

STATE OF HAWAII (USA)

INTRODUCTION

by Karin Z. Meier, James P. Laurel and James E. Maragos

Area: 16,770 sq.km.

Population: 1,250,000.

Hawaii is the only tropical and only island state of the USA. Hawaii consists entirely of islands, mostly of volcanic basalts to the southeast and coral limestone caps atop extinct volcanoes to the northwest. The archipelago is long, stretching 2,600 km along a northwest to southeast axis in the central tropical Pacific, and consisting of about 35 coral or volcanic islands. The northwest end of the chain consists of coral atolls at longitudes 29° to 30° N and at latitudes 176° to 170° W. The large volcanic islands at the southeast end of the Hawaiian chain are situated at latitudes 19° to 23° N and longitudes 155° to 161° E. The largest island is Hawaii (10,500 sq.km), or the "Big Island", followed by Maui (1,900 sq.km), Oahu (1,573 sq.km), Kauai (1,444 sq.km), Molokai (676 sq.km), Lanai (367 sq.km), Niihau (187 sq.km) and Kahoolawe (117 sq.km).

The Hawaiian archipelago has formed over a geological "hotspot" on the floor of the deep Pacific ocean. Over the past 50 million years, the earth's crust has been moving in a northwest direction over the hotspot, allowing a chain of volcanic islands to form and move to the northwest. The volcanic islands, thus, are progressively older to the northwest. As they age, the volcanic islands become eroded, subside, and eventually coral reefs form around their sides. Additional subsidence then causes the volcanic portion of the islands to submerge entirely to form atolls. Eventually the atolls drift out of the warm tropics, and when their upward growth can no longer keep pace with subsidence, they "drown", becoming seamounts. For example, the Emperor Seamounts off the east coast of Japan are the earliest of the Hawaiian volcanoes that have long since drowned many millions of years ago. The oldest of the existing Hawaiian islands are the atolls of Midway and Kure, approximately 25 million years old. At the opposite end of the chain, to the southeast, are found the youngest, and largest islands. For example, Hawaii (the Big Island) is less than one million years old, Maui and Molokai less than three million years, and Oahu less than six million years old. The young volcanic islands are also the highest; Hawaii's highest point is at 13,784 ft (4,202 m), Maui is 10,025 ft (3,056 m) high, Oahu is 4,025 ft (1,227 m) high, Kauai is 5,170 ft (1,576 m) high, Molokai is 4,970 ft (1,515 m) high, Lanai is 3,370 ft (1,027 m) high, Niihau is 1,281 ft (391 m) high, and Kahoolawe is 1,472 ft (449 m) high.

Hawaii has a mild tropical climate with average temperatures varying between 20° and 30°C throughout the year. The high islands trap more rainfall because the prevailing trade winds must rise over them, cool off, and drop moisture. On the low islands and open ocean areas away from the high islands, precipitation averages about 20 inches (508 mm) per year, but off the windward sides and peaks of the high islands, precipitation averages 100-300 inches (2,540-7,620 mm) per year. Mount Waialeale on Kauai is reputedly the world's wettest spot, with an annual precipitation rate of 500 inches (12,700 mm). On the back or leeward sides of the same high islands, rainfall rates are much below average. For example, the leeward sides of the Big Island and Maui average only 10 inches (254 mm) or less of rainfall per year. These climatic factors profoundly affect the distribution and type of wetlands in Hawaii.

Most of the people of Hawaii reside on Oahu (population 836,231), which also serves as the state's capitol. The other inhabited islands have much lower permanent populations, and in descending order of population size are Maui, Hawaii, Kauai, Molokai, Lanai and Niihau. A small Naval Air Station is situated at Midway Atoll, and a small research station is found on the atoll of French Frigate Shoals. The U.S. Coast Guard recently closed their navigation station at Kure, leaving the island abandoned. The remaining

Hawaiian Islands are uninhabited.

The ancient Hawaiians were the first settlers to reach Hawaii, about 1,000 to 1,500 years ago. The Hawaiians occupied all of the main islands and some of the smaller islands to the northwest, including Kaula and Nihoa, at least for extended periods. The early Hawaiians practised a subsistence lifestyle relying heavily on fish, taro and other garden crops. Meaningful western contact began with Hawaii's "discovery" by Captain James Cook in 1778. In the subsequent 200 years, the population has become more cosmopolitan due to the importation of foreign workers and a decline in the Hawaiian population from exposure to diseases brought in by foreigners. Today, the major ethnic groups in Hawaii include Caucasian, mixed Hawaiian, Japanese, Filipino, Chinese, Samoan, Korean and other groups. No one group achieves a population majority in Hawaii. Over a century ago, the economy of the islands shifted from subsistence to agriculture, with cane sugar, pineapples and coffee being the main export commodities. Later, macadamia nuts, bananas, flowers and papayas were exported. However, since World War II, agriculture has steadily declined in Hawaii relative to the importance of government expenditure and tourism. Military expenditure and tourism now account for more than half of the economic foundation in Hawaii.

Summary of Wetland Situation

Hawaii has many thousands of wetlands and a great variety of wetland habitats. In the compilation of information for the present inventory, most marine wetlands such as coral reefs and lagoons have been excluded, as well as many freshwater bodies such as highly modified or intermittent streams and most man-made reservoirs or ponds. Wetland types which have been considered in this inventory include perennial streams, natural lakes, a few reservoirs important for waterfowl, upland bogs, coastal marshes, mangrove swamps and anchialine pools (open brackish waters with tidal action but no visible surface connection to the sea). Over 450 significant wetlands have been identified throughout the islands.

Coastal marshes are confined to the portions of high islands with floodplains or coastal plains. Upland bogs are also confined to the high islands, especially along the wetter windward slopes and mountain ridges. Anchialine pools in basalt rock are confined to the youngest islands (Maui and Hawaii), where the lava rock is porous and creates broad shallow shelves near the coast. Limestone anchialine pools are also found in karstic formations, consisting of fossilized coral reefs, now positioned above sea level, which have undergone extensive weathering and dissolution to form the anchialine pits and pools. Hawaii has only five large natural freshwater lakes, again all located on the high islands. Mangrove swamps are not native to Hawaii, and began to spread throughout Hawaii when residents brought in alien mangrove species at the turn of the century. Perennial streams are confined to the islands with elevations greater than 3,500 ft (1,078 m). Most streams are located along the wetter windward sides of islands where volcanic rocks have weathered to form more impermeable soils. Kauai, being the wettest and most weathered of the high islands, has the most freshwater wetlands in Hawaii.

Prior to western contact, the human populations exerted little modification or control of wetlands with two notable exceptions: many low lying coastal marshes were walled and modified to support wet taro cultivation in ponds called *lo'i*. The downstream reaches of many streams were also walled and diverted to provide a constant supply of water to the taro patches through channels called *auwai*. The Hawaiians also constructed large rock-walled fishpond enclosures along broad shallow reef flats for the purpose of raising and corralling fish. Few of the taro fields, channels and fishponds are in use today, and many have been destroyed during modern urban development or have fallen into disrepair.

Major reclamation of coastal wetlands occurred due to the expanse of plantation-style sugarcane and pineapple culture during the previous century. Large land areas were flattened and graded and irrigation ditches installed in the drier agricultural areas. Many coastal ponds, lakes and marshes must have been buried or drained at this time. Ranching and livestock production also resulted in soil erosion and infilling of many coastal wetlands during the past century. Water was also diverted from large perennial streams along the

windward sides of islands to provide irrigation water for agricultural fields on the leeward (drier) sides. Ditches and tunnels were dug or blasted through mountains, slopes and valleys, to convey the water to the plantations. Rice was grown in Hawaii during the early part of this century, resulting in major loss or modification of wetland habitat. Many marshes and abandoned taro ponds were converted to wet rice culture. Rice did not prove to be economically viable and agricultural operations ceased in the years following World War II. However, taro production never experienced a revival, and many wetland areas remained in a degraded state.

Navigation projects in Hawaii, beginning at the turn of the century, also resulted in the destruction or modification of many coastal wetlands, including port development in Nawiliwili and Hanapepe on Kauai, Honolulu Harbor on Oahu, Kahului and Maalaea harbours on Maui, and Hilo Harbor on Hawaii. Military construction before, during, and after World War II also wrought additional destruction to reefs, fishponds and marshes at the Marine Corps Air Station at Kaneohe Bay, at Honolulu Harbor and at Pearl Harbor. Military airfield construction at Hickam Air Force Base and Bellows Air Force Base, both on Oahu, and channel dredging for Pearl Harbor and Honolulu Harbor modified the salinity and water quality conditions in those areas. Military seaplane dredging at Keehi Lagoon and southern Kaneohe Bay (both on Oahu) destroyed coral reef and estuarine habitats.

Non-military construction for housing and civil works projects has caused the most destruction to Hawaii's coastal wetlands during the post-war era. Large marshes were drained and filled at Ala Wai, Waikiki, Honolulu, Hawaii Kai (Kuapa), Enchanted Lake (Kaelepulu), Kawainui and Salt Lake (all on Oahu), to accommodate major residential or resort projects. Fishponds along the southern shoreline of Kaneohe Bay and some along the coasts of Molokai and Maui were filled for housing projects. Major airfield projects at Keehi Lagoon, Kahului and Hilo resulted in damage or burial of marshes and other wetlands. For example, Kanaha Pond, adjacent to the Kahului airport, has been reduced to less than half its original size, although it still supports large native waterfowl populations.

Stream diversion for agriculture and urban water supply has dried up many streams and degraded habitat for native species of fish which live in streams. Some of the species require migrations to and from the sea as part of their lifestyles, and the diversion of water now prevents these essential life cycle stages in many streams. Stream diversion has also degraded downstream estuarine habitat. The construction of wells and pumping of groundwater have diverted waters that would otherwise feed into streams. Few unmodified and undiverted streams now exist on Oahu, and many others face future diversion on the neighbouring islands (Maui, Molokai, Kauai and Hawaii).

Some public works projects have also benefited wetland habitat. Wetland areas in Pearl Harbor were created as mitigation for airfield construction at Keehi Lagoon. These wetlands are managed by the U.S. Fish and Wildlife Service as successful wildlife refuges. Several reservoirs in the state, including Waita Reservoir on Kauai and the Nuuanu Reservoirs on Oahu, are important habitat for Hawaii's dwindling waterbird populations.

Anchialine pools have been filled for residential or resort development, including a large pond complex at the Waikoloa Resort at Anaeho'omalu, on the island of Hawaii. Other proposed resorts along the western ("Kona") coast of the Big Island threaten additional anchialine pools.

Trash disposal has been implicated in polluting Kawainui Marsh on Oahu. Industrial production of canec board using termiticide additives has polluted ponds in Hilo Bay on Hawaii. Light and heavy industrial pollution in Honolulu has polluted the remaining waters of Keehi Lagoon and Honolulu Harbor. Sewage pollution has degraded habitats in Kawainui Marsh, Kaneohe Bay, Hilo Harbor, West Maui and Honolulu Harbor. Soil erosion and sedimentation from excessive grazing by feral ungulates on Molokai, and ranching and sugarcane culture on several high islands have degraded estuaries, marshes and coral reefs.

Introduced plants (alien species), including mangrove and various weedy grasses, have encroached on fishponds and marshes, leaving only a fraction of the original habitat area. Introduced animals have also had

major impacts on native waterbirds. Mongoose, dogs, cats, rats and pigs are all potential predators of waterbirds or their eggs, and the access of predators to nesting areas severely depletes or eliminates breeding activity. The consequences of habitat degradation and predation have placed all four endemic Hawaiian waterbirds on the verge of extinction. The Hawaiian Duck (*Arius wyvilliana*), Hawaiian Coot (*Fulica alai*), Hawaiian Gallinule (*Gallinula chloropus sandvicensis*) and Hawaiian Stilt (*Himantopus mexicanus knudseni*) are all listed as U.S. Federal Endangered Species, and another common inhabitant of open grasslands and coastal areas, the Hawaiian Owl (*Asio flammeus sandwichensis*), is depleted on several islands. Two other endemic species include the Laysan Duck (*Anas laysanensis*), whose habitat is confined to a saltwater lagoon at Laysan Island, in the northwest end of the Hawaiian chain, and the Hawaiian Goose (*Branta sandvicensis*), which has evolved into a grassland, rather than a wetland species.

The U.S. Fish and Wildlife Service and Hawaii State Division of Forestry and Wildlife have developed considerable resources and programmes to establish marsh and other wetland areas as refuges to protect the endangered waterbirds. Most of the established wildlife refuges on the high islands concentrate on wetland habitats and protection of waterbirds. The Hanalei National Wildlife Refuge on Kauai, the state wildlife preserve at Kanaha on Maui, and the several smaller national wildlife refuges on Oahu are essential for the preservation of Hawaii's endemic waterbirds. Wetlands which are either unprotected or unrestored, such as Kawainui Marsh on Oahu, Kealia Pond on Maui, Makalawena on Hawaii and several playa lakes on Niihau, are of much less importance for waterfowl.

Wetland Research

Important information on waterbirds and their wetland habitats was first collected by ornithologists and members of the Hawaii Audubon Society, and much of the written findings of bird counts is published in a local journal, *Elepaio*, devoted to Hawaiian ornithology. Of particular importance was the tradition among the birding community to conduct simultaneous bird counts at all important bird habitats in Hawaii during a 1-2 day period during the holiday season. Over the years, these so-called "Christmas counts" have provided valuable insights on wetland habitat changes and losses, and trends in population levels for waterbirds, forest birds and seabirds which frequent Hawaii's wetlands. The state and federal fish and wildlife agencies have collected and continue to collect data on a regular basis on the status and condition of existing refuges or preserves and other wetland areas they desire to acquire and establish as refuges or preserves.

Systematic research on Hawaiian wetlands began in earnest with the passage of U.S. laws designed to protect wetlands in the 1970s. The passage of the Clean Water Act and implementing regulations in 1977 and the U.S. Endangered Species Act in 1973 prompted the U.S. Army Corps of Engineers and the U.S. Fish and Wildlife Service to sponsor statewide inventories of selected wetland habitats. The Corps' inventories concentrated on coastal marshes, swamps and fishponds with emergent wetland vegetation, as well as describing a few upland bog areas. Each of about 70 sites on the islands of Oahu, Molokai, Hawaii, Maui and Kauai were surveyed in the field, photographed by air, mapped and evaluated. Wetland boundaries, vegetation zones, threats to wildlife and habitat, and species lists of animals and plants were compiled for each site (Elliott and Hall, 1977; Shallenberger, 1977; Elliott, 1981). These early surveys concentrated on wetlands greater than five acres (two hectares) in size. Later, the U.S. Fish and Wildlife Service concentrated on the inventory of a greater variety of wetland habitats and sizes, using high resolution colour aerial photography and mapping procedures. Their inventory classified and delineated all wetlands according to an ecosystem classification scheme devised by Cowardin *et al.* (1979), and produced a series of maps.

The U.S. Fish and Wildlife Service also sponsored a statewide evaluation on streams in Hawaii (Maciolek and Timbol, 1978; Norton *et al.*, 1978). This inventory resulted in mapping and evaluation of all streams in the state, which in turn led to the development of priorities to protect the most important stream systems. The U.S. Fish and Wildlife Service also sponsored the inventory of Hawaii's large natural lakes (Maciolek, 1969). More recently, the University of Hawaii Environmental Center evaluated the ecologically sensitive wetlands and associated groundwater resources responsible for maintaining those wetlands on the islands of Oahu

and Maui (Miller *et al.*, 1989). The Hawaii Heritage Program of the Nature Conservancy of Hawaii has also field evaluated some upland bog sites and has established a statewide database on certain wetlands, including upland bogs, anchialine pools, perennial streams and some estuaries and embayments. With time, the Heritage database is expected to expand to include other important wetland habitats.

Some individual wetlands in the state have been surveyed because of their important functions as wildlife habitat, flood control and wastewater management. For example, studies have been conducted at Kahana Stream, Oahu's most important stream estuary (Timbol, 1979; Maciolek, 1972; Archer *et al.*, 1980), Nuupia ponds, an important wetland and fishpond complex under the jurisdiction of the Marine Corps on Oahu (Drigot, 1983; Aecos Inc., 1983), Kawainui Marsh, Hawaii's largest remaining wetland (U.S. Army Corps of Engineers, 1981; Smith, 1978; Drigot and Seto, 1982; Chun and Dugan, 1981), Pearl Harbor, Hawaii's largest estuary and only embayment estuary (Evans, 1974; Turner, 1975; U.S. Department of the Interior, 1969), and Keehi Lagoon, formerly an important coastal wetland and marine lagoon complex on Oahu (Harvey, 1970; Berger, 1971; Bathen, 1970). Other important wetland sites on Oahu subject to intensive study include the Kuapa Pond at Hawaii Kai and the Ala Wai Canal, both now severely degraded by extensive dredging and filling but formerly two of Hawaii's most important wetlands. Several National or State wildlife refuges or preserves on Oahu are monitored on a regular basis as part of their overall management programme. On neighbouring islands, wetlands that have been intensively studied include: Hanalei Stream and wetlands, Alakai Swamp and Waita Reservoir on Kauai; Kealia, Cape Kinau-Ahihi and Kanaha wetlands on Maui; coastal fishponds along the southeast coast of Molokai; Kaloko and Makalawena wetlands on Hawaii Island; and wetland habitats at Laysan Island and French Frigate Shoals in the Northwest Hawaiian Islands.

Wetland Area Legislation

Before 1970, the most important U.S. legislation protecting wetlands included the River and Harbor Act of 1899 and the Fish and Wildlife Coordination Act of 1958. The first restricted the discharge of refuse and work in navigable waters of the United States, including wetlands in these waters. The second mandated the involvement of federal and state fish and wildlife agencies during the review and approval stages for civil works "water" projects (harbours, dams, channelization, hydro-power, water supply etc.).

Mitigation requirements to compensate for fish and wildlife losses were introduced at this time.

Passage of the National Environmental Policy Act (NEPA) on 31 December 1969 ushered in a new era of environmental protection in the United States, including significant emphasis on wetland protection. NEPA required federal agencies sponsoring or permitting projects to take into consideration the environmental consequences of their proposed actions, and required preparation of environmental impact assessments or statements for projects possibly resulting in significant impacts. The regulatory programme of the U.S. Army Corps of Engineers, which included administration of the River and Harbor Act (Section 10) permits, was substantially strengthened to evaluate the environmental consequences of proposed action.

Passage of the federal Water Pollution Control Act of 1972, and later the Clean Water Act of 1977, authorized the Corps and the U.S. Environmental Protection Agency to administer a permit programme for the express purpose of protecting wetlands and other special aquatic sites in accordance with section 404 of the Clean Water Act. Federal jurisdiction now extended to inland waters, including streams, adjacent wetlands and isolated wetlands (i.e. the "waters of the United States"), as well as encompassing the traditional navigable water of the United States. The Clean Water Act and Section 404 programme allowed the Corps to deny permit actions involving the discharge of dredged and fill materials in wetlands and other important ecosystems on the basis of environmental concerns. Implementation of this Act has greatly curtailed but not eliminated the filling and draining of wetlands in Hawaii. For example, the remnant portions of Salt Lake wetland are now protected from additional filling. On the other hand, a substantial number of anchialine pools were allowed to be filled during construction of the Waikaloa Resort at Anaehoomalu, Hawaii. The loss of the ponds was partially compensated by the construction of new "artificial ponds" and protection of adjacent natural ponds.

Although the Corps Section 404 and Section 10 permit programme has greatly curtailed the destruction of wetlands in Hawaii, more needs to be done to eliminate discretionary authority and other loopholes that may allow additional wetlands to be filled or drained.

In response to this need, the state and county governments have tried to strengthen their environmental review process to protect wetlands, and have gone so far as to introduce wetlands protection legislation (which has not yet passed).

Other important federal legislation protecting wetlands in Hawaii and the rest of the United States includes the Endangered Species Act of 1973 and the Coastal Zone Management Act of 1972. The Endangered Species Act resulted in the official designation of rare or depleted species as endangered or threatened; as noted earlier, all four endemic Hawaiian waterbird species are now listed as endangered. The listing protects these species from the adverse consequences of federal activities including projects sponsored or funded by the U.S. government, as well as others requiring federal permits.

Section 7 of the Act requires federal agencies to consult with the U.S. Fish and Wildlife Service and the National Marine Fisheries Services during the planning stages of projects to insure that the protective provisions of the Endangered Species Act realized. For example, a Corps permit to a developer can be denied on the grounds that the proposed action could jeopardize the continued existence of an endangered species, according to the biological opinion of the lead federal fish and wildlife agency. The Endangered Species Act also allows funding to carry out research and protect endangered species, and strengthens other authorities which authorize the establishment and management of protected areas including wildlife refuges. A waterbird recovery plan for Hawaii has been developed to help guide future federal fish and wildlife efforts in protecting endangered waterbirds and their important wetland habitat (U.S. Fish and Wildlife Service, 1985).

The Coastal Zone Management Act (CZMA) allows states and territories of the U.S. to develop and implement Coastal Zone Management programmes. Those conforming to federal guidelines are eligible for continuing federal funding under section 306 of the Act. The CZMA has been re-authorized several times during the past 20 years, and continues to serve a strong planning deterrent against unjustified destruction of important coastal habitats. Hawaii received authority for federal funding under the CZMA in 1978, and also passed its own coastal zone management legislation. Both the state and county governments have established permitting procedures to implement their coastal legislation. The counties have a Special Management Area permit system to control or influence development in the coastal zone (usually a zone 300 ft landward from the vegetation line). Also, no development is allowed within a smaller shoreline setback zone of about 40 feet. This ordinance is also administered by the counties. The state has also established a CZM consistency process for permit applications subject to federal approval. Each proposed action must be consistent with the state's CZM programme policies. If not, a permit cannot be issued until the matter is resolved, either by modifying the project in question or elevating the dispute to the lead federal CZM agency, the U.S. Department of Commerce, National Oceanic and Atmospheric Administration.

Although the above account clearly demonstrates federal, state and county resolve in protecting wetlands, still many existing wetlands, especially those along the coast, may be destroyed or degraded by future development or pollution activities. More importantly, little legislation has been passed and funded to restore degraded wetlands, including removal of exotic (alien) species of plants, establishing protected nesting sites, predator removal and control (e.g. fencing moats, nesting islands, trapping etc.), and to develop a unified regulatory policy for wetland protection. The prospects are good that additional legislation will be passed and implemented in the next few years to provide comprehensive protection to wetlands in Hawaii and elsewhere in the United States.

Wetland Area Administration

Wetlands in the State of Hawaii are administered by several state and one federal agency, and two agencies at county level. The U.S. Fish and Wildlife Service is responsible for managing National Wildlife Refuges in Hawaii, including refuges at the Campbell Complex (northeast Oahu), the Pearl Harbor complex (south Oahu), the Northwest Hawaiian Islands (all islands and reefs north of Kaula and south of Midway), Hanalei, Kilauea and Huleia (on Kauai), and Kakahaia (on Molokai). The State of Hawaii Department of Land and Natural Resources is responsible for administration of state refuges including the important wetland areas and Natural Area Reserves. Recently, administration of Kawainui Marsh was also transferred to the Department of Land and Natural Resources. The City and County of Honolulu is responsible for managing parks, some of which include wetlands, such as the man-made lake and marsh created on Hoomaluhia and the natural wetland and fishpond at Kualoa (both on Oahu). The county governments of the neighbouring islands may also be similarly involved with the management of parks with important wetlands. Upland bogs are found within several preserves administered by The Nature Conservancy of Hawaii, including reserves on Maui, Molokai and Oahu. The Alakai Swamp, Hawaii's largest upland bog and second largest wetland, is administered by the State of Hawaii Department of Land and Natural Resources. A number of other important wetlands in Hawaii are under private ownership.

Organizations involved with Wetlands

a) Governmental Organizations

(1) U.S. Federal Government

- U.S. Department of the Interior, Fish and Wildlife Service
 - National Wildlife Refuges
 - Administration of Migratory Bird Treaties; renewal of federal permits for compliance with the Endangered Species Act and Fish and Wildlife Coordination Act.
- U.S. Department of Commerce, National Oceanic and Atmospheric Administration
 - National Marine Fisheries Service
 - Renewal of federal permits for compliance with the Endangered Species Act and Fish and Wildlife Coordination Act.
 - Office of Oceans and Coastal Resources
 - Administration of the Coastal Zone Management Program; administration of the National Marine and Estuarine Sanctuaries.
- U.S. Environmental Protection Agency
 - Review and veto power over Corps of Engineers Section 404 permits; Section 404(b)(1) guidelines on wetlands and special aquatic sites; oversight responsibility for state managed water quality monitoring programme; various grants and research on wetlands and other valuable ecosystems.
- U.S. Department of Defense, Department of Army, Corps of Engineers Administration of the Section 10 and Section 404 permit programme, wetlands research, mitigation and restoration as part of its civil works mission.

(2) State of Hawaii Government

Department of Land and Natural Resources

- Division of Forestry and Wildlife
 - Management of wildlife refuges.
- Natural Area Reserve Commission
 - Management of natural area reserves.
- State Water Commission

- Regulates diversion of stream water flow.
- Division of State Parks
 - Management of State Parks.

Office of State Planning

- Management of the State's Coastal Zone Management Program

Department of Health

- Environmental and Health Services Division
 - Management of the State Water Quality Monitoring Program.

Office of Environmental Quality Control, Environmental Quality Commission Management of the State's Environmental Impact Statement Program.

(3) **County Level Governments**

Department of Parks and Recreation

- Management of county parks.

Department of Land Utilization and Planning

- Management of the Special Management Area Permit and Shoreline Setback System.

Department of Public Works

- Enforcement of grading ordinances.

b) **Non-governmental Organizations**

The Nature Conservancy of Hawaii

- Administration of the Hawaii Heritage Program, a database of natural communities and rare and endangered species; management of ecological preserves either owned by The Nature Conservancy or other agencies and landowners.

The Hawaii Audubon Society

- Lobbying on behalf of wetland protection; organization of annual bird censusing projects.

Kawai Nui Heritage Foundation

- Watchdog organization over the future of Kawainui Marsh, Oahu.

Oceanic Institute

- Research on anchialine pools.

University of Hawaii

- Departments of Zoology and Botany
 - Research on wetland biology and ecology.
- Sea Grant Extension Service
 - Extension services on aquaculture and coastal conservation.

Sierra Club, and Sierra Club Legal Defense Fund

- Lobbying and watchdog organization with interest in the protection of natural ecosystems.

Acknowledgments

The John D. and Catherine T. MacArthur Foundation provided a grant to the East-West Center Program on Environment (Lawrence Hamilton, principal investigator), which covered the time spent by James E. Maragos on the Hawaii Introduction.

The U.S. Environmental Protection Agency, the State of Hawaii Department of Health and the East-West Center (Richard Carpenter, study director) provided access to data from the Hawaii Environmental Risk Ranking Study.

The Environmental Center, University of Hawaii, provided information on ecologically sensitive wetlands on Maui and Oahu.

The Nature Conservancy of Hawaii provided information on rare natural communities in Hawaii through the Hawaii Heritage Program database.

WETLANDS

An Hawaiian Islands Wetland Database has been established by Karin Z. Meier as the Hawaiian contribution to the Oceania Wetland Inventory. This database, which will eventually contain information on over 450 wetlands, pulls together information on Hawaiian wetlands from numerous sources and presents it in a readily accessible form for use by government departments, conservation bodies and research institutions throughout the State of Hawaii. The database includes information on the location of each wetland, the wetland type (following the wetland classification system of Cowardin *et al.*, 1979), the geology of the area and the soil type, along with basic information on a wide variety of parameters such as protection status, social significance, physical significance, water source, water quality, aquifer system, aquifer type (hydrology and geology), development stage, utility, uniqueness and vulnerability to contamination. In many instances, the database also includes detailed lists of animal and plant species recorded at the site.

All sites included in the database have been identified as being of special conservation importance by one or other of the agencies or institutions involved with wetlands in the State. However, in many instances the information in the database is inadequate to permit evaluation on the basis of the Ramsar criteria, and it is unclear as to how many of the wetlands would qualify as wetlands of international importance in the context of the Ramsar Convention.

By February 1993, the Hawaiian Islands Wetland Database contained information on 386 sites. These included 171 perennial streams, 162 anchialine pool systems, 37 lowland ponds, marshes and coastal wetlands, six montane marshes and bogs, five reservoirs, four hypersaline lakes and one high altitude lake (see Table 1). However, information had still not been compiled for some 70 or 80 wetlands, including many of Hawaii's most important sites, notably the extensive riverine wetlands in Polulu, Waimanu and Waipio valleys in northern Hawaii, Kawainui Marsh on Oahu (the largest freshwater swamp and marsh in Hawaii), about 20 coastal ponds, marshes and riverine wetlands on Kauai, and Alakai Swamp, also on Kauai. The latter is much the largest and most important montane swamp in the State of Hawaii.

Much of the information in the Hawaiian Islands Wetland Database is stored in a form which cannot easily be adapted for presentation as site accounts of the type used elsewhere in this Directory. For this reason, and because of the major gaps in the database at the time of going to press, no attempt has been made to present a series of site accounts here. It is to be hoped that a summary of the data in the database will be published for wider dissemination when the main task of data compilation has been completed.

Table 1: Wetlands included in the Hawaiian Islands Wetland Database (February 1993)

Wetland type	Island	No. of sites	
Streams	Hawaii	38	Maui
	51	Molokai 5	
	Oahu	40	Kauai
	37		
Anchialine pools	Hawaii	126	Maui
	9	Kahoolawe	1
	Molokai	1	Oahu
	5		
Lowland ponds, marshes and coastal wetlands	Maui	7	Oahu
	30		
Montane marshes and bogs	Maui	5	Oahu
	1		
Reservoirs	Oahu	5	
Hypersaline lakes	Niihau	3	Laysan
	1		
High altitude lakes	Hawaii	1	

REFERENCES

(including references used in the compilation of the Hawaiian Islands Wetland Database)

- Aecos, Inc. (1977).** Field notes from Kanaha Pond. Honolulu, Hawaii. Unpublished report. 6 pp.
- Aecos, Inc. (1979).** Kanaha Pond, Hawaii coral reef inventory, island of Maui. U.S. Army Corps of Engineers, Pacific Ocean Division. Honolulu, Hawaii. Unpublished report. 84-95 pp.
- Aecos, Inc. (1983a).** Hydrological patterns and water quality of the Nuupia Ponds, Marine Corps Air Station, Kaneohe Bay, Island of Oahu, Hawaii. Prepared for the U.S. Fish & Wildlife Service. Rep. No. Aecos-374.
- Aecos, Inc. (1983b).** Draft Environmental Impact Assessment Marine Culture Enterprises Kahuku Aquaculture Facility, Kahuku, Oahu, Hawaii. Prepared for Marine Culture Enterprises, Tucson, Arizona. 222 pp.
- Aoyama, S.S. & Young, R.H.F. (1974).** A study of the effects of secondary effluent on Waimano and

- Waiawa Streams. Technical Report No.76. Water Resources Research Center, University of Hawaii, Honolulu. 49 pp.
- Apple, R. A. & Kikuchi, W.K. (1975).** Ancient Hawaii Shorezone Fishponds: An Evaluation of Survivors for Historic Preservation. National Park Service. 157 pp.
- Archer, K.M., Timbol, A.S. & Parrish, J.D. (1980).** Biological survey of Kahana Stream system: final report. Technical Report No.80-2. Hawaii Cooperative Fishery Research Unit, Honolulu, Hawaii. 40 pp.
- Belt Collins & Associates (1987).** Final Environmental Impact Statement Waialua-Haleiwa wastewater facilities plan. Prepared for Department of Public Works, City and County of Honolulu, Hawaii. 269 pp.
- Berger, A.J. (1972).** Kanaha Pond bird study; final report. Prepared for Hawaii Division of Fish and Game, Honolulu, Hawaii. Unpublished report. 35 pp.
- Bishop Corporation (1974).** An Assessment of Environmental Impact resulting from the proposed expansion of Waimea Falls Park. 37 pp.
- Board of Water Supply (1980).** Environmental Impact Statement Kahalu`u Well. City and County of Honolulu, Hawaii. 43 pp.
- Board of Water Supply (1982).** Environmental Impact Statement for Ioleka`a Well. City and County of Honolulu, Hawaii. 40 pp.
- Brock, R. (1985).** An assessment of the conditions and future of the anchialine pond resources of the Hawaiian Islands. TDC.
- Canfield, J.E. (1987).** Description and Map of the Plant Communities of Ka-loko-Honoko-hau National Cultural Park. Draft of University of Hawaii Cooperative National Parks Resource Study Unit. 39 pp. Mimeo.
- Carpenter, R.A., Maragos, J.E. & Meier, K.Z. (1992).** Environmental Risks to Hawaii's Public Health and Ecosystems. A report of the Hawaii Environmental Risk Ranking Study to the State of Hawaii Dept of Health. Honolulu, Hawaii.
- Chai, D. (1987).** Anchialine ponds of King's Landing and Keaukaha. Unpublished manuscript.
- Chai, D. (1988a).** An Inventory and Assessment of Kaloko Pond, Marsh and Anchialine Pools at Kaloko-Honokohau National Historical Park, North Kona, Hawaii. CPSU Report, draft.
- Chai, D. (1988b).** Field forms for survey of Ahihi-Kinau NAR, March 1988.
- Chinn, SS., Tateishi, G.A. & Yee, J.J.S. (1985).** Water resources data: Hawaii and other Pacific areas - water year 1985. Volume 1. U.S. Geological Survey Water-Data Report HI-85-1. Prepared in cooperation with Division of Water and Land Development, Dept. of Land and Natural Resources, State of Hawaii, Honolulu, Hawaii. 302 pp.
- Cowardin, L.M., Carter, V., Golet F.C. & LaRoe, E.T. (1979).** Classification of Wetlands and Deepwater Habitats of the United States. Biological Services Program. Fish and Wildlife Service, U.S. Department of the Interior, Washington. 103 pp.
- Cox, D.C. (1980).** Stream-flow effects of proposed diversion from Hanawi Stream, Nahiku, East Maui. SR:0026. Environmental Center, University of Hawaii, Honolulu. 15 pp.
- Cox, D.C. & Gordon, L.C. Jr. (1970).** Estuarine pollution in the State of Hawaii. Technical Report No. 31. Water Resources Research Center, University of Hawaii, Honolulu. 151 pp.
- Dames & Moore (1986).** Installation restoration program phase II: confirmation/quantification stage 1. Prepared for Hickam Air Force Base, O`ahu, Hawaii. 28 pp.
- De Aussen, T.T. (1966).** Coastline ecosystems in O`ahu, Hawaii. Master thesis (Botany), University of Hawaii, Honolulu. 114 pp.
- Denison, D.O. (1975).** An archaeological reconnaissance survey of Punalu`u Lands, Punalu'u, O`ahu. Prepared by Bernice P. Bishop Museum for Kaluanui Ventures, Department of Anthropology. 43 pp.
- Department of Land and Natural Resources (1983).** Statewide waterbird marking/movement study. Project No. W-18-R-8; Job No. R-III-F. 7 pp.
- Department of Land and Natural Resources (1983-85).** Statewide nongame and endangered species program. Project No. W-18-R-9, R-10; Job No. R-III-E(b). 2 pp.
- Department of Land and Natural Resources (1984a).** Surveys and inventories of waterbirds in the State of Hawaii. Project No. W-18-R-8; Job No. R-III-A. 33 pp.

- Department of Land and Natural Resources (1984b).** Statewide waterbird marking, movement, and disease study. Project No. W-18-R-9; Job No. R-III-F. 5 pp.
- Department of Land and Natural Resources & National Park Service (1990).** Hawaii Stream Assessment. Draft.
- Division of Public Works (1963).** A plan for development of a wildlife sanctuary and public park at Kanaha Pond, Kahului, Maui. In consultation with R.I. Bush for Department of Accounting and General Services, State of Hawaii, Honolulu. 38 pp.
- Elliott, M.E. (1981).** Wetlands and wetland vegetation of the Hawaiian Islands. Master thesis (Geography), University of Hawaii, Honolulu, Hawaii. 228 pp.
- Elliott, M.E. & Hall, E.M. (1977).** Wetlands and wetland vegetation of Hawaii. Prepared for the U.S. Army Corps of Engineers, Engineer District, Honolulu, Hawaii. 344 pp.
- Environmental Communications, Inc. (1978).** Environmental Impact Statement for the proposed Waikane residential subdivision, Waikane, Koolaupoko, O`ahu. 66 pp.
- Environmental Communications, Inc. (1981).** Final Environmental Impact Statement for the proposed Punalu`u Shores Project: Punalu`u, Koolauloa, O`ahu. 128 pp.
- Environmental Impact Study Corporation (1981).** Environmental Impact Statement for Honouliuli Wells. Prepared for the Board of Water Supply, City and County of Honolulu, Hawaii. 189 pp.
- Environmental Impact Study Corporation (1982).** Revised Environmental Impact Statement, Makawao and Kula water treatment plants. Prepared for Department of Water Supply. County of Maui, Hawaii. 126 pp.
- Evans, E.C. (1974).** Pearl Harbor biological survey: final report. Prepared for the Naval Undersea Center, San Diego, California. 800 pp.
- Evans, E.C., Murchison, A.E., Peeling, T.J. & Stephen-Hassard, Q.D. (1972).** A proximate biological survey of Pearl Harbor, O`ahu. Prepared for the Naval Undersea Research and Development Center, San Diego, California. 65 pp.
- Ford, J. & Yuen, A. (1988).** Natural history of Pelekunu Stream and its tributaries. Island of Molokai, Hawaii.
- Garnett, W. (1992).** Field notes from Kanaio survey, Maui. Unpublished report.
- Gon, S.M. (1976).** A preliminary report: The freshwater fauna of the Manawainui region. Manawainui research project, National Science Foundation. 289-298 pp.
- Gon, S.M. (1987a).** Note to anchialine pond files: pond in Kahaualea area. Memo, Hawaii Heritage Program.
- Gon, S.M. (1987b).** Trip report: Hawaii Island visit to anchialine ponds. Memo, Hawaii Heritage Program.
- Gon, S.M. (1988).** Observation of aerial photographs and USGS topo map of Niihau.
- Gon, S.M. (1992).** Field notes and observations from Kahoolawe field survey, February 1992.
- Gray, Hong & Associates (1982).** Revised Environmental Impact Statement for the proposed Kahalu`u industrial project development. 252 pp.
- Gray, Hong & Associates (1986).** Draft Supplemental Environmental Impact Statement for He`eia Kea Valley, He`eia, Koolaupoko, O`ahu. 99 pp.
- Green, R.E., Goswami, K.P., Mukhtar, M. & Young, H.Y. (1977).** Herbicides from cropped watersheds in stream and estuarine sediments in Hawaii. *J. Environ. Qual.* 6(2): 145-154.
- Group 70, Planners. (1985).** Revised Environmental Impact Statement for the proposed Kuilima Resort expansion, Vol I. Prepared for Kuilima Development Company, Honolulu, Hawaii. 200 pp.
- Hall, D.H. (1970).** Use of agricultural chemicals and factors contributing to their transport to estuaries in Hawaii. Technical report No.30. Water Resources Research Center, University of Hawaii, Honolulu, Hawaii. 44 pp.
- Hawaii Heritage Program (1988).** Field forms for Maui Land and Pineapple survey, October 1988.
- Hawaii Heritage Program (1990).** Biological information on distribution of indicator species in North Kauai.
- Hawaii Heritage Program (1991a).** Field forms and notes from Waianapanapa State Park survey, February 1991.
- Hawaii Heritage Program. (1991b).** Field notes from survey of Kiholo State Park, April 1991.
- Hee & Associates, Inc. (1980).** Environmental Impact Statement for 42-inch waterline from Waihe`e booster station to intersection of Likelike Highway and Kamehameha Highway. 34 pp.
- Hirota, Inc. (1983a).** Draft environmental impact statement for Kaupo water system improvements.

- Prepared for Department of Water Supply, County of Maui, Hawaii. 89 pp.
- Hirota, Inc. (1983b).** Draft environmental impact statement for Wailua - Hana water systems improvements. Prepared for Department of Water Supply, County of Maui, Hawaii. 84 pp.
- Howarth, F. (1992).** Descriptions of biologically significant caves of coastal lands of the Kiholo Bay area. Draft report.
- IUCN (1991).** IUCN Directory of Protected Areas in Oceania. Prepared by the World Conservation Monitoring Centre. IUCN, Gland, Switzerland and Cambridge, U.K.
- Johnson, J.M. (1972).** Kanaha Pond baseline data. Environmental Center unpublished report prepared for the Office of Environmental Quality Control and Department of Land and Natural Resources, Division of Fish and Game, Honolulu. 12 pp.
- Kensley, B. & Williams, D. (1986).** New shrimps (families Procarididae and Atyidae from a submerged lava.
- Kjargaard, J.I. (1972).** Scientific report of the Waihoi Valley Project. Prepared for the National Science Foundation. University of Hawaii, Honolulu. 252 pp.
- M & E Pacific, Inc. (1985).** Revised Environmental Impact Statement for the Waiahole Valley agricultural park and residential lots subdivision, Koolaupoko, O`ahu, Hawaii. 185 pp.
- Maciolek, J.A. (1969).** II. Lakes. 5. Oceania, New Zealand, Antarctica. Freshwater Lakes in Hawaii. Verh.
- Maciolek, J.A. (1971).** Aquatic ecosystems of Kealia Floodplain and Maalaea Bay, Maui; evaluation for perpetuation and public use. Hawaii Institute of Marine Biology, University of Hawaii, Honolulu. Technical Report No.27. 42 pp.
- Maciolek, J.A. (1972).** Diadromous Macrofauna and the Kahana Stream-Estuary Ecosystem. Terminal report for U.S. Fish and Wildlife Service, contract periods: 15 June 1970 to 15 June 1971 and 15 June 1971 to 15 June 1972. Contract numbers: 14-16-0001-4085; 14-16-0001-3476. 22 pp.
- Maciolek, J.A. (1982).** Lakes and lake-like waters of the Hawaiian Archipelago. Occasional papers of Bernice P. Bishop Museum 25(1): 1-14. Bishop Museum Press, Honolulu.
- Maciolek, J.A. (1986).** Environmental features and biota of anchialine ponds on Cape Kinau, Maui, Hawaii.
- Maciolek, J.A. & Brock, R. (1974).** Aquatic survey of the Kona coast ponds, Hawaii Island. UNIHI-Seagrant Report AR-74-04.
- Marshall, A.P. (1993).** The Status of the Laysan Duck. IWRB Threatened Waterfowl Research Group Newsletter No.3: 11-12. IWRB, Simbridge, U.K.
- Miller, J.N., Armann, SS., Chan-Hui, S.S.C. & Chiang, J. (1989).** Ecologically sensitive wetlands on Oahu: groundwater protection strategy for Hawai'i. Environmental Center Water Resources Research Center, University of Hawaii at Manoa. Honolulu, Hawaii. 369 pp.
- Mogi Planning and Research, Inc. (1974).** Kahana Valley State Park, O`ahu, Hawaii. Prepared for State of Hawaii Department of Land and Natural Resources, Division of State Parks. 63 pp.
- Mogi Planning and Research, Inc. (1978).** Draft Environmental Impact Statement for Kahana Valley State Park. 173 pp.
- National Park Service (1990).** Draft Resources Management Plan, Kaloko-Honokohau National Historical Park. National Park Service, Honolulu, Hawaii.
- Natural Area Reserves System (1988a).** West Maui Natural Area Reserve Management Plan. Prepared for the Department of Land and Natural Resources, State of Hawaii, Honolulu. Unpublished draft. 40 pp.
- Natural Area Reserves System (1988b).** Hanawi Natural Area Reserve Management Plan. Prepared for the Department of Land and Natural Resources, State of Hawaii, Honolulu. 33 pp.
- Newman, A. (1986).** Anchialine pond field survey report, 14-15 June 1986. Memo, Hawaii Heritage Program.
- Norton, S.E., Timbol, A.S. & Parrish, J.D. (1978).** Stream channel modification in Hawaii. Part A: Statewide inventory of streams, habitat factors and associated biota. Part B: Effect of channelization on the distribution and abundance of fauna in selected streams. Prepared for U.S. Fish & Wildlife Service, U.S. Department of the Interior. 157 pp & 47 pp.
- Nylen, A.R. & Nylen, R.H. (1984).** Final Environmental Statement/Proposed Residences at: 47-395 Ahaolelo Road, Kahalu'u, O`ahu. 22 pp.
- Oi Consultants, Inc. (1985).** Anchialine pond survey of the northwest coast of Hawaii Island.

- Okuda, B.R. Inc. (1987).** Final Environmental Impact Statement for the proposed general plan secondary resort area at Mokuleia. 107 pp.
- Park Engineering, Inc. (1977).** Environmental Impact Statement for Haleiwa Road drainage improvement project. Department of Public Works, City and County of Honolulu, Hawaii. 36 pp.
- Shallenberger, R.J. (1977).** An ornithological survey of Hawaii wetlands. 2 vols. Prepared for the U.S. Army Corps of Engineers, Engineer District, Honolulu, Hawaii. 131 pp & 278 pp.
- Stearns, H.T. (1985).** Geology of the state of Hawaii. 2nd edition. Pacific Books. Palo Alto, California. 335 pp.
- Stearns, H.T. & Macdonald, G.A. (1942).** Geology and ground-water resources of the island of Maui, Hawaii. Honolulu Advertiser Publishing Co. 344 pp.
- Stemmerman, M.A. (1976).** Ornithology report, Manawainui research project, National Science Foundation. 209-233 pp.
- Taniguchi, Ltd., P.T. (1982).** Revised Environmental Impact Statement for the deep well pump and construction of control building for Haiku Well at Haiku Valley, Koolaupoko, O`ahu. Board of Water Supply, City and County of Honolulu, Hawaii. 22 pp.
- Theobald, W.L. (1973).** Kahana Valley botanical survey, Koolauloa, island of O`ahu. Division of State Parks, Department of Land and Natural Resources, State of Hawaii. 57 pp.
- Thomas, K. (1973).** A contribution to the ecology and distribution of annelids in Paiko Lagoon, O`ahu. Master thesis (Zoology), University of Hawaii, Honolulu. 109 pp. **Timbol, A.S. (1972).** Trophic ecology and macrofauna of Kahana Estuary, O`ahu. Ph.D. thesis (Zoology), University of Hawaii, Honolulu. 228 pp.
- Timbol, A.S. (1979).** Limnological survey of Kahana Stream, O`ahu. U.S. Army Corps of Engineers, Pacific Ocean Division, Honolulu, Hawaii. 48 pp.
- Timbol, A.S. & Maciolek, J.A. (1978).** Stream channel modification in Hawaii. Part A: Statewide inventory of streams, habitat factors and associated biota. Prepared for U.S. Fish and Wildlife Service, U.S. Department of the Interior. 157 p.
- Towill, R.M. Corp. (1974).** Environmental Impact Statement for excavation and quarrying use at Waihee, O`ahu. 16 pp.
- Towill, R.M. Corp. (1979).** Environmental Impact Statement for the Kahalu`u wastewater treatment and disposal system. Prepared for the Department of Public Works, City and County of Honolulu, Hawaii. 124 pp.
- Towill R.M. Corp. (1981).** Environmental Impact Statement for the Kahana Valley water development project. 62 pp.
- Towill R.M. Corp. (1983).** Revised Environmental Impact Statement for Kahana 315 Reservoir project. Prepared for Board of Water Supply, City and County of Honolulu. 43 pp.
- Turner, B.W. (1975).** Mineral distribution within the Sediments of Pearl Harbor. Master thesis (Geology), University of Hawaii, Honolulu. 93 pp.
- UNEP/IUCN (1988).** Coral Reefs of the World. Volume 3: Central and Western Pacific. UNEP Regional Seas Directories and Bibliographies. IUCN, Gland, Switzerland and Cambridge, U.K./UNEP, Nairobi, Kenya.
- U.S. Army Corps of Engineers (1969).** Flood plain information: Ka`a`awa, O`ahu, Hawaii. Prepared for the State of Hawaii and the City and County of Honolulu, Hawaii. 25 pp.
- U.S. Army Corps of Engineers (1977).** Detailed project report, beach erosion control and Final Environmental Statement for Kualoa regional park, O`ahu, Hawaii. U.S. Army Corps of Engineers, Engineer District, Honolulu, Hawaii. 78 pp.
- U.S. Army Corps of Engineers (1979).** Detailed project report and environmental statement, Waiehu Beach Park (Withdrawn). 63 pp.
- U.S. Department of Agriculture, Soil Conservation Service (1972).** Soil survey of islands of Kauai, Oahu, Maui, Molokai, and Lanai, State of Hawaii. In cooperation with the University of Hawaii Agricultural Experiment Station. 232 pp.
- U.S. Department of Agriculture, Soil Conservation Service (1975).** Final Environmental Impact Statement Kahalu`u watershed project. 93 pp.
- U.S. Department of the Interior (1969).** Report on pollution of the navigable waters of Pearl Harbor. Federal Water Pollution Control Administration, Pacific Southwest Region. 55 pp.

- U.S. Fish and Wildlife Service (1985a).** Recovery plan for the Hawaiian Waterbirds. Prepared for U.S. Fish and Wildlife Service, Portland, Oregon. 99 pp.
- U.S. Fish and Wildlife Service (1985b).** Master plan for the Hawaiian Wetlands National Wildlife Refuge Complex. U.S. Fish and Wildlife Service, Honolulu, Hawaii. 77 pp.
- U.S. Geological Survey (1965).** Effects of water withdrawals by tunnels, Waihe`e Valley, O`ahu, Hawaii. In cooperation with State of Hawaii Department of Land and Natural Resources, Division of Water and Land Development, Hawaii.
- Walsh, G.E. (1963).** An ecological study of the He`eia mangrove swamp. Ph.D. thesis (Philosophy), University of Hawaii, Honolulu, Hawaii. 219 pp.
- Wanket, W.E. Inc. (1987).** Final Environmental Impact Statement Mokuleia development proposal, Mokuleia, O`ahu. 120 pp.
- Wilson Okamoto & Associates (1977).** Kahakuloa water study. Report No.R54. Prepared for the Department of Land and Natural Resources, Division of Water and Land Development, State of Hawaii, Honolulu, Hawaii. 84 pp.
- Wilson Okamoto & Associates (1979).** Environmental Impact Statement for the Salt Lake District Park. Prepared for the Department of Parks and Recreation, City and County of Honolulu, Hawaii. 136 pp.
- Wilson Okamoto & Associates (1987).** Draft Environmental Impact Statement Waialua-Kahuku regional water system improvements. Prepared for Board of Water Supply, City and County of Honolulu, Hawaii. 135 pp.
- Windward O`ahu Soil, Water Conservation District and City and County of Honolulu (1969).** Watershed work plan: Kahalu`u watershed (Wat Re-H 57 6B). 72 pp.
- Wirawan, N. (1974).** Floristic and structural development of native dry forest stands at Mokuleia, N.W. O`ahu. Master thesis, University of Hawaii, Honolulu, Hawaii. 123 pp.
- Yuen, A. (1986).** Preliminary aerial survey of coastal ponds between Leleiwi Point and Ka Lae, Hawaii. U.S. Fish and Wildlife Service report.
- Yuen, A. (1987).** Notes on ponds in vicinity of Hanamanioa, Maui. Unpublished report.