream channelization and a high proportion of impervious surfaces in the densely populated areas contribute to flash flooding which results in large discharges of fresh water, sediments and pollutants which negatively impact our near-shore areas. In addition, these flash-flood events often overwhelm sewage treatment facilities resulting in an overflow of raw sewage into our coastal waters that threatens public health and coastal zone ecosystems.

Thus, our upland forests, urban areas, our coastline and our near shore environment are all closely linked both spatially and culturally. This unique relationship was recognized when the Hawaii Coastal Zone Management (CZM) Program was established by the Hawaii legislature in 1977. In Hawaii, the CZM area encompasses all land in the state and not merely the “coastal zone” as it is interpreted on the U.S. Mainland. Because there is no point of land more than 30 miles from the ocean, a definite land-sea connection exists throughout the state. So, designating the entire state, up to the summit of our highest mountain Mauna Loa (13,679 ft), as the CZM area was logical. What occurs on land, even on the mountains, will impact and influence the quality of the coastal waters and marine resources. The CZM area also extends seaward to the limit of the State’s police power and management authority, to include the territorial sea. This legal seaward boundary definition is consistent with Hawaii’s historic claims over the Hawaiian archipelagic waters based on ancient transportation routes and submerged lands. (For more information on Hawaii’s Coastal Zone Management Program visit their website at http://hawaii.gov/dbedt/czm/program/program.php).

In the course of doing this assessment, our Kaulunani Urban and Community Forestry Committee was presented with a similar challenge, to spatially define the urban areas that were appropriate for their program. Because Hawaii does not have a municipal level of government, our cities and towns do not have defined legal boundaries as they do on the U.S. Mainland. So after a great deal of collaborative work with our GIS team, they developed the Urban Realm concept. Beginning with the definition of “Urban Forests” as places where people work, play and live, it was decided that Hawaii’s Urban Realm would extend beyond the coastline out into our nearshore waters (about as far out as a person can wade), and up into the mountains along hiking trails. This unorthodox approach to defining urban areas is consistent with the Hawaii CZM approach. It recognizes the direct linkage between all segments of our island geography, and recapitulates the concept of a 21st Century ahupuaa. (See Issue 4: Urban & Community Forestry for more detail on this topic.)

Priority Issues and Areas for Water Quality & Quantity

This Assessment and Strategy explicitly supports all existing approved plans and programs of our Federal, State, County and watershed partnerships. Our priority areas for groundwater recharge consist of all lands classified as the Conservation District by the Hawaii Land Use Law and/or any lands managed by a watershed partnership (Map 1.1).

In the process of developing this document we have begun to work closely with the Office of Planning and other local, state and federal partners through the Ocean Resources Management Plan Working Group in an effort to collaborate more effectively at a whole watershed, or
Priority Areas for Groundwater Recharge

Main Hawaiian Islands

Priority Areas for Groundwater Recharge

MAP 1.1 Priority areas for groundwater recharge

Data Source: The State of Hawaii GIS 2010
Date of Production: June 18, 2010
Contact: Ronald Cannarella, Forester, Department of Land and Natural Resources

Protection of Hawaii’s water recharge areas lead to the establishment of the original Forest Reserve System in 1903. The Board of Agriculture and Forestry, in 1903, and the establishment of the original Forest Reserve System was replaced by the Conservation District established by the Hawaii State Land Use Law of 1961. However, land ownership of the Conservation District was fragmented between private landowners, and Federal, State, and County entities. Watershed Partnerships began to organize in 1990’s to reestablish landscape-level coordination and reestablish landscape-level coordination in priority areas for groundwater recharge. Thus, our priority areas for groundwater recharge consist of the Conservation District and/or a formally established Watershed Partnership.
ahupuua level. The Hawaii Coastal Zone Management Program (CZM) and the Hawaii Department of Health (DOH) are working to develop a comprehensive Coastal Nonpoint Pollution Control Program in conformance with Section 6217 of the federal Coastal Zone Act Reauthorization Amendments of 1990 (CZARA) (see http://coastalmanagement.noaa.gov/nonpoint/docs/6217progguidance.pdf).

The Coastal Nonpoint Pollution Control Program is intended to be comprehensive and address methods to manage potential or ongoing water quality impacts from urban areas, agricultural areas, forestry activities, onsite wastewater disposal systems, marinas, wetlands protection and restoration and hydromodification (shoreline erosion, dams and stream channelization). The State has met most of the management conditions and has been working with EPA and NOAA to address the remaining conditions through the development of a watershed guidance package. The watershed guidance package is intended to guide the preparation and implementation of watershed plans. Further, the package will utilize the Coastal Nonpoint Pollution Control Program’s approach of addressing water quality impacts from a broad range of areas and activities as tools for more effective watershed planning and implementation the State’s Polluted Runoff Control Program supported by EPA Clean Water Act, Section 319 funds.

The State will be targeting the use of the watershed guidance package in watersheds identified as being in need of restoration and/or protection where there are also interested and capable stakeholders to develop and implement watershed plans. Map 1.2 “Watersheds Most In Need of Restoration 2009” is included here to summarize the most current statewide assessment of watersheds identified as most in need of restoration. Please refer to Appendix B: Plans Incorporated and Referenced for the complete Watershed Summit 2009 Summary Report and methodology for developing Map 1.2. The handouts from the Summit provide some insight into the numerous watershed planning projects currently underway. Map 1.2 is meant to merely provide a snapshot of one aspect of these efforts.

Benefits

Water quality and quantity conservation practiced at the watershed level creates benefits within and beyond the management area of interest. The magnitude of the benefits also depends considerably on economic policies accompanying conservation measures. One of the most important ecosystem functions is a consistent supply of water, which is needed for domestic, agricultural, industrial, and tourism needs. As important, forests slow the flow of water from steep mountainsides to coastal and near shore marine areas. This slow movement of water flowing through streams maximizes aquifer recharge and prevents flooding during heavy rains that cause topsoil erosion and sedimentation. Reefs are particularly vulnerable to smothering by fine sediment, which blocks the light necessary for their growth. Sediment deposition from streams and urban drainages is responsible for beach deterioration and reef degradation and, in some cases, death of the coral reef. Healthy forests and functional hydrologic processes are critical to ensuring our waters are fishable and swimmable, and that beaches and coastal watersheds are healthy, which are critical to food production and tourism; Hawaii’s largest industry.
Watersheds Most In Need of Restoration 2009

Watershed Restoration Composite Score

- Red: Identified as Most in Need For Restoration
- Category 2
- Category 3
- Category 4
- Category 5
- Light Blue: Watersheds Listed Both In Need of Restoration and Protection

Coastal Water Quality Class

- Class A: Strict Pollution Control Regulations to Protect Recreation & Aesthetic Values
- Class AA: Regulations Against Discharge to Preserve Pristine Condition

Map 1.2 Watersheds Most In Need of Restoration 2009

Data Source: The State of Hawaii GIS 2010, Coastal Zone Management Program of Hawaii

This map depicts the final score ranking watersheds for restoration. Watersheds in red fall in the top 50 scoring watersheds, most in need of restoration based on 15 indicators including 4 Urban Stressors, 3 Agriculture Stressors, 2 Soil Stressors, 3 Indicators of Sensitive Areas and 3 Asset Indicators. For a complete description of the methodology used for this dataset, please refer to the Watershed Prioritization Process and Watershed Summit 2009 Summary Report and Handouts available at http://hawaii.gov/dbedt/czm/initiative/nonpoint.php accessed on June 10, 2010, also found in Appendix B: Plans Incorporated & Referenced.

Data Source: State of Hawaii GIS
Date of Production: June 18, 2010
Contact: Ronald Cannarella, Forester
Department of Land and Natural Resources
Other ecosystem services provided from healthy watersheds and hydrologic functions are drought mitigation, traditional cultural resources, recreation, and preservation of unique native species. The cost of replicating any of these essential services through technology or engineering is staggering and often unnecessary if forethought and restraint is practiced under the enticement of quick economic gain.

In Hawaii the steep mountainous areas have long been recognized as crucial elements of a sustainable ecosystem. There is a direct connection between forest quality and water quality. A University of Hawaii study estimates the Koolau Mountains on Oahu alone provide benefits worth up to $14 billion. Beginning more than a century ago, upland areas began to be set aside for protection. The lands currently zoned “Conservation District” and those within the “watershed partnerships” are managed and responsible for providing billions of gallons of water each year. Some of the benefits of these partnerships are:

- More economical management of resource threats across landowner boundaries
- Limited state funds are leveraged with federal, county and private funds
- Private landowners increase their capacity and desire to protect their forests
- Resources and expertise are pooled to reduce redundancy

Threats

There are many threats to sustaining water quality and quantity in the Hawaiian Islands. At the core of all of these threats are the results from decisions made by humans. Sometimes the impact of the lack of action is as important as that of action. A proactive approach to reducing long term threats is needed if we are to affect impacts such as:

Fracture of Hydrologic Functions: Watersheds are impacted by humans through development and land use practices. There is a need to assess the health of, and distribute knowledge about, hydrologic functions and watershed sustainability to the public to inform policy makers.

Destructive Animals: Feral ungulates like pigs, goats, sheep, deer, and cattle trample and destroy vegetation, tear up the ground with their hooves, leaving the ground bare and exposed. This can further result in increased erosion, and allow seeds of fast growing non-native species to germinate and thrive.

Destructive Weeds: Habitat-modifying invasive species shade out natives, especially those that are shallow rooted and contribute to erosion. Some alien invasive species such as strawberry guava (Psidium cattleianum) or albizzia (Falcataria mulucana) have been shown to significantly alter the microhabitat rendering it less conducive to the support of native species.

Other important threats include urbanization, wildfire, the effects of climate change, terrestrial and aquatic pollutants, invasive species, pests, diseases, human activities such as use of ATVs and motorcycles, and the loss of important cultural practices.
Urbanization: The effects of urbanization and human activities such as burning, logging, cattle grazing, large scale agriculture and associated chemicals and fertilizers, and development have permanently altered many coastal and lowland areas and the native species that once inhabited them. In recent years, it has become increasingly clear that the nation’s waters have serious water quality problems. Virtually everywhere, the problems result from what is commonly called polluted runoff or non-point source pollution. These terms both refer to pollutants that enter a body of water as a result of water flowing over the surface of the land, such as rainfall or irrigation or common non-point source pollutants include soil, fertilizers, animal wastes, oil, grease, litter, and agricultural chemicals. These and other pollutants end up in public waters all across the country. In Hawaii, land-based activities are the primary source of polluted runoff problems statewide.\textsuperscript{4} The consequences of non-point source pollution are all too well known; increased risk of disease from water recreation, algae blooms, fish kills, destroyed aquatic habitats, and turbid waters. Some polluted runoff results from natural causes. Most, however, result from people’s activities on the land and water.

Feral Ungulates: The effects of Hawaii’s extreme isolation from other land masses are illustrated well by its absence of a single native mammalian herbivore. Hoofed grazing animals, a group of mammals present on islands and continents throughout most of the world, are completely absent from Hawaii’s evolutionary history. The pressures associated with ungulates such as trampling, heavy browsing and grazing have resulted in the loss of many species and/or their ability to evolve and adapt to new evolutionary pressures and climate change.

Cattle: In 1793, Captain George Vancouver delivered domestic cattle (\textit{Bos taurus}) as a gift to King Kamehameha I. A 20-year prohibition on their use (\textit{kapu}) was issued, and they were allowed to proliferate across the landscape without harm from the native Hawaiian population. During that time, they exacted heavy impacts on the native vegetation as well as cultivated crops.\textsuperscript{5} Currently, most cattle grazing takes place on private and State leased lands. However, wild cattle persist in many areas where inadequate or absent fencing have allowed them to wander into the forest in search of highly palatable foods. Unmanaged cattle are widely recognized as a major destructive agent in Hawaiian ecosystems and have had a significant effect on montane mesic forests.\textsuperscript{6}

Pigs: Initially introduced by the Polynesians was the relatively small, forty to fifty pound Polynesian pig. Europeans arrived over 1,000 years later and brought with them the domestic hog, a much larger animal than the Polynesian pig. Over the first 100+ years of occupation, the hog became well-established in the wild. In a 1930 Hawaii Planter’s record, G.A. McEldowney reported that pigs were a bigger threat to watersheds than cattle or goats because they eat seeds and seedlings of trees, upturn soil, and cause erosion. Pigs depredate native plants, facilitate the spread of alien plants through seed dispersal and creation of sites favorable for colonization, vector disease and pathogens, and facilitate erosion.\textsuperscript{7,8,9,10} (See Issue 2: Forest Health: Invasive Species, Insects and Disease for more information.)
**Non-Native Animals:** Fifty-three birds, 33 reptiles and amphibians, and 19 mammals are naturalized in Hawaii, and have the potential to become serious pests in watersheds. Rats, in particular, have significant affects on native vegetation and birds. Black rats (*Rattus rattus*) and Polynesian rats (*Rattus exulans*) are the dominant species throughout most of Hawaii’s forests. They consume the seeds, fruits, and flowers of numerous native plant species, including many rare ones. Rats also prey on native bird eggs and nestlings. Like ungulates, rats can affect water quality by serving as vectors for water-borne diseases such as Leptospirosis and Cryptosporidiosis. Other non-native animals that may pose problems in Hawaii’s watersheds include mongoose, feral cats, dogs, mice, chameleons and birds. Non-native forest birds have been observed in all vegetation types. They compete with native forest birds for food and other resources, provide vectors for avian diseases, and are vectors for the spread of alien plants. Over 3,300 alien arthropods are estimated as naturalized in Hawaii; this number grows by 20 to 40 per year. Alien arthropod species have been introduced intentionally and unintentionally over the past few centuries for a variety of reasons. Impacts of alien invertebrates include direct consumption of rare plants, interference with plant reproduction, predation and parasitism of native animals, transmission of disease, alterations to soil formation processes, and hybridization with native forms.\(^{11}\)

**Pathogens:** Koa (*Acacia koa*) is one of the two dominant tree species in Hawaii’s native forests. Pathogens have limited the success of numerous native species; most significantly, koa wilt disease, caused by *Fusarium oxysporum*, threatens the health of this tree. This soil born disease causes dieback and decline of koa in native forests by compromising the trees vascular system.\(^ {12}\) Additionally, rust species have the potential to negatively affect the other dominant tree species in Hawaii’s native forests, *ohia lehua* (*Metrosideros polymorpha*). A recently introduced strain of *Puccinia psidii* was found to be pathogenic to ohia. Although this race of rust has demonstrated low virulence to ohia, scientists are concerned about introductions of future strains. Compromised health of Hawaii’s dominant native tree species, koa and *ohia*, would have devastating effects on Hawaii’s forested watersheds. *(See Issue 2: Forest Health: Invasive Species, Insects and Disease for more information.)*

**Human Activities:** Hikers and hunters can spread seeds or propagules of invasive plants on their shoes, equipment or vehicles. Illegal trails have been created by ATVs, motorcycles, and bicyclists. Over harvesting of some culturally important plants may be occurring. Fires, whether caused inadvertently or maliciously, are a threat, primarily in dry forest or during drought periods.

**Aquatic Pollutants:** Numerous alien aquatic species that exhibit the characteristics of being invasive threaten to cause ecological and economic harm. The loss of these native stream fauna would degrade the entire native stream ecosystem. Invasive aquatic species could also cause economic impacts to agricultural users of water, resulting in crop damage, infrastructure damage, or contamination. Introductions of aquaculture and aquarium species into streams occur via flooding, effluents discharged back into streams, intentional introduction, and by overland travel. In addition, disease and pathogens associated with cage-reared species could potentially spread...
through streams and ditches. A number of fish distributed via the aquarium industry, directly
compete with native stream fauna for food and other resources.\textsuperscript{13}

\textit{Sediments}

Most water quality problems in the upper watershed do not have
anthropogenic origins. They are related
to soil erosion, a natural process in
forested areas that can be amplified by
animals and to lesser extent human
disturbances. Sediment pollutants
occur as siltation, suspended solids,
turbidity, nutrients, and pathogens.
Suspended sediments can: stress native
fish; damage the gills of some fish
species, causing them to suffocate;
increase water turbidity, which limits
light penetration and impairs
photosynthesis for aquatic plants; raise
water temperatures; and/or lower
dissolved oxygen concentrations,
which at decreased levels can kill
aquatic vegetation, fish, and bottom
dwellers. Settled sediment can: affect
levels of nutrients, solids and oxygen-
demanding materials; eliminate
essential habitat and bury food sources
and spawning sites for stream life;
smother bottom-dwelling organisms;
and reduce the capacity of stream
channels and ditches to carry water and
of reservoirs to hold water.

\textit{Toxins and Bacteria:} Leptospirosis and Cryptosporidiosis are potentially fatal
illnesses caused by water-borne
microorganisms spread by pigs, dogs,
mongooses, rats, and even frogs.
Leptospirosis is a bacterium,
transmitted from animals to humans where people contact the bacteria through water or mud that
has been contaminated by animal urine or droppings. About 500 cases, including seven deaths,
have been reported in Hawaii in the past decade. Cryptosporidiosis is a diarrheal illness caused

Figure 2. Brief but intense rainstorms are typical events in Hawaii. In this photograph, sediment from denuded
uplands of Molokai quickly reach the ocean and negatively
impact near shore habitats and smother coral reefs.
by a microscopic intestinal parasite, Cryptosporidium. People are typically exposed by eating food or drinking water contaminated with feces of infected animals, including cattle, rodents, cats, dogs, and humans.

Wildfire: Because Hawaii’s flora have evolved with infrequent, naturally-occurring episodes of fire, most native species are not fire-adapted and are unable to recover well after wildfires. Alien plants, particularly grasses, are often more fire-adapted than native species and will quickly exploit suitable habitat after a fire. Fire-adapted species are themselves flammable and foster an increase in frequency and/or intensity of fires. Increased occurrence of fire leads to erosion, and the whole cycle thereby reduces the integrity and biodiversity in Hawaii’s watersheds. (See Issue 3: Wildfire for more information).

Climate Change: Global and local climate change have the potential to affect Hawaii’s hydrology through the alteration of rainfall patterns and cloud banks thereby effecting agricultural water users over a broad geographic area. Sea level rise, an inevitable outcome of climate change, will impact islands dramatically by killing vegetation that is not adapted to salt water intrusion. Many cities and villages located near the ocean are already being impacted by frequent storm surges and reduction in beach length and width.

Watershed functions would be compromised from the drying of the air, vegetation and soil, that would result from an elevation of the cloud bank. Rare ecosystems and species may be affected by relatively quick changes in precipitation, temperature, and humidity that result from a rapid and drastic change in regional or local climate patterns. Such intensive rainfall events can cause flooding and damage to crops, human infrastructure and health. Climate change could also impact the local culture and lifestyle by causing a decline in culturally-used plants that are dependent on niche environments. Recreational opportunities might also be adversely affected. (See Issue 5: Climate Change/Sea Level Rise for more information).

Trends

Human activities such as intentional introduction of plants for food and ornament, accidental introductions and large scale modification of the natural landscape for agriculture and development has affected hydrologic functions. One legacy of Hawaii’s agricultural history is the development of miles of extensive ditches and culverts designed to divert water to reservoirs and irrigation systems that supplied the now waning sugar and pineapple industries. Stream diversions and channelization are more modern modifications created to support the ever increasing urban populations with negative impacts to Hawaii’s water. (See Issue 2: Forest Health: Invasive Species, Insects and Disease for more information.)

Trends in Stream Flow: Proper management of the water resources of the State requires an understanding of surface water and the long and short-term variability in stream flow characteristics that may occur. The U.S. Geological Survey maintains a network of stream gauging stations in Hawaii, including a number of stations with long-term stream flow records.
that can be used to evaluate long-term trends and variations in stream flow on the islands of Hawaii, Maui, Molokai, Oahu, and Kauai.

From 1913 to 2002, in streams for which data are available, base flows generally decreased, and this trend is consistent with the long-term downward trend in annual rainfall over much of the State during that period (see Figure 3). Monthly mean base flows generally were above the long-term average from 1913 to the early 1940's and below average after the early 1940's to 2002, and this pattern is consistent with the detected downward trends in base flow from 1913 to 2002. Long-term downward trends in base flows of streams may indicate a reduction in ground-water storage and recharge. Because ground water provides about 99 percent of Hawaii’s domestic drinking water, a reduction in ground-water storage and recharge has serious implications for drinking water availability. In addition, reduction in stream base flows may reduce habitat availability for native stream fauna and water availability for irrigation purposes.

![Figure 3. 1910-2001 trend depicting reduced mean base flow and annual rainfall in Hawaii. Image courtesy of U.S. Geological Survey.](image-url)

Statistically significant downward trends in annual base flow during 1913-2002 were detected at all seven stations. Long-term downward trends in base flow are consistent with long-term downward trends in rainfall over much of the state during this period. Thus, the downward trends in base flow at the long-term trend stations may be representative of many other streams throughout the state as well. For more recent periods, such as 1953-2002 and 1973-2002, significant trends in base flow generally were not detected at the long-term-trend stations (Oki, in press). For the period 1953-2002, a significant downward trend in base flow was detected at only one of 14 long-term-trend stations (16400000 on Molokai), and for the period 1973-2002, a significant downward trend was detected at only one of 16 stations (16019000 on Kauai). Detection of trends in base flow may be highly dependent on the period being considered. The downward trends detected during 1913-2002 may reflect higher than average base flows prior to the 1940’s, followed by a period after the 1940’s during which base flows did not trend significantly upward or downward.
A statistically significant downward trend in annual total stream flow (base flow plus direct runoff) during 1913-2002 was detected at only one of the seven long-term-trend stations (16229000 on Oahu). For more recent periods, such as 1953-2002 and 1973-2002, significant trends in total stream flow generally were not detected at the long-term-trend stations (Oki, In Press). For the period 1953-2002, a significant downward trend in total stream flow was detected at only one of 14 long-term-trend stations (16211600 on Oahu), and for the period 1973-2002, no significant trends in total stream flow were detected at 16 long-term-trend stations. (USGS 2010)

Trends in Land Management & Collaborative Partnerships

Over 100 years ago the territorial government of Hawaii established the Forest Reserve System to protect important public and private watershed lands and began to restore degraded forests. Since the inception of the first watershed partnership in 1991, the alliance of watershed partnerships has grown. Watershed partnerships are voluntary alliances of both public and private landowners committed to the common value of protecting forested watersheds for water recharge, conservation, and other ecosystem services through collaborative management. Partners commit to work collaboratively to protect their lands despite differences in priorities, mandates and constituencies.

Watershed Partnerships

The watershed partnerships’ goals are to develop and implement initiatives that support long-term sustainability of the watershed partnerships. The five main objectives identified to implement these goals are:

- Investigate long-term, sustainable funding options and determine solutions to support continued implementation of the management plans developed under the watershed partnerships.
- Address capacity-building needs for the watershed partnerships.
- Support policies and laws that will benefit Partnership goals and management plans.
- Facilitate the annual Watershed Symposium and/or other similar events to maintain communication amongst partners and facilitate information exchange.
- Expand outreach and education initiatives to develop support for the work done by watershed partnerships, particularly amongst the public and decision makers.

The watershed partnerships have a proven track record of on-the-ground management that has led to results oriented protection and restoration of forested watersheds through fencing and ungulate removal, invasive species control, native out plantings, and outreach and education involving schools and communities. Much of this success can be attributed to having committed partners, dedicated staff and leadership, directed management plans that prioritize threats and actions, effective organizational structures which insure dollars go directly to projects, and passionate volunteers and community support. To date, combined partnership success includes:
• 300,000 acres managed to control damage from caused by feral ungulates and destructive invasive species;
• Planted 83,000 native and endangered plants for forest restoration;
• Engaged 5,500 volunteers including community members, teachers, and school groups in projects;
• 40 miles of protective forest fence completed.

Today, there are twelve watershed partnerships on six major islands: Kauai, Oahu, Lanai, Molokai, Maui, and Hawaii. Together, these partnerships involve over 65 private landowners and 24 public agencies that cover over 2 million acres of land in the state. To learn more about the watershed partnerships and their many accomplishments visit the Hawaii Association of Watershed Partnerships website at http://www.hawp.org.

Urban Watershed Collaborations

An increasing trend, particularly in highly urbanized watersheds, is the establishment of collaborations that take a whole-watershed approach, or as previously stated, embrace the 21st Century ahupuaa. These collaborations cross boundaries, such as the forested Conservation District which often abuts suburban residential communities and highly urbanized areas. This section highlights only a few of these initiatives.

While non-point source pollution is associated as the cause of many water quality issues, a large number of non-point source pollution issues are preventable. The Center for Watershed Protection emphasizes that the key to maintaining and improving the quality of our valuable water resources is to minimize the collective impacts of urbanization and other land use changes at the local watershed scale.23

One example of a grassroots, community based collaboration in Hawaii working on local water quality issues is the project at Maunalua Bay initiated by Malama Maunalua (see http://malamamaunalua.org/). Malama Maunalua is a community-based initiative dedicated to creating a more culturally and ecologically healthy Maunalua region in Southeast Oahu. Malama Maunalua works in collaboration with the Polynesian Voyaging Society, Malama Hawaii, The
Nature Conservancy, Hui Nalu Canoe Club, State Dept. of Land and Natural Resources, and many, many others. Key issues being addressed by this initiative include sediment, nutrients and polluted runoff from modified streams and impervious surfaces. Trees and forests are considered part of the solution for improving these water quality issues. Trees can decrease the amount of stormwater runoff and associated pollutants that reach the ocean and promote the infiltration of rainwater into the soil.

Other successful public-private watershed based collaborations include the West Maui Watershed Restoration Action Strategy spearheaded by the West Maui Soil & Water Conservation District (http://www.hacdhawaii.org/districts/westmaui.html), and the Ala Wai Watershed Project on Oahu (http://www.alawaiwatershed.com/).

The Ala Wai Watershed Project is a multi-purpose project being undertaken by the U.S. Army Corps of Engineers (USACE), the Hawaii State Department of Land and Natural Resources (DLNR), and the City & County of Honolulu. The goal of the project is to improve the overall quality of the Ala Wai watershed, from the crest of the Koolau Mountains to the nearshore waters, while minimizing the risk of flood damages to the public. Specific project objectives include:

- Flood risk management
- Ecosystem restoration
- Recreation
- Water quality
- Water supply
- Coastal issues
- Infrastructure maintenance

Another collaboration produced a “Tropical Urban and Community Forestry Summit”, which was held November 4-5, 2009. The purpose of the summit was to clarify urban forestry conditions, threats, trends, visions and strategies. The collaboration included “Kaulunani”, an urban forestry program of the Division of Forestry and Wildlife, the USDA Forest Service, the Friends of Hawaii's Urban Forest, and The Outdoor Circle. (See Issue 4: Urban & Community Forestry for more information).

Summary

The importance of water quality to the State of Hawaii cannot be overstated. Water quality is vital to human health; cultural practices; leisure and recreation such as swimming, boating, snorkeling, diving, and surfing; the visitor industry; ecosystem and species health and diversity; and fishing and other food-gathering activities. Important threats to water quality and quantity include non point source pollution, the effects of climate change, terrestrial and aquatic pollutants, wildfire, pests, diseases, human activities, development, and the loss of important cultural practices. Watershed-level management requires collaboration and cooperation across...
lanscapes and organizations. The adoption of the *ahupuaa* approach, the work of the ORMP Policy and Working Groups, the Invasive Species Committees, The Hawaii Conservation Alliance and the watershed partnerships are only some of the examples of progress that we are making in managing our water resources in Hawaii. However if we are to successfully meet the new challenges of invasive species, conversion of prime agricultural lands to uses that negatively impact water, and climate change, then much more needs to be done. "Each time we lose another Hawaiian plant or bird or forest, we lose a living part of our ancient culture." Nainoa Thompson, Polynesian Voyaging Society.

**Data Gaps & Opportunities**

- Refinement of ungulate survey methods and conducting additional surveys.
- Increased monitoring of invasive species utilizing ground surveys in conjunction with aerial surveys using high resolution and multi-spectral imagery.
- Refined models of predicted effects of climate change at a spatial scale appropriate for Hawaii.
- Continued improvement in modeling and monitoring the effects of different land use practices on local water budget.
- Develop economic data and practical models for assessing the costs and benefits of “green engineering” effects on storm runoff mitigation on tropical urban areas.
- Increased collaboration with communities, government agencies, researchers and nongovernmental organizations (NGO) operating at the *ahupuaa* watershed scale.
- Identify specific areas, regions or watershed to target for concentrated efforts.
- Increase community outreach and education efforts.
- Better communication between the watershed partnerships and the invasive species Committees to consolidate our GIS data regarding the location of invasive species and the actions being taken to control them.
Strategies for Issue 1: Water Quality & Quantity

There are many factors affecting the quality and quantity of water in Hawaii. The priority areas for one department of State or Federal government and private landowners may differ significantly from another, however collectively the goal is to monitor, manage and protect all areas that impact water. Certainly this includes watersheds, but it also includes understanding and addressing issues around, above and below watersheds. The below table strives to capture the majority of issues, stakeholders, programs and management priorities pertaining to water across the State of Hawaii. The State acknowledges and strives to incorporate all existing management plans pertaining to water.

### Water Quality & Quantity: Invasive Species Control

<table>
<thead>
<tr>
<th>Long Term Strategy</th>
<th>Priority Landscape Area(s)</th>
<th>Secondary Issues Addressed</th>
<th>Program Areas that Contribute</th>
<th>Key Stakeholders</th>
<th>Resources Available &amp; Implementing Partners</th>
<th>Measures of Success</th>
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<tbody>
<tr>
<td>1) Control established and incipient invasive species by conducting weed surveys &amp; creating and implementing prioritized weed management plans for important watersheds.</td>
<td>Watershed Partnership Areas Statewide, The Conservation District, Dept. of Health, CZM/EPA &amp; Board of Water Supply Priority Watersheds</td>
<td>Reduced soil erosion, increased carbon sequestration, coral reef protection.</td>
<td>Watershed Partnerships, NARS, FRS, HISC, USFS Forest Health and Special Technology Development Program, FSP, FLP, CREP, LLCF, NAPP’s, FWS, FSCG</td>
<td>Private landowners, Watershed partnerships, DHHL, OHA, HI Counties, NPS, TNC, County water Departs, visitors to Hi</td>
<td>Special Technology Development Program, Americorps Internships, USFS, NRCS, USGS, US Army, USFWS, UH, CGAPS, HCA, YCC, DAR, IPIF</td>
<td>Acres surveyed/ treated for invasive species that threaten watersheds; # of weed management plans completed or updated, Improved hydrologic functions island wide.</td>
<td>1.1, 1.2, 2.1, 3.1, 3.4, 3.5</td>
</tr>
<tr>
<td>2) Control feral ungulates through fencing, public and staff hunting, trapping and other approved methods.</td>
<td>Same as above</td>
<td>Improved coral reef health, reduced mosquitoes.</td>
<td>Same as above</td>
<td>Same as above</td>
<td>Same as above</td>
<td># of acres fenced; Miles of fence line inspected and maintained; # of feral ungulates removed.</td>
<td>1.2, 2.2, 3.1, 3.4, 3.5, 3.6</td>
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### Water Quality & Quantity: Outreach & Education

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<td>1) Increase public involvement in watershed management through outreach education and volunteer programs for children and adults that integrate science with Hawaii’s unique cultural traditions.</td>
<td>Statewide</td>
<td>Improved policies &amp; more incentives promoting water quality enhancement.</td>
<td>Watershed Partnerships, NARS, FRS, HISC, USFS Forest Health and STDP, FSP, FLP, CREP, LLCF, NAPP’s, FWS, FSCG</td>
<td>Same as above</td>
<td>Americorps Internships, HISC, Hawaiian County, CGAPS, YCC, DAR, OHA</td>
<td># of outreach events and presentations; # of participants in outreach and education events; # of volunteers participating in watershed events; Increased partnerships.</td>
<td>3.6</td>
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### Strategies for Issue 1: Water Quality & Quantity

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<td>Major surface water areas statewide.</td>
<td>DAR, NARF, HAWP, FSCG, NRCS, FWS, Army, OHA</td>
<td>Same as above</td>
<td>HCA, TNC, PPF, NOAA, UH</td>
<td>Increased drinking water, improved water quality, increased aquifer recharge.</td>
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<td>2) Improve water quality in estuaries, bays and near shore waters.</td>
<td>Coastal bays &amp; estuaries, streams statewide.</td>
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### Water Quality & Quantity: Improve coastal watersheds

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Strategies for Issue 1: Water Quality & Quantity

Acronyms Used:
1. CZM – Coastal Zone Management
2. OHA – Office of Hawaiian Affairs
3. HAWP – Hawaii Association of Watershed Partnerships
4. EQIP – Environmental Quality Incentive Program (NRCS)
5. NARF – Natural Area Reserve Fund
6. NARS – Natural Area Reserve System
7. FRS – Forest Reserve System
8. RLA – Recovery Land Acquisition Program – FWS
9. FRPP - Farm & Ranchland Program - NRCS
10. LLCF - Legacy Land Conservation Program
11. FLP – Forest Legacy Program – Forest Service
12. FSCG - Forest Service Competitive Grants
13. DAR - Division of Aquatic Resources
15. HISC – Hawaii Invasive Species Council
16. FSP – Forest Stewardship Program
17. CGAPS – Committee Group on Alien Pest Species
18. NAPP - Natural Area Partnership Program
19. HCA – Hawaii Conservation Alliance
20. IPIF – Institute of Pacific Island Forestry
21. UCF – Urban & Community Forestry (Kaulunani)
22. NOAA – National Oceanographic and Atmospheric Administration
23. USGS – US Geological Service
24. YCC – Youth Conservation Corps
25. STDP - Special Technology Development Program
Section References


5 Cuddihy, L.W., and C.P. Stone. Alteration of Native Hawaiian Vegetation; Effects of Humans, Their Activities and Introductions. Manoa: Cooperative National Park Resources Study Unit University of Hawaii 1990.


