Inventory & Monitoring Program
Pacific Island Network
Monitoring Plan

Appendix A: Water Quality Report

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30 September 2004

Pacific Island Network (PACN)

Territory of Guam
War in the Pacific National Historical Park (WAPA)

Commonwealth of the Northern Mariana Islands
American Memorial Park, Saipan (AMME)

Territory of American Samoa
National Park of American Samoa (NPSA)

State of Hawaii
USS Arizona Memorial, Oahu (USAR)
Kalaupapa National Historical Park, Molokai (KALA)
Haleakala National Park, Maui (HALE)
Ala Kahakai National Historic Trail, Hawaii (ALKA)
Puukohola Heiau National Historic Site, Hawaii (PUHE)
Kaloko-Honokohau National Historical Park, Hawaii (KAHO)
Puuhonua o Honaunau National Historical Park, Hawaii (PUHO)
Hawaii Volcanoes National Park, Hawaii (HAVO)

http://science.nature.nps.gov/im/units/pacn/monitoring/plan/2004/

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EXECUTIVE SUMMARY

The PACN water quality workgroup is developing a monitoring plan to assess status and trends in freshwater, marine, and groundwater water resources that include streams, lakes, wetlands, fish ponds, anchialine pools, tide pools, coastal, and interstitial waters. The overall goal of NPS water quality monitoring is to gather data that will enable the network to develop a comprehensive understanding of water quality resource management challenges.

All the PACN network parks are located on tropical islands in the Pacific Ocean. The PACN covers a large geographical area that is governed by four different entities; the Territory of Guam, the Commonwealth of the Northern Mariana Islands, the Territory of American Samoa, and the State of Hawaii. Accordingly, legislation concerning PACN parks and their natural resources varies greatly. The most significant legislation to the water quality workgroup is the United States Clean Water Act (CWA) of 1977 requiring States and Territories to identify and publish water quality standards, those waters that do not meet the adopted standards, and the ones not expected to meet the standards. Prior to the CWA, the Coastal Zone Management Act (CZM) of 1972 established a voluntary national program within the Department of Commerce to encourage coastal States and territories to develop and implement coastal zone management plans that would define the boundaries of the coastal zone, identify uses of the area to be regulated by the State, the mechanism for controlling such uses, and broad guidelines for priorities of uses within the coastal zone.

Unlike emergent, dry, or fast lands, submerged lands and their resources are often not owned or administered by the NPS. Approximately one third of the marine areas within War in the Pacific NHP in Guam are owned by the NPS. The remaining lands are owned by the Territory of Guam or the U.S. Navy. In American Samoa (AS), the offshore waters for the National Park of American Samoan are under government jurisdiction but administered by the local villages and the AS Department of Marine and Wildlife Resources manages and protects the marine resources. The Commonwealth of the Northern Mariana Islands (CNMI) owns and administers the submerged land adjacent to American Memorial Park (AMME). The State of Hawaii owns and administers the submerged lands below the high tide line within three miles of all fast land within the state through the Department of Land and Natural Resources.

The water quality workgroup has developed a conceptual model to help distinguish causal relationships between natural resources, human activity, nature, and water quality. Discussion about the model will assists managers and monitoring planners in communicating complex ideas about ecological processes when selecting parameters for water quality monitoring.

Three types of water resources are shared by PACN parks; marine, freshwater, and groundwater. Some types of water bodies found in the PACN sub-alpine lakes, wetlands, coastal and submerged springs, shoreline fishponds, tide pools, anchialine pools, and a crater lake. All PACN parks are concerned about adjacent land uses and their impact to water resources.

- **War in the Pacific National Historical Park** (WAPA) contains over 1000 acres of marine area, a wetland, and numerous streams within the park's boundary. Sedimentation, intense fishing, sewage, litter, and the presence of relic WWII military equipment, including large numbers of unexploded ordinance are some of the water quality concerns for this park. WAPA has a marine natural resources program that has

recently attained critical mass in staffing and has begun the development of a comprehensive marine program.

- **American Memorial Park** (AMME) has no submerged lands within its boundary but contains an extensive wetland with native mangroves. In addition to threats associated with terrestrial runoff, areas offshore of AMME are impacted by a closed landfill adjacent to the park and the wetland area has been severely impacted by historical land use. Sea level rise is also a concern to this low-lying park.
- **National Park of American Samoa** (NPSA) contains extensive coral reefs and pristine streams which may be impacted by the rapid population growth in the region. Water quality at NPSA is impacted by non-point source pollution, groundwater withdrawal, and nutrients from human and animal wastes as well as other contaminants. Global warming and the subsequent increase in water temperature is also a concern there.
- **USS Arizona Memorial Park** (USAR) boundary does not extend past the high tide line, but the park does have joint jurisdiction with the US Navy over two submerged vessels: the USS Arizona and the USS Utah. This jurisdiction does not extend to the surrounding marine area of Pearl Harbor, which is a heavily altered and impacted embayment due to extensive and long-standing Naval operations and increasing urban development.
- **Kalaupapa National Historical Park** (KALA) legislative boundary extends a quarter mile offshore, and in addition to pristine marine resources, encompasses three offshore islands. The primary concern to water resources of this park is diversion of streams to supply upland development. This park boasts a crater lake with unique water quality characteristics.
- **Haleakala National Park** (HALE) boundary ends at the high tide line but has extensive and somewhat isolated intertidal regions, coastal springs, and pristine isolated streams. As with KALA, stream diversion and encroaching development are the main impacts to water quality in this park.
- **Ala Kahakai National Historic Trail** (ALKA) is a 175 mile trail corridor traversing the West Hawaii coast from the northern Upolu Point south to Ka Lae, and continuing up the Eastern side up through Hawaii Volcanoes National Park. Although this park does not technically include the nearshore marine areas, the water quality issues of this park are the same as those described for the four other PACN parks located on Hawaii Island:
- **Puukohola Heiau National Historic Site** (PUHE) administrative boundary extends into the marine area of Pelekane Bay. The park has an ephemeral brackish water pond located in an otherwise dry gulch which is impacted by flood events during periods of high rainfall upslope. Upland development and ranching contribute to erosion, runoff and associated sedimentation of Pelekane Bay. Kawaihae Small Boat Harbor is adjacent to the park and is slated for expansion.
- **Kaloko-Honokohau National Historical Park** (KAHO) contains numerous anchialine ponds, two fish ponds, and a large embayment down slope of a growing industrial area. Adjacent land use may contribute to contamination and nutrient loading of the groundwater which feeds the wetlands and anchialine pools which are subsequently conneted to the marine waters. A small boat harbor is located between park units and is a

source of petroleum, heavy metals, and phosphates from wash water. The threat of sedimentation onto the coral reef is increased by pond restoration activities, erosion of the sandy shoreline, and dredging and/or expansion of the harbor.

- **Puuhonua o Honaunau National Historical Park** (PUHO) boundary ends at the high tide line. Urban development up-slope from the park and the high level of tourism can have an impact on the water quality (sediment, nutrients, and contaminants) of springs, fishponds, tide pools, and the near shore marine environment. Island subsidence and the rising sea level, due to global, warming, may eventually lead to flooding of this low coastal park.
- **Hawaii Volcanoes National Park** (HAVO) boundary ends at the high tide line, limiting its significant marine resources to coastal intertidal areas, anchialine pools, and bogs in the upland rainforest. There are no known streams or lakes located in this park which is primarily made up of relatively fresh volcanic flows. Although the coastal area is large, the man-made stressors are limited by the volcanic activity which is the main agent of change there.

Various water quality studies are in progress or are being planned to assess conditions at or near PACN. Few of these programs involve long-term monitoring plans and even fewer are comprehensive in scope. Most study areas are outside of park boundaries and may have only one sampling location. Trends in water quality for the region are not well developed due to the overall lack of available information. In regards to the CWA Section 305(b), regulatory reporting to the USEPA by the Territories and the State of Hawaii demonstrates an increase in the number of impaired water bodies as determined by local water quality standards for their respective designated uses. This statement of increasing impairments is misleading as more water quality monitoring is taking place, and previously unmonitored and unlisted resources are being added to the CWA Section 303(d) list.

The Parks of the PACN contain numerous pristine and unique water resources that are worthy of protection by designation as ONWR. The absence of the legislative framework for establishing such a classification is common to all PACN parks. As discussed in Chapter 1 of the PACN Monitoring Plan, development of the NPS long-term monitoring program in the PACN provides an opportunity to address this and may instigate the development of ONWR designations within the States and Territories of the PACN.

A successful monitoring program will relate to management questions which are consistent with the mission of NPS, its resource protection goals, and the enabling legislation for individual parks. And conversely, successful management of park water resources will rely heavily on the monitoring questions asked.

INTRODUCTION

SCOPE OF TPOPIC AREA

Water quality, as addressed by this workgroup, includes the status of freshwater, marine, and groundwater water quality. These water bodies include streams, lakes, wetlands, fish ponds, anchialine pools, tide pools, coastal, and interstitial waters. Aquatic issues that may be addressed include not only water column quality, but also habitat quality measures, sediment quality, pore water quality, bioaccumulation of toxins, and biological indicators such as invertebrate populations and primary production.

BACKGROUND

The Water Quality Workgroup for the Pacific Island Network (PACN) was organized in August, 2002, and tasked with developing the water quality component of an integrated monitoring program for the PACN. Many people have contributed their time and expertise towards making this document a valuable tool for building a successful monitoring program. Although this program is primarily funded through National Park Service-Water Resources Division (NPS-WRD), it is to be developed along side the NPS National Inventory and Monitoring Program. Several NPS documents are being used to guide our process (http://science.nature.nps.gov/im/monitor/protocols/wqPartB.doc, and http://science.nature.nps.gov/im/monitor/vsmTG.htm).

MONITORING GOALS AND OBJECTIVES

The overall goal of NPS water quality monitoring is to gather data that will enable the network to develop a comprehensive understanding of water quality resource management challenges. A monitoring program for marine, brackish, freshwater, and groundwater will provide a system-wide understanding of the current status of water resources allowing prioritization and improved management of threatened resources. Scientific information can be used to guide rational and responsible management actions and policies relating to the environment and should be readily available for resource managers to identify stressors and potential causes of change. Without the proper measures in place, environmental stressors may not be detected or remedied until irreversible or catastrophic change has occurred.

The objectives for this workgroup appendix are to:

- Summarize existing water quality issues at each park in the PACN;
- Identify Outstanding National Resource Waters (ONRW) or impaired segments (or undesignated equivalents) as priorities for monitoring;
- Construct a Conceptual Model emphasizing common stresses among parks and identify common issues of concern throughout the network;
- Outline a strategy for long and short-term water quality monitoring in the PACN.

LEGISLATION AND POLICY

As a federal agency, the NPS operates under a hierarchy of legislative mandates, including federal laws, executive orders, Department of the Interior and NPS policies and directives, as well as county, state, commonwealth, and territorial regulations. Further, management of submerged resources is complicated by jurisdictional or administrative issues that are often managerially more challenging than similar issues on land. These complexities require the NPS to cooperate with numerous and often overlapping federal and local agencies to achieve its objectives.

The PACN monitoring program is rooted in a mixture of enabling legislation, the United States Code, executive orders, mandates and federal regulations. Some of these policies are specific to water quality such as the Service-wide Government Performance and Results Act (GPRA), the Clean Water Act (CWA), and Executive Order number 13089, which is an extension of the CWA pertaining to coral reefs. Mandates and legislation that the network's monitoring program is based on are listed at http://www.nature.nps.gov/im/monitor/#Legislation. Additional, information on park-enabling legislation can be found at http://www.nature.nps.gov/im/units/pacn/resources.htm

I & M - NATURAL RESOURCE CHALLENGE

The Natural Resource Challenge (NRC), initiated in 1999, is an action plan for preserving natural resources through the National Park Service (NPS). The NRC assisted NPS to establish 32 Inventory and Monitoring networks, which includes 270 National Parks. In the Networks, parks are grouped that share geographical and natural resource characteristics. The Inventory and Monitoring (I&M) Program is designed to first complete basic inventories of natural resources in parks, on which to base long-term monitoring efforts. Monitoring programs are based on monitoring critical parameters (Vital Signs) within each network to incorporate into natural resource management and decision-making. "Vital Signs are measurable, early warning signals that indicate changes that could impair the long-term health of natural systems" (NPS, 2003).

INTERNATIONAL

International Convention for the Prevention of Pollution from Ships (1973): The International Convention for the Prevention of Pollution from Ships (MARPOL) is an international treaty regulating the disposal of waste generated by vessel operation and includes regulations for: oil, noxious liquids carried in bulk, harmful substances carried in packaged form, sewage from ships, garbage from ships, and air emissions.

FEDERAL

FEDERAL LEGISLATION

NPS Organic Act (1916): The NPS Organic Act of 1916 established the National Park System "…to conserve the scenery and the natural and historic objects and the wild life therein and to provide for the enjoyment of the same in such a manner and by such means as will leave them unimpaired for the enjoyment of future generations." While long considered a dual mission, court decisions (e.g. Southern Utah Wilderness Alliance vs. Dabney) support only a single mission: conservation (=preservation) of natural and cultural resources. According to the courts, without conservation of these irreplaceable resources, the perceived second mission could not be accomplished.

Service-wide Government Performance and Results Act (GPRA) goals (Strategic Plan 2001-2005): The NPS has developed a framework for performance management that involves setting goals and measuring performance. In this plan, the water goal is listed as goal 1a4 which states, "85% of 265 Park units have unimpaired water quality". Little has been done in the PACN parks with regards to long-term water quality monitoring, which is a prerequisite to identifying (un)impairments. A solid, cohesive water quality monitoring program will not only benefit each of the PACN park units, but will also allow us to understand the condition of our water resources to work towards GPRA goals.

Clean Water Act (CWA): The Clean Water Act of 1977 requires States and Territories to identify and publish water quality standards, those waters that do not meet the adopted standards, and the ones not expected to meet the standards. Water bodies are categorized based on classifications or use designations developed by each state or territory. If water quality results, based on a minimum number of sampling events, fail to meet previously determined criteria for its type and uses, said waters are added to the state's "303d list." Once waters are listed, state and federal agencies are tasked with developing Total Maximum Daily Loads (TMDL) for that resource and its corresponding pollutant(s) including a plan for bringing it back into compliance. In Hawaii, most of the water resources for which any data is available have not accumulated the minimum number of sampling events required to be evaluated for listing. This situation is mirrored throughout the Pacific Islands highlighting the need for a comprehensive approach to long term monitoring which would help fill these gaps in sampling events and allow the spirit of the CWA to be fulfilled. Details pertaining to each of PACN water bodies that have been listed by the reporting agency are discussed in "Impaired Water Bodies" below.

Rivers and Harbors Appropriation Act (1899): This act prohibits construction of any bridge, dam, dike or causeway over or in any navigable waterway of the US without Congressional approval. It also prohibits (without Congressional approval) the building of any wharfs, piers, jetties and other structures and then any fill or excavation requires approval of the Chief of Engineers. Authority to issue permits was given to the Corp of Engineers and the Fish and Wildlife Coordination Act provides authority to the US Fish and Wildlife Service to review and comment on effects on fish and wildlife of activities proposed or undertaken by the Corp of Engineers.

Sport Fish Restoration Act (1950): Also known as the Dingell-Johnson Act, it was created for management, conservation, and restoration of fishery resources. This act authorizes the Secretary of the Interior to provide financial assistance for fish restoration and management plans. Furthermore, the Sport Fish Restoration Program was created under this Act and was funded by revenues from taxes on fishing equipment. Amendments included the enactment of excise taxes with the Wallop-Breaux Amendment in 1984, inclusion of wetlands conservation in 1990, and creation of boat-related waste disposal facilities in 1992.

National Environmental Policy Act (1969): The National Environmental Policy Act (NEPA) forms the framework of modern environmental policy for all federal projects, agencies and employees and it is mandated that all federal actions take into account the effects of the proposed activity on the environment. NEPA also provides for public input into the federal process.

Coastal Zone Management Act (1972): The Coastal Zone Management Act (CZM) established a voluntary national program within the Department of Commerce to encourage coastal States and territories to develop and implement coastal zone management plans that would define the boundaries of the coastal zone, identify uses of the area to be regulated by the State, the mechanism for controlling such uses, and broad guidelines for priorities of uses within the coastal zone.

Federal Water Pollution Control Act (1972): This legislation, more commonly known as the Clean Water Act, is aimed at restoring and maintaining the chemical, physical and biological integrity of the nation's waters. This Act authorized the EPA to prepare comprehensive programs for eliminating or reducing the pollution of interstate waters and tributaries and improving the sanitary condition of surface and underground waters. Due regard was to be given to improvements necessary to conserve waters for public water supplies, propagation of fish and aquatic life, recreational purposes, and agricultural and industrial uses. A number of other provisions found in the current Act were adopted prior to 1972. Section 404 of this act gives authority to the U.S. Army Corp of Engineers as the primary federal agency with responsibility for wetland management.

Endangered Species Act (1973): The Endangered Species Act provides broad protection for species of fish, wildlife and plants that are listed as threatened or endangered in the U.S. or elsewhere. Provisions are made for listing species, as well as for recovery plans and the designation of critical habitat for listed species. The Act outlines procedures for federal agencies to follow when taking actions that may jeopardize listed species, and contains exceptions and exemptions. The Endangered Species Act also is the enabling legislation for the Convention on International Trade in Endangered Species of Wild Fauna and Flora, commonly known as CITES.

Magnuson-Stevens Fishery Conservation and Management Act (1976): This act recognizes that marine and anadromous fish are valuable and renewable natural resources and that they have been damaged by loss of essential habitat and overfishing. This law finds it necessary to implement a national program for the conservation and management of fisheries to prevent overfishing, rebuild stocks, and ensure conservation before irreversible harm occurs. While this act does not appear to cover species that occur exclusively within non-federal waters (e.g., on coral reef flats), it specifically applies to anadromous fish species regardless of their location and should offer protection for offshore species when their juveniles use nearshore habitats such as reefs.

Redwood Amendment to the 1970 Act for Administration (1978): This amendment, reaffirmed the mission of the park service to protect, manage and administer its areas and required the NPS to let nothing cause "…derogation of the values and purposes for which these various areas have been established…." This act required the NPS to examine, address and protect parks from all impacts, including impacts originating on non-park lands adjacent to NPS-owned land (including non-federal lands). This amendment was in response to the several court cases concerning logging on private lands adjacent to Redwood NP (e.g. Sierra Club v. Department of the Interior).

Park System Resource Protection Act (1990): This Act has been successfully used in instances of vessel groundings and provides specific protection to all natural resources. While this Act does not authorize the removal of a vessel, it does provide legal means for recovering costs for response and recovery for “all necessary actions to prevent or minimize the destruction, loss of, or injury to park resources.” This act is particular powerful in this particular situation given the challenges associated with maritime law in the USA and legal difficulties that can arise with grounded vessels.

National Invasive Species Act (1996): This Act directly mandates federal agencies to manage marine invasive species. This includes activities (among others) to understand and minimize economic and ecological impacts and to develop and carry out environmentally sound control methods to prevent, monitor, and control nonindigenous species.

Sustainable Fisheries Act (1997): The Sustainable Fisheries Act of 1997 (P.L. 104-297) addresses the issues associated with “overfishing, protection of fish habitats, and Pacific Insular Areas; purposes – concerning promotion of catch-and-release programs, non-wasteful development of underutilized fisheries, and protection of fish habitats; and policies—regarding efficiency, bycatch, and Pacific Insular Areas."

National Parks Omnibus and Management Act (1998): Commonly called the "Thomas Bill", the National Parks Omnibus and Management Act (NPOMA) clarified the role of the NPS as a conservation and science agency. Among the items it specifically mandated were the establishment of an inventory and monitoring program to obtain baseline information on natural resources, the development of a broad, rigorous scientific research program, and the hiring and training of scientists within the NPS. Additionally, NPOMA granted protection for key natural resources, particular geological/paleontological resources within the parks by restricting sensitive information from release under the Freedom of Information Act.

The Coastal Zone Act Reauthorization Amendments of 1990: The Coastal Zone Management Act established a voluntary national program within the Department of Commerce to encourage coastal States and Territories to develop and implement coastal zone management plans that would define the boundaries of the coastal zone, identify uses of the area to be regulated, the mechanism for controlling such uses, and broad guidelines for priorities of uses within the coastal zone. The Coastal Zone Act Reauthorization Amendments of 1990, Section 6217 entitled Protecting Coastal Waters, mandates states with coastal waters to submit and implement management plans to protect coastal waters from non-point source pollution, and for the plans to be approved by the United States National Oceanic and Atmospheric Administration and the United States Environmental Protection Agency (USEPA).

The Coral Reef Conservation Act of 2000 (16 U.S.C. §6401 et. seq.) The Coral Reef Conservation Act provides matching funds to agencies conducting coral reef conservation projects in the United States. The overall purpose of this act is "to preserve, sustain, and restore the condition of coral reef ecosystems."

Marine Turtle Conservation Act (2003): The Marine Turtle Conservation Act (H.R. 3378) was enacted to "assist in the conservation of marine turtles and the nesting habitats of marine turtles in foreign countries by supporting and providing financial resources for projects to conserve the nesting habitats, conserve marine turtles in those habitats, and address other threats to the survival of marine turtles." This act is important because many of the sea turtles found in US or its territory's waters travel large distances and often in international waters.

EXECUTIVE ORDERS

E.O. 13089. Coral Reef Protection (1998): This document provided federal protection to coral reefs within the U.S., its territories and commonwealths such that federal agencies may not partake nor federal funding be used in actions that can have a detrimental impact on coral reef ecosystems. This Executive Order also established the Coral Reef Task Force. This executive order is an extension of the CWA and other environmental statutes aimed at protecting coral reef ecosystems. It specifies that all federal agencies which may impact U.S. coral reef ecosystems identify their actions that do so, use their programs and personnel to "protect and enhance the conditions of such ecosystems," and to avoid degradation of coral reefs through their activities. The act further provides that "…Federal agencies whose actions affect U.S. coral reef ecosystems, shall…provide for implementation of measures needed to research, monitor, manage, and restore affected ecosystems…"

E.O. 13112. Invasive Species (1999): This Executive Order commits the US government to preventing the introduction, of invasive species, controlling existing populations of invasive species, and minimizing the economic, ecological and health impacts associated with invasive species. This Executive Order addresses invasive species in all lands and territorial seas of the United States.

E.O. 13158. Marine Protected Areas (1999): This Executive Order commits the federal government to the protection of marine resources through the development and protection of Marine Protected Areas (MPAs). This Executive Order extends to all federal lands and water over which the U.S. exercises jurisdiction.

NPS

PARK ENABLING LEGISLATION

Each park, except USAR, has enabling legislation that describes the primary purpose and mission of the park. (USAR operates under a Memorandum of understanding with the US Navy.) Parks' Enabling Legislation often contains specific directives requiring the conservation of key natural resources, including marine resources. Resources specifically named in the Enabling Legislation will require special attention from the park, and may require park-specific monitoring and/or research to accomplish the legislated mandate. Additionally, park enabling legislation may mandate specific strategies for park resources that require maintaining these resources in such a way that may be inconsistent with the objectives of this monitoring plan. This is most often manifested in the form of maintaining a cultural landscape (e.g., maintaining vegetation as it occurred at a certain time period or in a certain condition) and will supercede other management objectives for the park.

NPS MANAGEMENT POLICIES

NPS Management Policies were revised in 2000 and contain extensive guidance on Natural Resource Management (see Chapter 4 of the NPS Management Policies Handbook). All monitoring activities must fall within the framework of these Management Policies. Difficulties may arise in that few policies are specific to marine environments or resources and require creative interpretation and use of policies by resource managers.

PARK-SPECIFIC MANAGEMENT POLICES

Some parks will have park-specific management policies required to meet the mission or conditions of their enabling legislation. These park-specific policies must be considered in the development of the park's monitoring plan and in the decision process. Park-specific management policies may include Superintendent's compendia.

DIRECTOR'S ORDERS AND OTHER NPS DOCUMENTS

Several DOI and NPS directives and documents provide guidance and support for natural resource management.

Memorandum to Secretary of the Interior from the Solicitor (16 April 1998): This memorandum analyzes the Secretary's legal duty to protect parks from activities on non-NPS land adjacent to park boundaries. While not explicit in the Redwoods Amendment, this memo provides support for involvement in natural resource issues lying outside the park boundary.

D.O. 55 (2000): D.O. 55 further clarifies language within the NPS Organic Act and the 1970 Act for Administration including the Redwood Amendment by reiterating the single mission of the NPS: to preserve resources. This Director's Order also clarifies what constitutes impairment, park resources and values, and provides guidance for decision making, including requiring scientific data in accordance with the National Parks Omnibus and Management Act.

REGIONAL

STATE OF HAWAII

Hawaii State Constitution, Article XI, Section 1: Conservation & Development of Resources. States that "the State and its political subdivisions shall conserve and protect Hawaii's natural beauty and all natural resources, including land, air, mineral and energy sources, and shall promote the development and utilization of these resources in a manner consistent with their conservation and in furtherance of the self-sufficiency of the State."

Hawaii State Constitution, Article XI, Section 7: "The legislature shall provide for a water resources agency which, as provided by law, shall set overall water conservation, quality and use policies; define watersheds and natural stream environments; establish criteria for water use priorities while assuring appurtenant rights and existing correlative and riparian uses and establish procedures for regulating all uses of Hawaii's water resources. (Add. Constitutional Convention 1978 and election November 7, 1978)"

Hawaii State Constitution, Article XII, Section 9: Environmental Rights. States that "each person has the right to a clean and healthful environment, as defined by laws relating to environmental quality, including control of pollution and conservation, protection and enhancement of natural resources."

State of Hawaii Administrative Rules 11-54: These rules define water quality standards for water bodies based on their designated uses and corresponding classifications.

TERRITORIAL

Activities conducted in the marine environment need to meet many state regulations, especially where lands are not under the ownership or control of the NPS. In addition to whatever local permits may be required, many activities conducted in the marine environment will require permitting from the Army Corp of Engineers under section 404 of the Clean Water Act. This permit requires a federal consistency review by all relevant state agencies for compliance with local water quality regulations. Familiarity with these regulations is essential for a NPS marine monitoring program to succeed.

AMERICAN SAMOA

American Samoa Code Annotated (ASCA): Natural Resources and Environmental Ecosystem Protection and Development (Title 24). The following chapters in title 4 pertain to the marine environment (http://www.asbar.org/Newcode/Title%2024.htm).

Environmental Quality Act of 1972 (ASCA 24.02). The Environmental Quality Act contains standards for water quality. This program is administered by the American Samoa Environmental Protection Agency/Environmental Quality Commission.

Office of Marine and Wildlife Resources (ASCA 24.03): It is the policy of American Samoa "to preserve, protect, perpetuate and manage the marine and wildlife resources within the territory." Some of the Public Laws contained within this policy are a prohibition on drift gill net fishing, requirements for reporting by fishermen and processors (including a duty).

American Samoa Coastal Management Act of 1990 (ASCA 24.05). The American Samoa Coastal Management Act mandates "the establishment of a system of environmental review, along with economic and technical considerations, at the territorial level intended to ensure that environmental concerns are given appropriate consideration in the land use decision-making process." This program is administered by the Economic Development Planning Office/American Samoa Coastal Management Program (EDPO/ASCMP).

Endangered Species (ASCA 24.07): In this chapter, a commission was recommended to be formed to identify both endangered and threatened species for the Territory and to suggest programs for conservation, protection and propagation of these species.

Executive Order (2001): This executive order was issued by the Governor to ban the use of scuba equipment while fishing in American Samoan waters. It was believed that this practice contributed to the decline of reef fish abundance.

COMMONWEALTH OF THE NORTHERN MARIANA ISLANDS (CNMI)

Coastal Resources Management Act (PL 3-47): Established the Coastal Resources Management Office (CRMO) and regulation for activities permitted in 'Wetland and Shoreline Areas of Particular Concern' (APCs). Regulations protect mangroves and critical wetland habitat or endangered or rare species.

Fish and Game Endangered Species Act (PL 2-51): Established the Division of Fish and Wildlife and contains regulation regarding fish and wildlife management. This act also authorizes the designation of endangered species and critical habitat.

Environmental Protection Act (PL 3-23): Established the Division of Environmental Quality. This act also includes regulations for water quality certification and waste water discharge.

Public Land Exchange Act (PL 5-33): Includes framework for land acquisition for public purposes including wetland protection.

Managaha Marine Conservation Act (2000): The Managaha Marine Conservation Act (MMCA) was established by the CNMI Legislature to protect the island and the surrounding waters for recreational and cultural purposes. These waters were established as Class I no-take marine protected areas with human activity based on permit basis. The Division of Fish and Wildlife (DFW) is authorized to monitor natural resources and enforce protection of these waters and land. (NOTE: Also, should I include PL 10-18 in 1997 that established Sasanhaya Fish Reserve on Rota, PL 12-46 in 2001 that established Bird Island Marine Sanctuary on Saipan, PL 12-46 that established Forbidden Island Marine Sanctuary on Saipan in 2001, and in 2000 DFW Regulations that established Lighthouse Reef Trochus Reserve and Lau-Lau Bay Sea Cucumber Reserve. Fishing and anchoring are restricted in MPA's.

GUAM

Revised Guam Water Quality Standards (2001): Public Law 26-32 was enacted to amend the Guam Environmental Protection Agency water quality standards.

Guam Soil Erosion and Sediment Control Regulations (2000): The Guam Soil Erosion and Sediment Control Regulations, Public Law 25-152 regulates "soil erosion and sedimentation resulting from the construction of sub-divisions, industrial and commercial developments, highways and other activities requiring excavation and filling" requiring a permitting process.

ADMINISTRATIVE CONTROL OF SUBMERGED LAND

Administrative responsibility for marine areas varies depending on the local statutes. Within the State of Hawaii, the NPS does not have legal jurisdiction over marine resources, yet there is a management interest, especially in parks that include an authorized marine area. In the Territories of Guam and American Samoa, the NPS has management jurisdiction over some marine waters. The NPS does not have any marine acreage nor management authority in the Commonwealth of the Northern Mariana Islands (CNMI), although on-going court cases may change this.

Unlike emergent, dry, or fast lands, submerged lands and their resources are often not owned or administered by the NPS. This situation creates a unique problem when implementing or enforcing management decisions. Some National Parks in the PACN have (legislated) boundaries that extend into adjacent waters, while others do not. Parks with submerged lands within their boundary (regardless of ownership or control) include: NPSA, WAPA, KALA, KAHO, and PUHE. Parks with adjacent marine waters, but whose boundaries end at the mean high tide line include: HAVO, PUHO, AMME, and HALE. ALKA, at present, is still trying to determine trail alignment, but historically followed 175 miles of the shoreline on the island of Hawaii. USAR has administrative control over two submerged vessels, the USS Arizona and the USS Utah. They have no legal jurisdiction over any other submerged lands or objects.

The State of Hawaii owns and administers the submerged lands below the high tide line within three miles of all fast land within the state. The jurisdiction falls under the Department of Land and Natural Resources.

The marine area of NPSA encompasses 2,550 acres with 20 miles of coastline. The park boundary extends ¼ mile offshore (6 fathom depth) with 3 coastal units. The NPS has 50-year lease agreements with 8 villages that share boundaries with the park units. The offshore waters for all the park units are under the American Samoan government jurisdiction but administered by the local villages. The Department of Marine and Wildlife Resources manages and protects marine resources.

The Commonwealth of the Northern Mariana Islands (CNMI) also owns and administers the submerged land adjacent to American Memorial Park (AMME). There are133 acres of land affiliated as memorial park to CNMI, with the NPS offering its services towards technical and planning assistance only. The 133 acres are owned and under CNMI jurisdiction. However, the 133 acreage was leased to the Department of Defense (DOD) who, in turn, re-leased the land that falls within AMME's border back to the CNMI government. The present jurisdiction of the park ends at the mean high tide mark so all marine waters are adjacent to the designated AMME boundary.

WAPA has 4 miles of coastline and 1002 acres of submerged resources divided between two shorefront units within its boundary. Approximately one third of the submerged lands within War in the Pacific NHP (WAPA) are owned by the NPS; the remaining lands are owned by the Territory of Guam, which, through an MOU with the NPS, has ceded administrative control of these lands to WAPA. A condition of the MOU, however, ensures the continuation of traditional subsistence fishing within the park in accordance with territorial fishing regulations. The situation in Guam is further complicated because some submerged lands within WAPA are owned by the Department of Defense (U.S. Navy), which has it own resource mandates and MOUs with the territorial government.

WATER QUALITY STANDARDS

Federal, State, and Territorial regulations on water quality standards provide a framework for determining whether a resource is degraded or pristine. Although Hawaii, American Samoa, Guam and Saipan are governed by different water quality standards through their respective federal or local Environmental Protection Agencies, in the PACN, water bodies are designated and protected for specific uses. Decisions made for this monitoring program are based on the current report of standards for each area (Hawaii-2004, American Samoa-1999, Guam-2003, and CNMI-2002).

HAWAII

Hawaii's surface and marine waters are classified according to their use by the Hawaii Department of Health under Hawaii Administrative Rules, Title 11, Ch. 54, 2000. These standards were updated in 2004. Pristine coastal waters are protected by classification as AA "with an absolute minimum of pollution or alteration of water quality from any human-caused source or actions" including zones of mixing which are allowed in Class A marine areas. Freshwater resources, including wetlands and anchialine pools, of national parks in Hawaii have some special protection as Class 1a waters prohibiting "any conduct which results in a demonstrable increase in levels of point or nonpoint source contamination." Marine bottom ecosystems are classified as I; to remain "in their natural pristine state with an absolute minimum of pollution from any human-induced source," or II; allowing alteration upon approval through the established permitting process.

Hawaii State Department of Business and Economic Development and Tourism (DBEDT) published Hawaii's Coastal Nonpoint Pollution Control Program Management Plan in June 1996 (available at http://www.state.hi.us/dbedt/czm/6217.html#CNPCPMgmt) and joined with the Hawaii State Department of Health (DOH), Clean Water Branch (CWB) in formulating Hawaii's Implementation Plan for Polluted Runoff Control in July of 2000. The State Water Code, Chapter 174C, Hawaii Revised Statutes, requires that the Hawaii State Department of Land and Natural Resources (DLNR) Commission on Water Resource Management (CWRM) implement and utilize comprehensive water resources planning in its regulation and management of the State's water resources. In 1990, CWRM drafted the Hawaii Water Plan which was updated in 1992 into four sections created by state and county agencies; the Water Resources Protection Plan by CWRM, the Water Quality Plan prepared by DOH, the Water Use and Development Plan for each county, and the State Water Projects Plan developed by DLNR. In 1999, the CWRM adopted a Statewide Framework for Updating the Hawaii Water Plan (available at http://www.hawaii.gov/dlnr/cwrm/planning/frame.htm). The most current version is DLNRs State Water Projects Plan of February 2003 which includes county plans in its volumes (available at http://www.hawaii.gov/dlnr/cwrm/planning/swpp.htm).

Guam

Guam Environmental Protection Agency (GEPA) also has a classification system for water bodies based on “Designated Uses” and “Use Support Criteria” which amount to water quality standards. Marine waters are classified as M-1, M-2, or M-3, and freshwater as S-1, S-2, and S-3. Within NPS boundaries, marine waters are classified as M-2. This classification means that the waters are of “Good” quality, and the “Primary Designated Uses” are whole-body contact recreation, aquatic life protection and consumption. Inland waters for this park have been designated S-3 indicating the lowest quality for this resource. The Northern Guam Lens aquifer has been listed as impaired as of the 2004 GEPA CWA 303(d) report, although, the non-potable perimeter of the aquifer has been classified as G2 , which allows discharges that will not contaminate the underlying potable groundwater.

Saipan

Under the jurisdiction of the CNMI, Division of Environmental Quality (DEQ), Saipan has two classifications (AA and A) for marine waters, and two for fresh surface water (1 and 2). The coastal waters of AMME to the North of Puntan Muchot are considered Class A waters “protected for their recreational use and aesthetic enjoyment. Other uses are allowed as long as they are compatible with the protection and propagation of fish, shellfish, and wildlife, and recreation in and on these waters of a limited body contact nature.” The AMME coastal areas south of Puntan Muchot are Class AA; to remain in their natural state with a minimum of alteration and no dumping permitted. AMME fresh waters are class 1 carrying the objective of an absolute minimum of human influence and the prohibition of wastewater discharges and mixing zones for these waters. At this time, groundwater quality management zones are being developed to protect the island’s drinking water sources. In April 2004, DEQ published proposed changes to the CNMI Water Quality Standards that included revisions to the microbiological criteria and anti-degradation policy.

American Samoa

Similar to Hawaii, American Samoa designates areas based on usage and includes “Special Management Areas,” although, NPSA waters are not specifically protected above and beyond other waters in the territory. Special management areas within the territory’s open coastal waters include Fagatele Bay National Marine Sanctuary, the Territorial Marine Park on Ofu and NPSAs Ofu unit. Marine waters are classified by their type, embayment, open coastal, or ocean waters, for which a designated use is described. At this time, only Pago Pago Harbor, an area not within NPS boundaries, has been designated as impaired by the American Samoa Environmental Protection Agency (ASEPA). The ASEPA water quality standards designate wetlands in a separate category from surface waters. All wetlands and Class 1 surface waters are to remain in as near their natural state as possible with a minimum of pollution from any human activity. Surface waters that are designated Class 2 are protected for the support and propagation of indigenous aquatic life, recreation in and on the water, and aesthetic enjoyment. Groundwaters are classified as 1G when potable and 2G if the natural salinity exceeds 10,000 mg/L.

ECOLOGICAL CONTEXT

GEOGRAPHY

All the PACN network parks are located on tropical islands in the Pacific Ocean. Eight of the parks are in the Hawaiian Islands in the Central Pacific between 19 and 22 degrees North latitude. HAVO, KAHO, PUHE, PUHO, and the recently designated ALKA are on the island of Hawaii, the youngest of the main Hawaiian Islands at the southern and eastern end of the archipelago. HAVO is located on the southeast slope of Hawaii Island, where it extends from sea level to the summits of Kilauea and Mauna Loa Volcanoes. The newly designated Kahuku unit of HAVO is positioned on southern Mauna Loa and extends down both the eastern and western flanks of the volcano. PUHE, KAHO, and PUHO are coastal parks of the western side of the island. KAHO is centrally located with PUHE to the north and PUHO to the south. HALE is on Maui, the second youngest Hawaiian Island. HALE extends from sea level to the summit of East Maui. KALA is on a peninsula projecting from the north shore of Molokai, centrally located in the main Hawaiian Islands. USAR is within Pearl Harbor on southern or leeward Oahu. Two PACN parks are situated in the western Pacific Ocean between 13 and 15 degrees north latitude in Micronesia. WAPA is on the western side of the island of Guam and AMME is on the west coast of Saipan, one of the Northern Mariana Islands. NPSA is on the Polynesian islands of American Samoa, approximately 13 degrees south latitude. One unit of NPSA is on the island of Tutuila, and three others are on Tau, Ofu, and Olosega of the Manua Island group 96 km (60 miles) east of Tutuila.

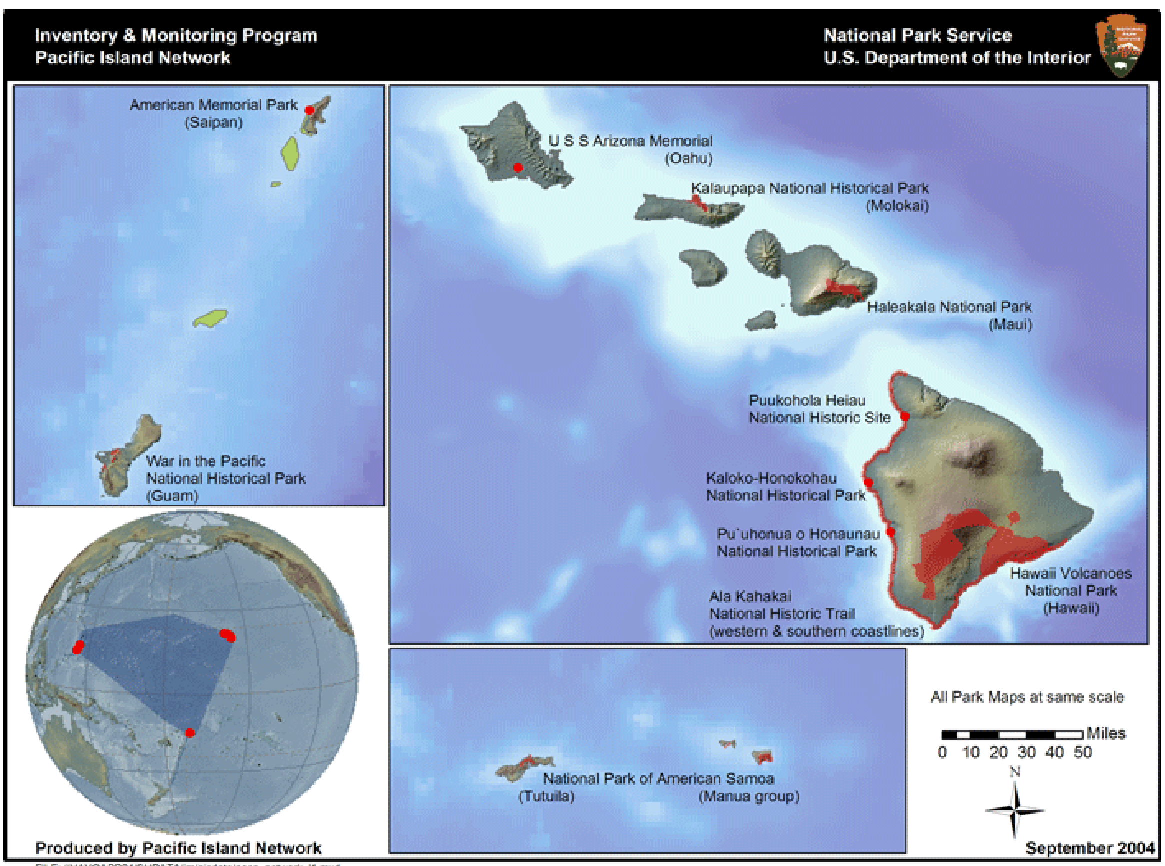

Figure 1. Pacific Island Inventory and Monitoring Network

GEOLOGY

The parks of the Western Pacific (WAPA, AMME) are on the islands of Guam and Saipan which have long-extinct volcanoes. These islands have complicated geologic origins involving both volcanism and subduction of the Mariana Trench. Hence, the northern half of Guam and portions of Saipan have limestone substrates elevated above a weathered volcanic base. WAPA units are on the volcanic substrates of the southern half of Guam, and at least one unit includes elevated limestone caps.

The islands of American Samoa and Hawaii are oceanic volcanic islands arising from hotspots. The oldest of the Samoan Islands are dated at more than two million years, but there was volcanic activity between Tau and Olosega approximately 150 years ago (Whistler 1994). In Hawaii, HALE protects the summit of the inactive Haleakala Volcano and its impressive crater, which is the result of stream erosion, the merging of Kaupo and Keanae Valleys, and subsequent volcanic activity. KALA encompasses the Kalaupapa peninsula, formed on the north shore of Molokai during the Pleistocene (MacDonald and Abbott 1970). The volcanoes on both Molokai and Oahu are extinct.

The five parks on Hawaii Island are on active or dormant volcanoes. A significant portion of HAVO is covered with recent lava flows that are sparsely vegetated. HAVO also contains the rift zones and summit calderas of both Mauna Loa and Kilauea Volcanoes, two of the most active volcanoes on earth. PUHO is on prehistoric pahoehoe flows of Mauna Loa, and PUHE substrates are old weathered soils of Kohala Volcano. All substrates of KAHO are flows from Hualalai Volcano less than 10,000 years old, including one sparsely-vegetated lava flow dated at 1,000-3,000 years (Moore et al.1987).

ELEVATION GRADIENTS

Among the Hawaiian parks, HAVO and HALE have the greatest elevational range, extending from sea level to the summits of tall volcanoes >3,000 m (>10,000 ft) in elevation. KALA has an elevational range from sea level to almost 1,220 m (4,000 ft) elevation. The three parks of leeward Hawaii Island are coastal parks and extend upslope to an elevations less than 100 m. ALKA is also in the coastal lowlands of western and southern Hawaii Island.

Among the three Western Pacific parks, AMME is restricted to coastal lowlands on the western shore of Saipan. WAPA includes both coastal units and inland sites on the slopes of Mt. Alifan and Mt. Tenjo, with one unit extending above 305 m (1,000 ft) in elevation. NPSA is composed of four units; Ofu and Olosega are largely coastal but the Tutuila and Tau units range from sea level to 491 m (1,610 ft) and 966 m (3,170 ft) elevation, respectively. The planned expansion of NPSA on Ofu and Olosega will include the summits of both islands, which are 499 m (1,621 ft) and 639 m (2,096 ft) respectively.

RAINFALL AND CLIMATE

The largest two Hawaiian parks, HAVO and HALE, include within their boundaries several climatic zones with a range of rainfall regimes. HAVO contains two of the four rainfall minima of Hawaii Island, the Kau Desert with mean annual rainfall <750 mm and the interior lands of Mauna Loa. The highest mean annual rainfall within the park is found in Olaa Tract, a rain forest with >4,000 mm per year (Giambelluca et al. 1986). In general, the eastern windward portion of HAVO has high rainfall, which diminishes upslope, particularly above the trade wind inversion layer near 1,830 m (6,000 ft) elevation. The upper elevations of the park are moist to very dry, and the summit of Mauna Loa receives on average <500 mm precipitation. The leeward, western portions of HAVO are in rain shadows of Mauna Loa and Kilauea summit, and are typically dry.

HALE also has a range of climates, as it extends from sea level on the windward, eastern slope of Haleakala to the summit of East Maui. This park also includes lands in the leeward rain shadow of Haleakala, down to 1,220 m (4,000 ft) elevation. Annual precipitation in the park varies from 1,250 mm in the Crater, the southern slope, and Kaupo Gap to >6,000 mm on the upper northeastern slopes of Haleakala. KALA, on the north shore of Molokai receives 1,000 mm of precipitation annually at sea level and >3,000 mm at the upper elevations of Waikolu Valley (Giambelluca et al. 1986). The USAR on Oahu is located within Pearl Harbor on the dry leeward side of the island in an area than has on average 600 mm rainfall per year.

The four Hawaii Island parks are in relatively low rainfall areas with constant warm temperatures and pronounced daily wind patterns of land and sea breezes (Blumenstock and Price 1967). KAHO has a mean annual rainfall of approximately 600 mm and a seasonal climate with higher rainfall during summer months (Canfield 1990a). The climate of PUHO is similar to that of KAHO, with mean annual precipitation of 659 mm. PUHE is located within one of the four rainfall minima of the island of Hawaii and receives <250 mm of rain annually (Giambelluca et al. 1986). Because ALKA covers a large linear coastal transect along West Hawaii, the rainfall pattern is variable.

The climate of Guam and the Northern Marianas (CNMI), including Saipan, is warm, wet, and tropical. Temperature varies between 90 and 70o F. Relative humidity is high, often exceeding 80% and seldom falling below 50%. The rainfall pattern is strongly seasonal with a wet season from July to November and a pronounced dry season from December to June. Average annual rainfall of the Marianas is 2,160 mm (85 in) (Baker 1951), and on Guam the annual mean is 2,175 mm (Mueller-Dombois and Fosberg 1998). Typhoons are yearly events, which occur during the monsoonal wet season. Trade winds blow from the northeast, but easterly and southeasterly winds prevail during several months in the spring (Baker 1951). Because Guam and the Marianas are relatively low islands, there is no pronounced rain shadow effect, and leeward shores are not drier than those of the windward sides (Mueller-Dombois and Fosberg 1998).

NPSA has a warm tropical climate with little seasonal variation in temperature. Rainfall is high in the four units of the park. On Tutuila, annual rainfall averages 3,200 mm (at the airport), and may be even higher on the upper mountain slopes within the park. Rainfall is seasonal with greater monthly means from October to May and a dry season from June to September. Hurricanes are occasional but not annual events (Whistler 1994). Tau Island unit is only about 96 km (60 miles) east of Tutuila and shares its warm and wet tropical climate. Tau average rainfall is more than 2,500 mm per year and is highest in December. The dry season is June to September, and droughts sometimes occur on the island (Whistler 1992).

CONCEPTUAL ECOLOGICAL MODEL

Documenting condition and trends of water quality is an integral part of understanding the condition of natural resources but its relevance to their management is a matter of perspective. Conceptual models of ecosystem components and their relationships are an effective way of communicating this perspective and relating the objectives of monitoring to the management issues at hand. They can also aid planners in prioritization of monitoring needs and as justification in selecting vital signs.

After consultation with resource managers at PACN parks, the PACN Water Quality Workgroup developed a first draft conceptual model for use in relating water quality to ecosystems in the Pacific Islands. At this stage, the model is meant to encompass water quality for all resource types (fresh, marine, and ground water). This model is intended to help distinguish causal relationships between natural resources, human activity, nature, and water quality. The revision process encourages discussion about ecosystem issues and assists managers and monitoring planners in communicating complex ideas about ecological processes.

The model shown in Figure 1 and described here is the most current version which has incorporated comments from members of the water quality workgroup and NPS-WRD staff. Revisions from the first draft clarified the connections between drivers and stressors were made clearer while keeping the model broad enough for the broad purposes of the model.

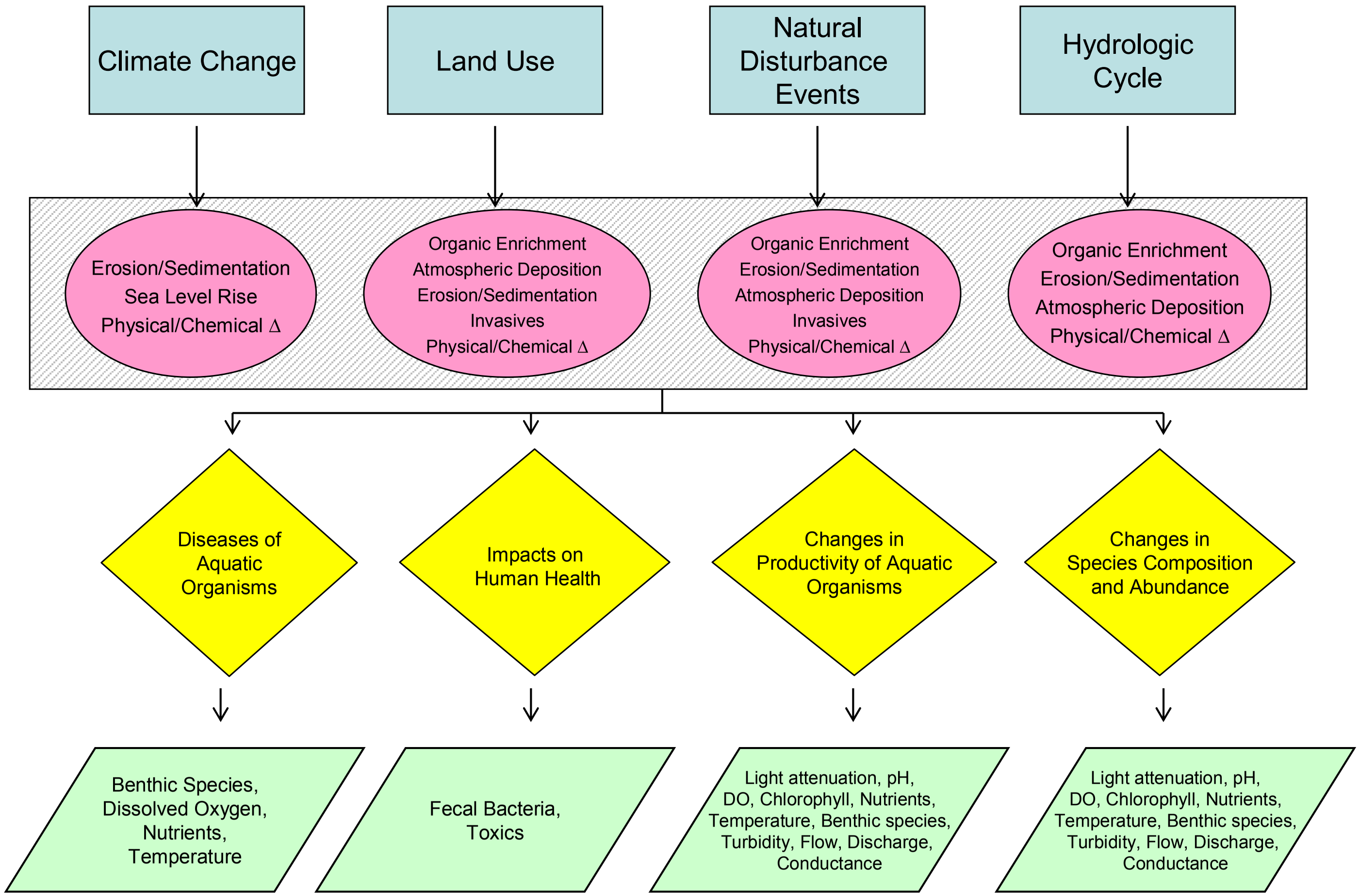

Figure 2. Water Quality Conceptual Model. Drivers are symbolized using blue rectangles, stressors are indicated with pink ovals, ecosystem responses are contained in the yellow diamonds, and the measurable attributes are listed in the green parallelograms.

DRIVERS AND STRESSORS

Drivers and stressors are factors that directly influence the environment and may have human or natural origins. Drivers are ambient factors within which stressors operate. Stressors are changes in natural conditions that result from the operation of a driver. Drivers occur independently of one another, but may also operate simultaneously, magnifying the effect of associated stressors on the ecosystem. This is indicated in the conceptual model by enclosure of the stressors into one box relating to ecosystem responses. In the interest of including all water types, this model represents a very broad explanation of aquatic systems.

CLIMATE CHANGE

Change in climate refers to global processes that affect ambient conditions in such a way that prospective conditions are different from historical ones. Because parks in the PACN are coastal parks, all are impacted by the rising sea level as global warming alters the physical condition of seawater. Changes in sea level affect shoreline dynamics and hydrological factors leading to erosion of coastal areas and sedimentation of nearshore areas. Coastal wetlands, anchialine pools, and historical fishponds are most threatened by changes in sea level. The impact to areas susceptible to seawater intrusion into drinking water sources is also important. Nearshore habitats may experience regime shifts when temperatures are no longer tolerable for corals, leading to changes in benthic habitat, species composition, and offshore topography. Terrestrial ecosystems may experience similar changes in composition and structure due to climatic influences.

HUMAN USE

Human activity results in stress to water quality. Organic enrichment and other chemical changes in water quality may occur due to the presence of farms, human waste, waste water systems, solid waste, and landscaped areas. Land use, such as agriculture, construction of roads, piers, and barriers in coastal areas, as well as stream channelization, contributes to erosion and subsequent sedimentation, in addition to other physical and chemical changes in aquatic environments (De Carlo et. al. 2000). Power plants, quarries, vehicles, and construction activities are sources of particulates that cause contamination of water resources through atmospheric deposition, discharges, and storm events. Human population growth and resulting urban development destroys native habitat often simultaneously introducing new species into disturbed areas where they out-compete the native biota. Large scale removal of vegetation can influence precipitation patterns increasing the likelihood that drought, fire, and erosion will contribute to degradation of streams, wetlands, anchialine pools, fishponds, and reefs. Recreational and commercial activities involving fishing, swimming, and boating alter marine and stream resources by influencing species composition and introducing chemical and physical pollutants.

NATURAL DISTURBANCE EVENTS

Atmospheric deposition, earthquakes, and tsunamis are examples of natural events that can have unpredictable effects on water resources. Natural disturbance events such as flooding and high winds can impact water quality by disturbing human structures designed to contain pollutants. Sewers, storm drains, and wastewater treatment plants may overflow into streams causing physical and chemical changes that eventually affect groundwater and/or nearshore receiving waters (De Carlo et. al. 2000). Erosion and sedimentation are accelerated during hurricanes and typhoons directly or through loss of vegetation, and are likely to be repopulated with invasive species. In addition, flowing lava can alter the quality of seawater when the molten rock enters the ocean (Sedwick et. al. 1990)

HYDROLOGIC CYCLE

Understanding water flow and its rate of movement is an important aspect of water quality monitoring. Water resources may impact one another through direct connections such as a stream entering the ocean, or indirectly as when evaporation falls on terrestrial water bodies as rain (Garrison et.al. 1999). Moving water carries its physical and chemical constituents to the receiving body (De Carlo et. al. 2000). When a system is operating within natural ranges of water movement, potential stressors are balanced over time by ecosystem processes. Changes in the hydrologic cycle may offset the capacity of a system to restore itself, resulting in degraded water quality. For example, groundwater reservoirs are recharged by rainfall in undisturbed systems. When groundwater is withdrawn at a higher rate than it is replenished, changes in relative quantity are accompanied by physical and chemical changes that will affect other water bodies dependant on this groundwater supply such as wetlands and anchialine pools.

ECOSYSTEM RESPONSES AND MEASURES OF CHANGE

In order to evaluate water resource issues, an understanding of the effects of stressors on the ecosystem is important. PACN aquatic ecosystem responses were divided into generalized categories represented by diamonds in the model and described below. Several possible measures of ecological change due to water quality are indicated for each category of ecosystem response. Once the issues of ecosystem changes are described and prioritized, metrics can be applied to test the theorized relationships.

DISEASES OF AQUATIC ORGANISMS

Examples of diseases in aquatic organisms are avian botulism, fibropapillomas on turtles, and mortality, such as “red tide” algal blooms and/or low oxygen levels. Bioaccumulation of toxins and metals can raise the incidence of tumors and other diseases in all types of aquatic life. Aquatic organisms may be affected directly or indirectly by ambient water quality. Water quality variables such as temperature, pH, and redox potential have been shown to increase the risk of avian botulism in wetlands (Rocke and Samuel 1999). Physical stress is one mechanism that may predispose an organism for disease. Poor health may also result from changes in foraging habitat or a decline in the prey base. The health of monk seals, whales and dolphins is also susceptible to poor water quality but they are not ideal indicators of local conditions due to their wide-ranging behavior. The long-term stress of less than ideal conditions contributes to variation in growth, survival, and reproduction rates among species which may be quantified by monitoring benthic organisms. Considering their sedentary nature and influential position in the trophic web, benthic invertebrates and algal communities are a logical choice as indicators of ambient water quality conditions.

Corals and macroalgae are also sensitive to water quality. Coral and macroalgae may be smothered by influxes of sediment (Wolanski et. al. 2003) or corals can be bleached by elevated temperatures in the ambient seawater (Hoegh-Guldberg 1999). Macroalgae may experience increased productivity with elevated water temperatures resulting in the temporary dominance of a particular species (Glenn et. al. 1990) and, possibly, a decrease in biodiversity. The onset of diseases in coral reefs is rapidly becoming an area of concern in the Pacific as more outbreaks are discovered in areas thought to be pristine and little is known about the cause (Aeby 2004). White syndrome, a general term for unexplained loss of tissue from the skeleton, black band disease and coral tumors are examples of coral diseases currently found in the Pacific. White syndrome on Acroporids is one disease that has been found on reefs across the Pacific, occurring in the Northwestern Hawaiian Islands, American Samoa, and on several other South Pacific reefs.

IMPACT ON HUMAN HEALTH

When marine ecosystems become contaminated, communities reliant on subsistence fishing and tourism are impacted. Toxins and microbial contamination are already affecting fishing areas and recreational opportunities throughout the PACN. For populations dependent on surface or groundwater supplies for drinking water and irrigation, maintaining the quality of these resources is imperative to sustaining their quality of life.

Although many stressors impact human health, the measurable effects are well-defined with microbial indicators and chemical contaminants such as mercury or PCBs. The majority of long-term aquatic monitoring programs in place are directed at human health parameters. Experts on tropical marine microbiology are currently developing alternatives to microbial water quality criteria for this region due to the inadequacy of the standard sewage pollution indicators, *Escherichia coli* and *Enteroccoci*, for predicting illness rates in coastal recreation areas (Fujioka 1998, 2004 in press).

CHANGE IN PRIMARY PRODUCTIVITY

When species are influenced by environmental stressors, they often experience changes in productivity. Productivity affects ecosystem processes such as nutrient cycling and the rate of succession, compounding the effect of the stressors themselves. There are many measures and even more methods for describing productivity. Benthic species abundance and composition is often used to characterize an ecosystem in terms of general water quality parameters. Certain benthic and plankton species need specific conditions of water clarity, nutrient availability, temperature, pH, primary productivity, dissolved oxygen, and salinity. Some chosen parameters may not directly affect productivity, but are likely a factor in the impact of other, related variables in ecosystem processes. For example, the rate of water flow through a system is crucial to tracking the dynamics of nutrient cycling, temperature, salinity, and the accompanying changes in indicators of primary productivity; chlorophyll a, pH, dissolved oxygen, and clarity.

CHANGE IN BIOLOGICAL SPECIES AND ABUNDANCE

As with primary producers, the composition of other trophic level species and their abundance is a factor of reproduction, growth, and survival that is influenced by environmental stressors. The close relationship of change in productivity to change in species composition and abundance is reflected by the same array of parameters to describe them. As with change in productivity, some measures are direct indicators of change and some help assess the expected impact of other stressors. For example, benthic surveys are direct indicators of species composition and abundance, but flow or discharge rates control the influx of nutrients and indirectly affect these attributes.

REVIEW AND REVISION

Just as natural systems are dynamic, the conceptual model must be also. As more is learned about the interactions of its components, the model will reflect all aspects found to be significant to water resources. The relative importance of issues and effects are not demonstrated in this diagram but weighting may be added later or used in more detailed models of specific water types or for specific components.

Development of this model will help promote expansion of resource conservation from the traditional values of human health concerns to include resource sustainability. Vital sign prioritization and refinement will also help improve the present model. These processes will work together so that the monitoring program reflects the needs and priorities of the PACN parks.

PARK AND NETWORK WIDE ISSUES

NETWORK-WIDE WATER RESOURCE CONCERNS

Three types of water resources are shared by PACN parks; marine, freshwater (see Appendix A), and groundwater. Network-wide concerns for these resources include atmospheric deposition, changes in hydrology and climate, chemical and microbial contamination, organic enrichment, invasive species, erosion, and sedimentation. Natural disturbance events contribute to the transfer of sediment and chemicals from land into nearby streams, groundwater and marine resources. Expansion of urban land use often affects the hydrology of nearby ecosystems by diversion of streams and withdrawal of groundwater. Human population growth alters the aquatic habitat physically when construction and recreation activities contribute to erosion, pollution, and the introduction of alien species. Chemicals from land-based sources enter groundwater via surface water connections possibly contaminating drinking water supplies and eventually coastal resources (De Carlo et. al. 2000). With global climate change, solar radiation and ambient temperature affect water quantity and quality, and as a direct result, the well-being of organisms living in impacted areas.

PARK ISSUES

Through surveys of staff and partners and other communications, each park has identified the stressors which are most threatening to their water resources. Unique PACN water bodies include sub-alpine lakes, wetlands, coastal and submerged springs, shoreline fishponds, tide pools, anchialine pools, and a crater lake. Systems can be impacted by invasive species, sedimentation, organic enrichment, and chemical run-off. These problems are accelerated with urban development and agricultural land-uses. Chemical and microbial contaminants from terrestrial sources leach into the groundwater and eventually into coastal resources such as anchialine pools and wetlands. Atmospheric deposition of chemicals and particulates may cause problems in sub-alpine lakes and anchialine pools. Since these water bodies may be unique to their park and have water quality issues due to specific stresses, research and monitoring requirements will need to be addressed individually.

All PACN parks have near shore reef communities that may be impacted by situations inside or outside of park boundaries. Adjacent land uses have impacts on the marine environment and, moreover, the Hawaii PACN parks do not have jurisdiction over the submerged lands containing reef resources that they are mandated to protect. Harbor operations, such as boat maintenance and fueling facilities contribute to chemical pollution in these areas by lead paints, paint base, diesel, oils, and heavy metals. The operation of cruise ships, commercial fishing, and diving charters raises the likelihood of illegal dumping of chemicals, sewage and debris. PUHE, KAHO, and so ALKA, are adjacent to State Harbors that are in the planning stages for expansion. Harbor expansion will escalate these and other threats to the marine community such as, fishing pressure, introduction of alien algae and invertebrates, boat groundings and other physical damage to reef resources from increased recreational activities.

Development of adjacent lands and watersheds is a concern at all PACN parks. Runoff from agricultural and urban development and sedimentation due to natural and man-made causes add to eutrophication, bacterial and chemical contamination, and increased turbidity. Human population growth contributes to loss of habitat buffers and subsequent degradation of water quality. Almost all PACN parks are susceptible to the effects of feral animals that degrade native vegetation, increasing fire hazards and accelerating erosion. Shoreline erosion and sedimentation of the reef is also accelerated by the rising sea level, due to global warming. In addition, coral bleaching, mortality and disease are occurring due to warming sea surface temperatures.

PARK SPECIFIC ISSUES

Park specific issues other than the reef concerns covered above are identified here on a park-by-park basis.

AMME

Additional marine water body and potential groundwater concerns include seepage/runoff from a garbage dump up-current and a site where PCBs were "cleaned up." This is compounded by the barrier reef which constricts water flow into and out of the marine area. Wetlands are present in the inland corner of the park where encroaching development, illegal dumping (past and present), flooding, and groundwater contamination from sewage are major concerns. Highly saline water resulting from a reverse osmosis drinking water facility is discharged into an intermittent stream on the parks boundary despite EPA directives for pre-treatment of the effluent to meet permitting requirements.

WAPA

Sedimentation of the reefs in Guam is aggravated by fires that consume the vegetation upslope. There is a power plant down current of the parks with a submerged thermal discharge pipe. Heavy metals and PCBs were detected in sediment (Denton et. al. 1997) and marine organisms (Denton et. al. 1999) in four of Guam's Harbors, including Agat Marina, which demonstrated the lowest level of these contaminants of the harbors studied. The Asan unit has wetlands which are susceptible to contamination from unsewered residential areas and flooding events which bring soil and agricultural runoff. Inland units are unexplored and/or inaccessible making characterization of these water bodies difficult there.

NPSA

Due to the traditional communal land tenure in American Samoa, the park area is leased from surrounding villages. Subsistence use of the land and water resources is allowed contributing to erosion from agricultural use and contamination from sewage. In a few instances, the upper portion of a stream will be within NPSA boundaries, while the lower part flows through a village before entering the sea. Impacted stream water reaching the reef may inhibit natural stream fauna from repopulating streams after a juvenile marine stage. Streams are also degraded by feral pigs. Tide pools located at the shoreline are impacted by visitor use and climate change. In the Ofu unit of NPSA, there is a closed dump site that continues to percolate water of unknown quality into the marine environment and there are temperature tolerant corals, which are an especially valuable resource. The location and possible extension of a landing strip in this area is of great concern. Offshore of the Ta'u unit, there are giant, single coral heads of significant age which are invaluable to studies of climate and marine ecology.

USAR

This park is located in Pearl Harbor where military, industrial, and agricultural pollution are long-standing issues which have contributed to the degradation of this estuary. The centerpiece of this park is a sunken ship which has remained relatively undisturbed in spite of the release of petroleum products from within the hull as it rusts away. The ship also contributes to the presence of heavy metals dissolved in the water column and deposited in the sediment.

KALA

Feral pigs, deer and cattle degrade stream resources in and around this park. This adds to the stresses caused by diversion and input due to agriculture and urban development. Village areas in the park may have issues with the leaching of untreated sewage. There is a large, deep, water-filled crater unique to this park.

HALE

There are numerous freshwater streams in this park which also has coastal springs and a sub-alpine lake unique in this network. Although it has a relatively small coastal shoreline, it has a very large watershed in which the streams and lake are threatened by encroaching development, feral animals, and alien species. Fishing and swimming are common in streams which enter the ocean. Stream diversion may be an issue as watershed partnerships affect management of this area.

ALKA

This entire park is situated in coastal habitats subject to the pressures from human uses. Motorized vehicles, foot traffic, and construction activities together with natural processes contribute to erosion of the trail and adjacent beaches. This increases the probability of sedimentation impacts to reefs, wetlands and anchialine pools as they become more accessible to the public. Due to the lack of restrooms and potable water, the likelihood of microbial contamination and misuse of freshwater resources is high. Camping, hiking and marine recreational activities also create problems with contaminants and debris.

PUHE

A recreational harbor exists adjacent to the park and a commercial shipping facility on the other side of that. A recreational park is located on the other side of PUHE and a concrete manufacturing plant upslope. These contribute to the likelihood that marine recreation activities such as fishing and diving will increase leading to a subsequent increase in fuel spills, pollution, and alteration of the substrate. Dirt biking along coral flats and stream beds, municipal and industrial wastewater discharges, residential and resort development, and land-based recreational activities all contribute to erosion and pollution of the near shore water. A stream originating upslope from the park is influenced by diversion, storm water runoff, and erosion of the top soil. There is a marsh area between the park and recreational harbor, which is uncharacterized.

KAHO

There are numerous anchialine ponds, two fish ponds, and a large embayment in this park located down slope of a growing industrial area. Leaching from upslope cesspools and septic tanks and industrial development may contribute to bacterial contamination and nutrient loading of these resources (Nance 2000). A small boat harbor is located between park units and is a source of petroleum, heavy metals, and phosphates from wash water. The threat of sedimentation onto the coral reef is increased by pond restoration activities, erosion of the sandy shoreline, and dredging and/or expansion of the harbor. Island subsidence and the rising sea level, due to global warming, will also contribute to erosion of the shoreline.

PUHO

Urban development up-slope from the park and the high level of tourism can have an impact on the water quality of springs, fishponds, tide pools, and the near shore marine environment. There are inland ponds that are vulnerable to sedimentation and eutrophication. There is a submerged, natural discharge presumably through a lava tube which is unique to this park and could be a conduit for contaminants, such as agricultural chemicals, originating upslope. It is expected that island subsidence and the rising sea level, due to global, warming will eventually flood this low coastal park.

HAVO

There are no known streams or lakes located in this park which is primarily made up of relatively fresh volcanic flows. Although the coastal area is large, the man-made stressors are limited by the volcanic activity which is the main agent of change there. There are anchialine pools along the coastal section and wetlands or bogs in the forested Ola’a unit which have been inventoried but not assessed in detail for water quality characteristics.

MONITORING

Various water quality studies are in progress or are being planned to assess conditions at or near PACN. Few of these programs involve long-term monitoring plans and even fewer are comprehensive in scope. Most study areas are outside of park boundaries and may have only one sampling location. In general, adjacent monitoring projects are non-NPS and specific to one resource issue; usually relating to human health conditions. The table in Appendix B gives an indication where monitoring information is lacking relative to water quality stressors.

AMME

The DEQ (http://www.deq.gov.mp/) regulates water quality and contaminants and is the permitting agency for pollution control, sewage disposal and earth-moving activities. It monitors water quality and administers most of the federal clean water laws. They conduct weekly monitoring of enterococci, fecal coliform, and nutrients near the Hyatt sewage outfall into the ocean adjacent to the park. They also monitor runoff at a site adjacent to the park boundary and at a storm water discharge basin created to prevent pollution runoff into the area near Smiling Cove Marina.

The University of Guam, Water and Energy Resources Institute (WERI) (http://www.uog.edu/weri) conducts research projects on surface and groundwater quality, pesticide and heavy metal contamination, and soil run-off. WERI is involved with some water quality work in the Puerto Rico Mud Flats, located northeast of the park, which is the site of a military dump that has recently been closed. This area could qualify as a superfund site.

The DEQ-Coastal Resource Management is involved with benthic studies.

A hydrological study of the AMME wetland has been funded by the United States Geological Survey (USGS), Water Resources Division (WRD) for FY05. This wetland has fresh water at the periphery and is saline in the center indicating some connection to the ocean. Still in the planning stages, USGS will be doing this work and may monitor the groundwater level and salinity.

WAPA

NPS-WAPA has started a watershed-level project monitoring sedimentation on the near shore reefs. The marine monitoring portion currently includes water temperature and photosynthetically active radiation (PAR), and will soon add coral recruitment, and percent cover analysis.

Limited studies have been conducted on water quality indicators important to coral reefs. Guam EPA regularly monitors point source pollution and tests for faecal coliform on Guam's beaches, but there is limited information on parameters such as nutrient load, turbidity, or contaminants. This is expected to change in the near future with the implementation of GEPA Environmental Monitoring and Assessment Program (EMAP) procedure.

Guam Environmental Protection Agency (GEPA)

(http://www.guamepa.govguam.net/programs/index.html) monitors recreational beach waters weekly for enterococci. Three sample locations are adjacent to WAPA units. One site is just north of the Asan Unit and the other two are to the North and South of the Agat Unit boundaries. GEPA is in the planning stages of a marine monitoring program that will be using EMAP, also still in the design process.

The area south of Orote Peninsula is monitored by the United States (US) Navy as part of remediation for the Orote dump. This monitoring program includes analysis of water, invertebrates and fish for PCBs, heavy metals, dioxins, ferro-cyanins, and chlorinated pesticides. The area is currently open to recreational swimming but closed for fishing.

The University of Guam, Water and Energy Resources Institute (WERI) (http://www.uog.edu/weri) conducts research projects on surface and groundwater quality, pesticide and heavy metal contamination, and soil run-off. They also analyze duplicate samples from the Navy's remediation program for the Orote Peninsula.

Recently University of Guam scientists and associates have investigated some aspects of southern Guam erosion and its impacts on the reef environment (Scheman, et al., 2002 and Wolanski et al., 2003 and Wolanski et al. In Press). The high clay content of Guam's soils exacerbate the impact of high erosion rates, as the small clay particles travel easily to the coast where they rapidly coagulate into "marine snow" and settle on the estuary bottom (Wolanski et al., 2003).

The more significant use of fertilizers and pesticides on Guam's nine golf courses is carefully controlled through requiring GEPA approved Turf Management Plans and continuous monitoring through monitoring wells.

NPSA

The NPSA staff and ASEPA have been working with the USEPA to complete an assessment of American Samoas coastal resources using the USEPA-EMAP which has been implemented nationally in a staggered timeline for funding and completion in each of the USEPA regions. They are in the process of collecting data and water samples from 50 randomly selected sites around four islands. This pilot study will include basic water quality parameters, sediment analyses, and bioaccumulation of toxins in fish tissues.

The American Samoa Environmental Protection Agency (ASEPA) is currently monitoring streams in the territory based on a probabilistic design within a human impact framework. One of their pristine sites is located in NPSA (Fagatuitui). This stream is sampled monthly for temperature, dissolved oxygen, pH, sp conductivity, nutrients, bacteria and flow. Sampling started in April, 2003 and will continue for 1 year. At that time another round of streams will be chosen randomly which may include another site in NPSA.

The World Wildlife Fund has received a grant through the Environmental Protection Agency to do climate change research in the territory. Two of their seven sites are located in NPSA (Vatia and Tafeu Cove). As part of the project, paired water quality samples are taken from the stream and coral reef. Parameters include: nutrients, Chl a, DOC, and CDOM. Sampling started in October, 2002 and will continue quarterly until June, 2004.

NPSA currently has long-term temperature loggers on the reef in Vatia and Ofu. Surface and bottom water temperature have been recorded hourly since January of 1999.

ASEPA staff conduct all monitoring required by the ASEPA Nearshore Marine Water Quality Monitoring Plan, the ASEPA Stream Water Quality Monitoring Plan, and the American Samoa Coastal Nonpoint Source Monitoring Strategy. The ASEPA Intensive Coral Reef and Reef Flat Monitoring is conducted by Coral Reef Biologists on occasional short term loan from CNMI Division of Environmental Quality, and the US Fish and Wildlife Service (USFWS). Monitoring required by the Water Quality Monitoring Strategy for Pago Pago Harbor and the Sediment Toxicity Study for Pago Pago Harbor are conducted by contracted consulting firms. The ASEPA Drinking Water Systems Water Quality Monitoring is conducted by ASEPA staff.

The US Fish and Wildlife Service has surveyed reefs in all of the U.S. Equatorial and southern tropical Pacific Islands including those around NPSA in 2004. In conjunction with this work, the

NOAA Coral reef conservation program observed conductivity, temperature, depth, DO, and chlorophyll *a* while mapping bottom habitat.

USAR

USGSs Curt Storlazzi, NPS-USARs Marshall Owens, and the Submerged Resources Centers Matt Russell deploy and recover two instruments to measure the physical and chemical environment around the USS Arizona Memorial. Beginning in November 2002, A Sontek Triton wave/tide gauge has been measuring the daily variations in the physical environment: current velocity and direction, tidal and wave action, including surface wind waves. Water temperature, salinity, pH, dissolved oxygen, and oxidation-reduction potential are monitored using a YSI 6600 Sonde multisensor. These instruments must be recovered to download monitoring data approximately every two months. The program is anticipated to end after 12 to 15 months of data collection.

The US Navy has several monitoring programs for its various industrial activities in Pearl Harbor. The analytical work is performed by the Navy Public Works Center Environmental Laboratory located in the Pearl Harbor Naval Complex. The outfall from Fort Kamehameha Wastewater Treatment Facility discharges near the mouth of Pearl Harbor and its mixing zone is monitored quarterly for temperature, ammonia, nitrate/nitrite, total nitrogen, total phosphorous, turbidity, chlorophyll a, salinity, dissolved oxygen, and pH. The effluent is monitored continuously for total residual chlorine, and daily determinations are made for 5-day BOD, total suspended solids, pH, settleable solids, and oil and grease. Monthly analyses are performed to monitor effluent levels of ammonia, nitrate/nitrite, total nitrogen, total phosphorous, 5-day BOD and total suspended solids percent removal, heavy metals (cadmium, chromium, copper, lead, mercury, nickel, selenium, silver, and zinc) and toxicity testing with *Ceriodaphnia dubia* and *Tripneustes gratilla*.

After qualifying rainfall events, storm water runoff is monitored at eight industrial sites in and around the Pearl Harbor Naval Compound. Depending on the industrial activities in the drainage area being sampled, analytes may include aluminum, arsenic, cadmium, chromium, copper, total cyanide, iron, lead, magnesium, mercury, nickel, selenium, silver, titanium, zinc, MBAS, chemical oxygen demand, biological oxygen, demand total suspended solids, total dissolved solids, ammonia, nitrate/nitrite, total nitrogen, total kjeldahl nitrogen, total phosphorous, pH, specific conductance, oil and grease, total petroleum hydrocarbons (THP), THP as gasoline, THP as diesel, total fuel hydrocarbons, and 21 organic compounds.

The EPA implemented their Hawaii coastal EMAP in 2002 which included 1 randomly selected site in Pearl Harbor’s Middle Loch. Sampling will begin again in 2004 at a new set of randomly selected locations.

KALA

No water quality monitoring is being conducted in this park at this time.

The framework for a cooperative monitoring system on an islandwide level is in place through work with the federal Enterprise Community (EC) designation and implementation, and United States Department of Agriculture (USDA), Natural Resources Conservation Service (NRCS), Watershed Restoration Action Strategy for the south shore of Molokai.

HALE

USGS-WRD has a stream gauge inside the park at Kipahulu monitoring its flow only and has plans to install an additional gauge in another stream inside the park.

The EPA implemented their Hawaii coastal EMAP in 2002 which included 1 randomly selected site near the coast of HALE. Sampling will begin again in 2004 at a new set of randomly selected locations.

ALKA

Mauna Kea Soil and Water Conservation District (MKSWD) is a watershed partnership that is monitoring stream dynamics and erosion upslope from the park. They have instigated changes in land use aimed at decreasing the impact of the cattle ranch, stream diversion, and recent drought. Management partnerships have been developed with cattle ranches that include vegetative growth studies and water storage and distribution strategies that will aid in fire suppression. Other projects include precipitation, sediment and vegetative cover monitoring by University of Hawaii, Hilo staff and students. New rain gauges and check dams are being installed to monitor the watershed, and an automatic sampling device is ready to be implemented under a bridge over Makeahua Stream pending final approval from Hawaii State Department of Transportation. This device will automatically measure and store data on flow rate and turbidity upon flood events and at regular intervals when the stream is running. Another automatic sampler is planned for Makahuna Stream. MKSWD is actively involved in developing a useful monitoring plan for the marine area of Pelekane Bay.

The Hawaii State DOH monitors monthly for enterococci and *Clostridiumn perfringins* using the membrane filtration method at Kawaihae Harbor, Spencer County Beach Park, Hapuna State Beach Park, two sites near Puako Bay, Anaehoomalo Bay, two sites at Honokohau Harbor, two sites in Kailua Bay, "Banyans" surf spot, Disappearing Sands County Beach Park, Kahaluu County Beach Park, and Keauhou Bay. Portable meters are used at these collection sites to measure temperature, salinity, turbidity, dissolved oxygen, and percent dissolved oxygen. A one-time collection for water chemistry is planned for three sites in Pelekane Bay: one from the pond formed by the damming of Makeahua Stream, and two marine samples to the North and the South sides of the bay. Inorganic nutrients (nitrate/nitrite, ammonium, phosphate, and silicate), total nitrogen, total phosphorous, temperature, pH, salinity, dissolved oxygen, turbidity, and total suspended solids will be determined for these locations.

A subset of a large complex of anchialine pools in Waikoloa was established as the Waikoloa Anchialine Pond Preservation Area (WAPPA) in 1986 by a resort development, which filled in all but twelve acres of the original pool complex. The water quality and fauna of these ponds is reassessed annually to detect ecological impacts from the surrounding development, which contains luxury resorts, golf courses, residential housing and associated infrastructure (Brock and Kam 1985, 1988, 1990, 1994). Salinty, dissolved oxygen, temperature, total organic carbon, silicate, chlorophyll *a*, nutrients, and pesticides are determined along with the abundance of native shrimp.

Biweekly bacteria testing is being conducted by AECOS lab at a man-made recreational pond inside a resort at Kaupulehu.

Natural Energy Laboratory of Hawaii Authority (NELHA) has an on-going water quality monitoring program at Keahole Point that was begun in 1982. Twenty-one groundwater monitoring wells are sampled monthly for temperature, pH, salinity, dissolved oxygen, fecal coliform, enterococci, total phosphorous, total nitrogen, and the inorganic nutrients; nitrate/nitrite, phosphate, ammonium, and silicate. Two anchialine ponds, two aquaculture outfalls, seven coastal locations and six offshore transects, surface and bottom, are monitored quarterly for the same parameters as the wells listed above with the addition of chlorophyll a and turbidity measurements.

Bacterial monitoring is also conducted on a saltwater swimming pool inside the Royal Sea Cliff Condominiums south of Kailua by AECOS.

The National Parks Service Inventory and Monitoring Program has initiated an inventory of the anchialine ponds which includes limited water quality monitoring.

The EPA implemented their Hawaii coastal EMAP in 2002 which included 7 randomly selected sites along the coast of ALKA. Sampling will begin again in 2004 at a new set of randomly selected locations across the state.

PUHE

Mauna Kea Soil and Water Conservation District (MKSWD) is a watershed partnership that is monitoring stream dynamics and erosion upslope from the park. They have instigated changes in land use aimed at decreasing the impact of the cattle ranch, stream diversion and recent drought. Management partnerships have been developed with cattle ranches that include vegetative growth studies and water storage and distribution strategies that will aid in fire suppression. Other projects include precipitation, sediment and vegetative cover monitoring by University of Hawaii, Hilo staff and students. New rain gauges and check dams are being installed to monitor the watershed, and an automatic sampling device is ready to be implemented under a bridge over Makeahua Stream pending final approval from Hawaii State Department of Transportation. This device will automatically measure and store data on flow rate and turbidity upon flood events and at regular intervals when the stream is running. Another automatic sampler is planned for Makahuna Stream. MKSWD is actively involved in developing a useful monitoring plan for the marine area of Pelekane Bay.

The Hawaii State DOH monitors monthly for enterococci and *C. perfringins* using the membrane filtration method at Kawaihae Harbor to the North and Spencer State Beach Park adjacent to the South boundary. Portable meters are used at these collection sites to measure temperature, salinity, turbidity, dissolved oxygen, and percent dissolved oxygen. A one-time collection for water chemistry is planned for three sites in Pelekane Bay: one from the pond formed by the damming of Makeahua Stream, and two marine samples to the North and the South sides of the bay. Inorganic nutrients (nitrate/nitrite, ammonium, phosphate, and silicate), total nitrogen, total phosphorous, temperature, pH, salinity, dissolved oxygen, turbidity, and total suspended solids will be determined for these locations.

The EPA implemented their Hawaii coastal EMAP in 2002 which included 2 randomly selected sites near PUHE. Sampling will begin again in 2004 at a new set of randomly selected locations across the state.

KAHO

A two-year project funded by NPS Water Resources Division to monitor nutrient fluctuations in wells, anchialine pools, Kaloko Fishond and Aimakapa Fishond will be implemented in 2004. This project will perform isotope tracer studies to determine the residence time of water in the pools and ponds and will collect samples to analyze for biologically available nitrogen and phosphorus in the groundwater. Salinity, dissolved oxygen, silica, chlorophyll a and other pigments will also be monitored.

KAHO staff and community groups will be removing invasive algae from Kaloko Pond and monitoring for changes in benthic biota and substrate.

The Natural Energy Laboratory of Hawaii Authority (NELHA) has an on-going water quality monitoring program at Keahole Point two miles North of Kaloko Pond that was begun in 1982. Twenty-one groundwater monitoring wells are sampled monthly for temperature, pH, salinity, dissolved oxygen, fecal coliform, enterococci, total phosphorous, total nitrogen, and the inorganic nutrients; nitrate/nitrite, phosphate, ammonium, and silicate. Two anchialine ponds, two aquaculture outfalls, seven coastal locations and six offshore transects, surface and bottom, are monitored quarterly for the same parameters as the wells listed above with the addition of chlorophyll a and turbidity measurements.

The Hawaii State DOH monitors monthly for enterococci and C. perfringins using the membrane filtration method at two Honokohau Harbor boat ramps directly adjacent to the park and two locations near the pier in Kailua Bay, a few miles to the South. Portable meters are used at these collection sites to measure temperature, salinity, turbidity, dissolved oxygen, and percent dissolved oxygen.

PUHO

No water quality monitoring is being done in this park at this time.

HAVO

David Foote of the USGS Pacific Islands Ecosystem Research Center has a funded I&M project to inventory selected invertebrates and water chemistry in some anchialine pools.

IMPAIRED AND OUTSTANDING NATURAL RESOURCE WATERS

WATER BODY CLASSIFICATION AND USE DESIGNATIONS

Water body designations for PACN water resources are listed for each park in Table 1 (303(d), impairment, unique or pristine, and use designations). Several parks have unique and/or pristine water resources that could be considered as Outstanding National Resource Waters (ONRW) but this classification has not been developed by governments in the region. This provides an opportunity for the NPS I&M Program, together with other organizations, to set the precedent for determination and evaluation of such resources in Hawaii and the Pacific Territories. The identification of impaired waters for 303(d) listing is limited by the shortage and small scope of existing monitoring programs and, although these programs are often State-based, Territories and other affiliated nation-states have begun to participate in the process of identifying resources that are not meeting their designated uses.

IMPAIRED WATER BODIES

Table 1 shows the water resources that have been identified as impaired on the 2004 USEPA CWA 303(d) report. For WAPA, no park waters are listed in the draft 2004 CWA 303(d) list compiled by GEPA. The Northern Guam Lens Aquifer, as it is defined, may not extend beneath park boundaries, but it may be within the proposed water quality area of interest for the PACN. This sole source aquifer is exceeding designated use criteria for bacteria, nutrients, and toxic contaminants. Agana Bay, to the East and up current of the Asan Unit, is also listed as impaired due to exceedances in turbidity and dissolved oxygen in more than ten percent of annual samples.

In May 2004, the DEQ published the "Commonwealth of the Northern Mariana Islands Integrated 305(b) and 303(d) Water Quality Assessment Report," posted at http://www.deq.gov.mp/305b%202004%20Final.pdf. This report lists Saipan Lagoon, offshore of AMME, and six coastal shoreline sites within or offshore of park boundaries as non-supporting or only partially supporting their designated uses based on the percentage of violations for Enterococci, dissolved oxygen, and orthophosphate. Only one of these sampling sites, Outer Cove Marina, was fully supportive of its designated uses, but for dissolved oxygen only. The report speculates that the water quality standards for orthophosphate are set too low because all water bodies tested around Saipan, Tinian, and Rota exceeded the set value. The Puerto Rico Industrial area, to the Northeast and up current of AMME, contains several more coastal sites within Saipan Lagoon that are listed as impaired.

There are no listed water bodies in the Territory of American Samoa that are in or near NPSA. The current ASEPA 305(b) and 303(d) drafts are combined in "Territory of American Samoa Integrated Water Quality Monitoring and Assessment Report, 2004."

As of August 2004, the State of Hawaii, Department of Health, Environmental Planning Office has published their "Final 2004 List of Impaired Waters in Hawaii" prepared under CWA Section 303(d) and posted it at:<?xml:namespace prefix = o ns = "urn:schemas-microsoft-com:office:office" /> http://www.hawaii.gov/health/environmental/env-planning/wqm/wqm.html#303pcd. This report lists <?xml:namespace prefix = st1 ns = "urn:schemas-microsoft-com:office:smarttags" />Pearl Harbor, the location of USAR, as exceeding water quality standards for nutrients, suspended solids, and PCBs. Pearl Harbor waters are delineated as the enclosed portion of the bay and nearshore waters to 30' from Keehi Lagoon to Oneula Beach. Adjacent to the Pearl Harbor visitor center, Halawa Stream is listed as exceeding standards for nutrients and turbidity. Pelekane Bay, offshore of PUHE and ALKA, and five additional public beaches along the historic coastal trail of ALKA: Spencer Park Beach, Hapuna Beach, Magic Sands Beach, and Kealakekua Bay have demonstrated impairment for either turbidity, chlorophyll *a*., or both, and total phosphorus at Kailua Bay.

OUTSTANDING NATURAL WATER RESOURCES (ONWR)

The Parks of the PACN contain numerous pristine and unique water resources that are worthy of protection by designation as ONWR. The absence of the legislative framework for establishing such a classification is common to all PACN parks. As discussed in Chapter 1 of the PACN Monitoring Plan, development of the NPS long-term monitoring program in the PACN provides an opportunity to address this and may instigate the development of ONWR designations within the States and Territories of the PACN.

Table 1. PACN parks' water bodies for (303(d) impairment use designations, and unique or pristine resources,.

Park	Unique or Pristine Resources[a]	303d[b]	Groundwater[c]	Inland Waters designation[d]	Marine Waters Designation[e]	Marine Bottom Ecosystem designation[f]
WAPA	Wetlands	Agana Bay and the Northern Guam Lens Aquifer (NGL)	NGL perimeter is G2[g]	S3	Asan and Agat are designated M2.	NA
AMME	Wetlands	Saipan Lagoon	Management zones are currently under development[h]	Class 1[i]	Class A and AA[j]	NA[j]
NPSA[k]	Coastal waters off Ofu and Ta`u, and Laufuti Stream	None	1G and 2G	Class 1 and Class 2	Embayment and Open Coastal	NA
USAR	None	Pearl Harbor	NA	NA	A	II
KALA	Kahakau crater lake and coastal waters	None	NA[c]	1a	AA	I
HALE	Streams, springs, and coastal waters in Kipahulu district and sub-alpine lakes	None	NA[c]	1a (possibly 1b also)	AA[j]	I[j]
ALKA	Park traverses coastal waters, wetlands, streams, and anchialine pool complexes	Pelekane Bay, Spencer Park Beach, Hapuna Beach, Kailua Bay, Magic Sands Beach, and Kealakekua Bay	NA[c]	1a	A and AA[j]	I and II[j]
PUHE	None	Pelekane Bay	NA[c]	1a	AA	II
KAHO	Wetlands, anchialine pools, and coastal waters	None	NA[c]	1a	A and AA	I and II

Park	Unique or Pristine Resources[a]	303d[b]	Groundwater[c]	Inland Waters designation[d]	Marine Waters Designation[e]	Marine Bottom Ecosystem designation[f]
PUHO	anchialine pools and coastal waters	None	NA[c]	1a	AA[j]	II[j]
HAVO	anchialine pools, coastal waters, and Ola`a bogs	None	NA[c]	1a	AA[j]	II[j]

NA. Not applicable to this park.
a. Outstanding Natural Water Resources have not been designated in the PACN region.
b. Refers to a section of the Clean Water Act that requires states to identify and list impaired water bodies (see http://www4.law.cornell.edu/uscode/33/1313.html for full details).
c. Groundwater designations have not been developed by the State of Hawaii. For identification and description of Hawaiian Island aquifers see Mink, John F. and L. Stephen Lau. 1990 – 1993. "Aquifer Identification and Classification of Hawaiian Islands: Groundwater Protection Strategy for Hawaii" (6 reports) for the University of Hawaii Water Resources Research Center.
d. See http://www.hawaii.gov/doh/rules/11-54.pdf for full details.
e. See http://www.hawaii.gov/doh/rules/11-54.pdf for full details.
f. see http://www.hawaii.gov/doh/rules/11-54.pdf for full details.
g. From the Unified Watershed Assessment 1998 Clean Water Action Plan for Guam available at http://www.guamepa.govguam.net/programs/water/GuamCWAP.pdf
h. See http://www.epa.gov/ost/standards/wqslibrary/territories/northern_mariana_9_wqs.pdf for full details.
i. See http://www.epa.gov/ost/standards/wqslibrary/territories/northern_mariana_9_wqs.pdf for full details.
j. Authorized park boundary only borders, does not encompass, marine waters.
k. See http://www.epa.gov/ost/standards/wqslibrary/territories/american_samoa_9_wqs.pdf for full details.

AVAILABLE WATER QUALITY DATA FOR ASSESSING HINTS OF TRENDS IN THE PACN

Trends in water quality for the region are not well developed due to the overall lack of available information. In regards to the CWA Section 305(b), regulatory reporting to the USEPA by the Territories and the State of Hawaii demonstrates an increase in the number of impaired water bodies as determined by local water quality standards for their respective designated uses. This statement of increasing impairments is misleading as more water quality monitoring is taking place, and previously unmonitored and unlisted resources are being added to the CWA Section 303(d) list.

Implementation of the USEPA EMAP in Hawaii, American Samoa, and Guam is under way and will provide insight into the current condition of their coastal waters that can be used for trend analysis in the future.

An interagency agreement between NPS I&M and the USGS to provide a statistical analysis of data obtained by that agency relating to park water resources will be forthcoming late in 2005.

The following presents a brief preliminary assessment of available water quality data for each park that may be useful for trend analysis.

WAPA

Groundwater is the primary resource for drinking water on Guam. The Northern Guam Lens, a sole source aquifer, was listed as an impaired water body in 2004 due to water quality standard exceedances of chlorides, nutrients, bacteria, and toxic contaminants. Data on this groundwater resource indicates saltwater intrusion due to increasing withdrawal along with impacts resulting from land use. Although the boundaries of this aquifer lie upslope and to the North of the Asan unit of WAPA, it undoubtedly has an impact on nearshore areas of the park. The GEPA Notice to the Public: 303(d) List for 2003-2004 noted sedimentation from land sources and nutrients discharged in groundwater as the primary causes of reef impairment on Guam.

The Guam Waterworks Authority tested Asan Spring for synthetic organic chemicals, volatile organic chemicals, and inorganic chemicals such as metals and salts. Data from 1996 to 1999 does not indicate any trends or exceedances in these analytes.

A two-year study of spring water discharge from the Northern Guam Aquifer into the marine preserve of Tumon Bay has recently been completed (PCR Environmental, 2002a; PCR Environmental, 2002b; and PCR Environmental, 2002c). Total discharge estimated for the springs is 17 million gallons per day. Chemicals detected above Guam EPA water quality standards in the discharges included PCE, TCE, Aluminum, Antimony, Arsenic, Magnesium, Sulfate, Oil & Grease, Total Coliform Bacteria and Fecal Coliform Bacteria. Pesticides Dieldrin, Alpha-Chlordane, and Gama Chlordane were also detected in discharges. Impacts from the chemicals on Tumon Bay are planned to be mitigated by locating and eliminating sources of the chemicals.

Limited data from the GEPAs ongoing Recreational Beach Monitoring Program indicates the possibility of increasing turbidity and total phosphorous at Agat Bay reef flat, north of Agat Sewage Treatment Plant outfall from the late 1980s to the late 1990s. This outfall is out of use as of 2002 (D. Minton 2003, personal communication). The GEPA formerly monitored streams and rivers in the Surface Water Monitoring Network between 1980 and 1999. River sites monitored adjacent to or upslope of Agat included three sites along the Namo River and two from its mouth, and two sites in the Salinas River mouth. The Matgue River in Asan and the Masso River which passes through Piti were also monitored for turbidity.

Denton, et. al., (1997) found evidence of contamination from chromium and nickel at Agat Marina and high levels of copper, lead and zinc in Agana Boat Basin to the East of the Asan Unit. Heavy metal contamination of these areas is attributed to the harbor operations and boat maintenance activities because higher levels are present where these activities are most prevalent and long-standing (GEPA 2000).

AMME

The CNMI DEQ has been monitoring five sites within AMME since 1994 for compliance with water quality standards for their designated uses as public swimming areas. A sample collection site adjacent to the recently closed Puerto Rico Dump was not monitored in 1997, but in 1998, two sites were implemented at this location north of the AMME boundary.

The AMME wetlands were surveyed baseline salinity values by NP,S ACOE, and CNMI FWS (Joel Wagner) in 1990 pertaining to the proposed Garapan Flood Control Project.

NPSA

NPSA currently has long-term temperature loggers on the reef in Vatia and Ofu. Water temperature is measured hourly by monitors within or near the park's reefs.

ASEPA Ocean Water Monitoring: 3rd 1998 & 1st 2001 quarters. One site inside NPSA at Vatia Bay was established on the 2001 collection date. The data comes from water quality surveys conducted by the American Samoa Environmental Protection Agency in August 1998 and February 2001. The surveys were conducted in order to: (1) Determine current status of water quality surrounding the islands of Tutuilla and Manu'a, (2) Obtain data to establish long term water quality trends, (3) Detect problem water bodies, (4) Verify appropriateness of American Samoa Water Quality Standards.

The World Wildlife Fund (WWF) has received a grant through the Environmental Protection Agency to do climate change research in the territory. Two of their seven sites are located in NPSA (Vatia and Tafeu Cove). As part of the project, paired water quality samples are taken from the stream and coral reef. Parameters include: nutrients, Chl a, DOC, and CDOM. Sampling started in October, 2002 and will continue quarterly until June, 2004.

A Preliminary Survey of Laufuti Stream, Ta'u Unit, National Park of American Samoa conducted between April to July, 1997 collected water samples from nine sites once and three stations three times. The National Park of American Samoa conducted this survey to explore Laufuti Stream, collect water quality data for comparison with other American Samoa streams, and to inventory the macrofauna.

One stream inside NPSA was surveyed in 1980 as part a 1978 to 1980 US Army Corps of Engineers study that was part of the American Samoa Water Resources Study. Temperature, conductivity and salinity were measured once at the mouth of an unnamed stream near Tafeu Cove.

USAR

There is only one water quality project with data available for the immediate vicinity of the sunken memorial. An 18 month study has just been completed by the NPS Submerged Resources Center and USGS. Various other water quality assessments have taken place throughout Pearl Harbor including sediment assessments by the Navy and an on-going Leeward Community College environmental educational program led by Dave Krupp.

Pearl Harbor is also the location of site-intensive studies in association with the EPA EMAP which is in its second round of random site selection for coastal assessment in Hawaii.

KALA

No long-term data is available for this park except for measurements of flow by the USGS near diversion tunnels of headwater streams.

HALE

DOH monitoring of Oheo Gulch provides a sparse, but long-term, dataset for this water body which can be compared to similar monitoring data across the PACN.

As with KALA, stream flow data has been collected intermittently by the USGS in areas concerned with diversion and withdrawal of water resources.

ALKA

This extensive trail passes through many different ecosystems with varying land uses requiring ecological assessments for zoning changes, permits requirements, and commercial concerns. A short list of the available data from long-term water quality monitoring in areas crossed by this trail include results from the NELHA CEMP, DOH beach monitoring, and anchialine pool complexes near resort developments. Additionally, numerous Environmental Impact Statements have been prepared for resources along the trail, which may provide insight into conditions at or before the tome of development.

PUHE

No long-term water quality data is available for this park although adjacent DOH sites at Kawaihae Harbor to the North and Spencer Beach Park to the South may give an indication of the status of the marine area, Pelekane Bay, offshore of the park.

KAHO

DOH monitors for human health parameters and some limited water quality at Honokohau Harbor which lies inside KAHO but is not administrated by the park. Honokohau Harbor expansion/circulation and faunal changes have degraded between the initial study in 1971 and the follow-up study after expansion of the harbor in 1979 (Bienfang 1980).

There is limited data available from three monitoring wells within park boundaries and numerous short-term water quality studies of the park's anchialine pools, fishponds, and nearshore areas (Maciolek and Brock '74, Chai '91, Brock and Kam '97). This information is still very disparate and will take a coordinated effort by NPS staff and researchers to compile the available information into a meaningful dataset.

PUHO

No long-term water quality data is available for this park, although DOH monitors for human health parameters and some limited water quality at Napoopoo and Honaunau Bay to the North of park boundaries.

HAVO

No long-term data is available for this park although measurements of flow were collected in the past by the USGS in ephemeral streams in the southern area of HAVO.

PLANNING STRATEGY

In the interest of collaboration, the water quality workgroup sponsored a planning meeting to consider water quality components of the PACN monitoring plan and its purpose. Discussion topics focused on park resource issues and values, monitoring objectives, desired future conditions and potential monitoring boundaries. Ideas generated from this process will be used to develop the full monitoring plan. A complete report of this meeting is available at http://www.nature.nps.gov/im/units/pacn/monitoring/plan/waterq/wq-mtg_20030812.doc.

WATER QUALITY AREA OF INTEREST

PARK LANDS

Park managers need to be aware of the impacts to water quality from neighboring land uses and ecosystem processes. For this reason, monitoring the water quality of areas outside of the parks is important to the successful management of resources inside the parks. Water resources in the PACN are governed by layers of legislation concerning park boundaries, state boundaries, and private, State, or Territorial lands and waters. Consequently, park water resources are affected by activities and conditions in areas out of their jurisdiction. Streams which pass through a park may be altered upstream through diversion or use as an outfall for industrial waste. Offshore currents may bring pollutants from nearby industrialized areas into an embayment or onto a reef. Fire and flood may increase sediment loading through a surrounding watershed.

Watersheds: Watersheds will be included due to the simple fact that water flows down hill, and streams originating inside or upslope of parks are affected by both natural and anthropogenic events. Most PACN parks are located in areas with high precipitation and porous substrate contributing to pollutants leaching directly into coastal areas. Those with more arid or less porous conditions are vulnerable to catastrophic flood events which result in erosion and uncontrolled dispersion of urban wastes.

Nearshore: Many of the PACN parks are located next to population centers with poor or non-existent waste treatment facilities and various sources of industrial pollutants. Currents running parallel to the shoreline can carry pollutants from nearby human activities into parks or cause changes in beach areas managed by the park.

MARINE BOUNDARIES

For offshore distances, arbitrary distances of ½ mile, or depth contours of 100’ or 120’ are being considered. In all cases, the existing park boundary should be used if it extends farther than the chosen criteria. Offshore study areas should extend laterally along the coast from the authorized park boundary up to one half mile up current or to the next point which may create an embayment. In most shoreline parks, the current runs from east to west. They should also encompass any immediately adjacent embayment, up or down current

LAND BOUNDARIES

Stream water and groundwater quality can be helpful for determining early warning signs of change. Water quality study areas should encompass the entire park land area and be inclusive of the adjacent watershed. They should extend from the park boundary upslope to the top of the watershed, and downslope approximately 1 mile. In some Western Pacific Islands, the whole island may be included as the monitoring area using this criteria. On the island of Hawaii, this may mean watersheds that are orders of magnitude larger than parks. After preparing draft samples of maps reflecting these boundaries for all parks, these definitions will be refined.

REVISION PROCESS

Using the strategy outlined above, proposed areas of interest for monitoring were drawn onto existing park maps. Some parks make up their own watershed and are quite expansive, while others are dwarfed by their surrounding watershed. In either case, the proposed area could cover most of the island. For this reason two types of maps were made. The marine boundary map shows the proposed shoreline boundary up and down current from the park borders along with both proposed offshore limits. Lines showing where 1/2 mile from the shoreline and the 120 foot depth contour are also shown. Another map depicts each park within its respective watershed. Proposed maps for each park can be found in Appendix C. The locations of USGS monitoring wells and stream gauges will be included in future monitoring area maps. These preliminary charts will be circulated back to the resource staff at each park and other qualified experts for comment. Final monitoring areas will be proposed after a thorough review and consultation process which includes the practicality of the scope of work involved.

PARTNERING

In the context of the larger network monitoring program, overlap between water quality and other subject areas have been identified. Especially critical is the link between water quality and the topics covered by the marine biology, freshwater biology, and geology workgroups. Although groundwater is typically handled through the geology workgroup, the obvious link in the islands between ground and surface water resources cannot be ignored (e.g. anchialine pond concerns focus on nutrients, oxygen, salinity, and ground water quantity inputs). Because of this, we concern ourselves with groundwater quality and quantity where appropriate. It is essential to work closely with these and other workgroups to gain an ecosystem-wide understanding of resource management challenges. Multiple lines of evidence will also better support management claims.

In addition to working with others in our agency, it is critical to work with other organizations that also have water quality goals and objectives. An extensive list of potential partners is being developed as information about current and past water quality studies is gathered (Appendix D: Potential partners).

DESIRED FUTURE CONDITIONS

After collaboration with government, non-government, and academic experts on marine and freshwater conditions throughout the PACN, the following priorities for the future have come to the fore. The primary goal is the protection of ecological health, condition, and function so that the water quality is of a level to support biodiversity, larval dispersal, growth and reproduction. This goal is to be accomplished while accommodating cultural uses which influence water quality. These two priorities necessitate the third which is to disseminate water quality information widely, and with interpretation, so that park managers, government regulating agencies, and commercial and recreational users can understand the shared values of the resource in question and manage it appropriately. It is everyone's desire to fulfill these goals, but when resources are not valued in the same way by all, the way to achieve them is not so clear.

To be successful in the stewardship of water resources, we should keep conditions at least at the present level of quality, with no further degradation, and initiate recovery or restoration of degraded areas. This means maintaining natural processes or patterns with sustainable resources varying within normal ranges for the given climate. Naturally existing shoreline conditions and dynamics should be maintained. An environment conducive to the survival and perpetuation of native biological communities will encourage a diverse ecosystem with healthy populations. This is especially critical to the protection of rare or endangered biota. One important aspect of this is the identification and preservation of the water quality in nursery areas. Turbidity and nutrient levels are important indicators of change and should be maintained in a natural condition.

Human influence is often contrary to achieving the goals stated above. It is highly desirable that land use not affect sediment or nutrient dynamics in aqueous systems. The impact of cultural uses, past and present, should be defined so that management practices can be developed where human disturbances are minimized. In addition, standards for all States and Territories in the network need to be reviewed with the sustainability of the resource as the goal. This may require different standards for different water bodies and habitat types as well as different baseline criteria to be monitored.

Understanding human impact on water quality is achievable once the planned monitoring program is implemented, but for the most part we do not have baselines to work from in the PACN. It is important to recognize that our conception of what is attainable may change over time and so preliminary monitoring will be necessary to come up with more specific desired future conditions. Currently unimpaired waters should be used as a baseline for ideal conditions, and these areas should be island-specific. This is also helpful in avoiding sliding baselines where changes that occur over generations are not noticed and the new environmental conditions are thought of as 'normal'.

CONCLUSIONS

The status of freshwater, marine, and groundwater water quality is the focus of monitoring for this PACN monitoring plan appendix. These water bodies include streams, lakes, wetlands, fish ponds, anchialine pools, tide pools, coastal, and interstitial waters.

Each of the park units in PACN is unique in location and in stressors that affect their water resources but there are also many shared concerns. Increased visitor use accompanying human population growth contributes to loss of habitat buffers and subsequent degradation of water quality in all systems. Development of adjacent lands and watersheds and control of feral animals that degrade vegetation and accelerate erosion is a concern at all parks. Runoff from agricultural and urban development and sedimentation due to natural and man-made causes contribute to organic enrichment, bacterial and chemical contamination, and increased turbidity. These issues are aggravated by natural events such as fire, flood, and climate change. Marine waters are also impacted by chemical and sewage pollution from groundwater discharge, commercial ships, harbor operations, and recreational activities such as fishing, swimming, camping and boating. Freshwater, wetland and estuarine habitats are important biologically (Iliffe 1986, Chang 1994, Englund et. al. 2000) and are especially vulnerable due to their small size and low flow. Diversion of and discharge into streams affects groundwater, coastal resources such as anchialine pools and wetlands, as well as nearshore areas. Impacted stream water reaching the reef may inhibit natural stream fauna from repopulating streams after a juvenile marine stage. Groundwater quality and hydrology is of critical importance to both humans and ecological communities and is often the water resource impacted first by anthropogenic factors.

Information on local drivers and stressors to water quality was obtained from management personnel at each park as well as water quality experts in the island groups. Key drivers/stressors include:

- Land use – filling, population/urban development, industrial and individual wastewater systems, agriculture/animal production, feral animals, waste disposal, roads, and commercial shipping operations. introduction of alien aquatic species
- Weather and Climate – tropical storms, climate change, global warming.
- Recreation – fishing, boating/personal watercraft, SCUBA diving/snorkeling

The benefits of this monitoring program reach beyond the needs of NPS natural resource managers. Education and conservation organizations can supplement their research and management programs with monitoring information and other community groups will benefit from the availability of credible scientific information about their valued resources. Public distribution of monitoring results will help to alleviate community concerns or misconceptions, and to justify management guidelines and regulations. Regulatory and public health agencies are also interested in monitoring data that assists them in evaluating their respective environmental management concerns.

ACKNOWLEDGEMENTS

We would like to thank the following NPS resource managers, hydrologists, water quality specialists, and ecologists who contributed to this document: Sallie Beavers, Gordon Tribble, Terrence Teruya, Watson Okubo, Barry Hill, Dale Mikami, Annie Leong-Guerrero, Peter Houk, Jesse Cruz, Brian Beardon, Guy Didonato, Patricia Young, Walt Nelson, Ben Machol, Linda Koch, Greta Aeby, and Thierry Work. Workgroup members provided early direction and goals for this workgroup, and their participation is appreciated. They include Sallie Beavers, Dwayne Minton, Peter Craig, Eva Didonato, Ed Laws, Gordon Tribble, Bill Walsh, Robert Nishimoto, Sara Peck, Roy Irwin, Kevin Summers, Fritz Klasner, Gordon Dicus, and Darcy Hu. Other NPS resource and administrative managers and technicians that provided valuable information throughout this process, include Stan Bond, Marshall Owens, Duane Minton, Aric Arakaki, Mike Donoho, Guy Hughes, Tim Tunnison, Eric Anderson, Ben Saluda, Malia Laber, Allison Cocke, Sandy Margriter, Bobby Camara, Ana Dittmar, and Mike Matz. Valuable input was gained from participants and collaborators at a vital signs meeting held in March. We also thank the PACN workgroup and park facilitators that collaborated, shared sources, leads, and information. Many thanks to Fritz Klasner, Sallie Beavers, Roy Irwin, Penny Latham, Jerry Freylich, Leslie Haysmith, Jean Licus for editorial assistance.

LITERATURE CITED

Aeby, Greta. personal communication 2004

Baker, R. H. 1951. The avifauna of Micronesia, its origin, evolution, and distribution. University of Kansas Publications, Museum of Natural History 3(1): 1-359.

Bienfang, P. 1980. Water quality characteristics of Honokohau Harbor: a subtropical embayment affected by groundwater intrusion. Pacific science: 34:p.279-291.

Blumenstock, D. I., and S. Price. 1967. Climates of the states: Hawaii. Environmental Science Data Service, Climatology of the United States, No 60-51. U. S. Government Printing Office,Washington, D. C. 27 pp.

Brock, Richard E., Kam, Alan K. H. 1997. Biological and water quality characteristics of anchialine resources in Kaloko-Honokohau National Historical Park Technical Report 112: Cooperative National Park Resources Studies Unit, University of Hawai`i at Manoa.

Chai, David K. 1991. An inventory and assessment of Kaloko Pond, marsh, and anchialine pools at Kaloko-Honokohau National Historical Park, North Kona, Hawai`i Technical report 76: Cooperative National Park Resources Studies Unit, University of Hawai`i at Manoa.

Chang, Deborah L. 1994. Description of anchialine ponds. Unpublished report.

De Carlo, E.H., V.L. Beltran, M.S. Tomlinson, K.J. Spencer, and J.E. Hubert. 2000. Trace Elements in the Aquatic Environment of Hawaii: Effects of Urbanization. *Am. Chem. Soc*., 5pp. UNIHI-SEAGRANT-CP-00-02.

Denton, G.R.W., H.R.Wood, L.P. Concepcion, H.G. Siegrist, Jr., V.S. Eflin, D.K. Narcis, and G. T. Pangelinan. 1997. Analysis of in-place contamination in marine sediments from four harbor locations on Guam. Water and Environmental Research Institute, University of Guam. Technical Report No. 81. 120 pp.

Denton, G.R.W., H.R.Wood, L.P. Concepcion, V.S. Eflin, and G.T. Pangelinan. 1999. Heavy metals, PCB=s and PAH=s in marine organisms from four harbor locations on Guam. Water and Environmental Research Institute, University of Guam. Technical Report No. 87. 158 pp.

Englund, R. A., D. J. Preston, R. Wolff, S. L. Coles, L. G. Eldredge, and K. Arakaki. 2000. Biodiversity of freshwater and estuarine communities in lower Pearl Harbor, Oahu, Hawaii with observations on introduced species. Bernice Pauahi Bishop Museum Hawaii Biological Survey Technical Report.

Fujioka, Roger S. 2004 in press. Evaluation of the applicability of USEPA Recreational Water Quality Standards for Tropical Environments.

Fujioka, Roger S. 2004 in press. Confirming the Natural Presence of Fecal Indicator Bacteria in Environmental Soil and Water on the Islands of Kauai and Hawaii

Fujioka, Roger S., Geeta K. Rijal, J. Alfredo Bonilla. 1998. An innovative approach to Assess and Monitor the Quality of Coastal Water. Project Completion Report: WRRC-98-13 Water Resources Research Center, University of Hawaii at Manoa, Honolulu, Hawaii. Prepared for Sea Grant College Program, University of Hawaii.

Garrison, G.H., C.R. Glenn, and G.M. McMurty, 1999. A Study of Submarine Groundwater Discharge into Hawaiian Coastal Waters. Poster abstract, UH Seagrant, fall meeting.

Giambelluca, T. W., M. A. Nullet, and T. A. Schroeder. 1986. Rainfall atlas of Hawaii. Report R76. Water Resources Research Center, University of Hawaii at Manoa with the cooperation of the Department of Meteorology. State of Hawaii, Department of Land and Natural Resources, Division of Water and Land Development, Honolulu, Hawaii.

Glenn, E.P., C.M. Smith, and M.S. Doty. 1990. Influence of Antecedent Water Temperatures on Standing Crop of a Sargassum spp.-dominated reef flat in Hawaii. Marine Biology 105, 323-328.

Hoegh-Guldberg, O. 1999. Climate change, coral bleaching and the future of the world's coral reefs. Marine and Freshwater Research 50:839-866.

Iliffe, Thomas M. 1986. The Zonation Model for the Evolution of Aquatic Faunas in Anchialine Caves. Stygologia 2 (1/2), 2-9.

MacDonald, G. A., and A. T. Abbott. 1970. Volcanoes in the sea; the geology of Hawaii. University of Hawaii Press, Honolulu, Hawaii.

Maciolek, John A., Brock, Richard E. 1974. Aquatic survey of the Kona Coast Ponds, Hawai`i Island UNIHI-Seagrant-AR-74-04: University of Hawaii.

Moore, R. B., D. A. Clague, M. Rubin, and W. A. Bohrson. 1987. Hualalai volcano: a preliminary summary of geologic, petrologic, and geophysical data. Pp. 571-585 in R. W. Decker, T. L. Wright, and P. H. Stauffer (editors). Volcanism in Hawaii, Vol. 1. U. S. Geological Survey Professional Paper 1350. U. S. Government Printing Office, Washington, DC.

Mueller-Dombois, D., and F. R. Fosberg. 1998. Vegetation of the tropical Pacific islands. Springer-Verlag, New York.

Nance, T. (Watre Resource Engineering) 2000. Potential Impact of Water Resources of Phases III and IV of the Kaloko Industrial Park in North KOna, Hawaii. In: Final Environmenta; Impact Statement: Kaloko Industrial Park, Phaeses III and IV, Kaloko, North Kona, Hawaii: Appendix A.

Rocke, Tonie E. and Michael D. Samuel. 1999. Water and Sediment Characteristics Associated with Avian Botulism Outbreaks in Wetlands. J. Wildl. Manage. 63(4):1249-1260.

Sedwick, P.N., G.M. McMurty, and G.W. Tribble. 1990. Chemical alteration of seawater by lava from Kilauea Volcano, Hawaii. *Marine Geology*, 96 (1991) 151-158.

Wagner, Joel. 1990. Trip Report for travel by Joel Wagner to American Memorial Park, Saipan, Commonwealth of the Northern Marianas.

Whistler, W. A. 1994. Botanical inventory of the proposed Tutuila and Ofu units of the national Park of American Samoa. Cooperative National Park Resources Studies Unit Technical Report 87. University of Hawaii at Manoa, Department of Botany, Honolulu, Hawaii.

Whistler, W. A. 1992. Botanical inventory of the proposed Tau unit of the National Park of American Samoa. Cooperative National Park Resources Studies Unit Technical Report 83.University of Hawaii at Manoa, Department of Botany, Honolulu, Hawaii

Wolanski, E., R.H. Richmond, G. Davis, and V. Bonito. 2003. Water and fine sediment dynamics in transient river plumes in a small, reef-fringed bay, Guam. Estuar. Coast. Shelf Sci. 56: 1029-1043.

LITERATURE REVIEWED

ACOE. 1986 (updated in 1987). "Garapan Flood Control Study Final Detailed Project Report and Environmental Impact Statement"

Baker, R. H. 1951. The avifauna of Micronesia, its origin, evolution, and distribution. University of Kansas Publications, Museum of Natural History 3(1): 1-359.

Bhambare, D.N. 1996. Design and development of a remotely controlled mobile data acquisition system for continuous and long-term monitoring of water quality in Hawai`ian anchialine ponds : water quality characteristics of Kaloko Pond : a small case study: University of Hawai`i at Manoa, Civil Engineering Department.

Bienfang, P., Johnson, W. 1980. Planktonic properties of Honokohau Harbor: a nutrient-enriched subtropical embayment. Pacific science: 34:p.293-300.

Blumenstock, D. I., and S. Price. 1967. Climates of the states: Hawaii. Environmental Science Data Service, Climatology of the United States, No 60-51. U. S. Government Printing Office,Washington, D. C. 27 pp.

Brasher, Anne M. 1999. Development of a monitoring program to assess physical, chemical and biological components of Kaloko Fishpond at Kaloko-Honokohau National Historical Park on the Island of Hawaii.

Brock, R.E. (Environmental Assessment Co.). 2003. Preliminary inventory of the anchialine resources at Kohanaiki, North Kona, Hawaii. Prepared for Rutter Development Corp., 18012 Cowan, Suite 200, Irvine, California, 92614. EAC Rept. No. 2003-14.

Brock, R.E. (Marine Research Consultants). 2000. An assessment of Potential Effects to the Marine and Pond Environments on the vicinity of the Kaloko Industrial Pasrk, Phases III and IV, North KOna, Hawaii. In: Final Environmenta; Impact Statement: Kaloko Industrial Park, Phaeses III and IV, Kaloko, North Kona, Hawaii: Appendix B.

Brock, R. E. and A. K. H. Kam. 1994. The Waikoloa anchialine pond program fifth status report. Prepared for the U.S. Army Corps of engineers, Honolulu. Sea Grant College Program unpublished tech Rept., Univ. of Hawaii, Honolulu. Vii+71p. 1992-4th report.

Brock, R.E. and A.K.H. Kam. 1990. The Waikoloa pond program third annual report. Prepared for the U.S. Army Corps of Engineers, Honolulu. Hawaii Institute of Marine Biology unpublished technical report. University of Hawaii, Honolulu. 64p+appendices.

Brock, R. E. and J. E. Norris. 1988. The Waikoloa Anchialine Pond Program: Second Status Report. Typescript, 65 pp.

Brock, Richard E., Norris, James E., Ziemann, D.A., Lee, M.T. 1987. Characteristics of water quality in anchialine ponds of the Kona, Hawai`i, USA coast. Pacific Science: 41:1-4, p.200-208.

Brock, Richard E, No Proceedings Author. 1987. Status of the anchialine pond system of the Kona Hawai`i coast, Second International Symposium on Indo-Pacific Marine Biology, Western Society of Naturalists, University of Guam, 23-28 June 1986, Bulletin of marine science, p. 633.

Brock, R. E. 1985. An assessment of the conditions and future of the anchialine pond resources of the Hawaiian Islands. Prepared for Transcontinental Development Co., Honolulu.

Canfield, J. 1990a. Description and map of the plant communities of Kaloko-Honokohau National Cultural Park. Cooperative National Park Resources Studies Unit Technical Report 73. University of Hawaii at Manoa, Department of Botany, Honolulu, Hawaii.

CNMI FWS. 1985. "Final Coordination Act Report" for the Garapan Flood Control Study.

De Carlo, E.H. and S.S. Anthony. 2001. Spatial and Temporal Variability of Trace Element Concentrations in an Urban Subtropical Watershed, Honolulu, Hawaii. *Applied Geochemistry* 17 (2002) 475-492.

Dollar, S.J., R.E. Brock and S.V. Smith. 1995. Implementation of a water quality monitoring program on the west coast of the island of Hawaii in support of a proposed amendment to state water quality standards. Draft final report submitted to State of Hawaii Department of Health, Environmental Planning Office, Honolulu. 54p.

Duenas and Associates. 2003. Draft Guam Nonpoint Source Pollution Management Program. Guam Coastal Management Program.

Gallagher, Brent. 1980. Physical structure and circulation in Honokohau, a small Hawai`ian harbor affected by groundwater. Pacific Science: 34:3, p.301-311.

Giambelluca, T. W., M. A. Nullet, and T. A. Schroeder. 1986. Rainfall atlas of Hawaii. Report R76. Water Resources Research Center, University of Hawaii at Manoa with the cooperation of the Department of Meteorology. State of Hawaii, Department of Land and Natural Resources, Division of Water and Land Development, Honolulu, Hawaii.

Guam Environmental Protection Agency. 2003. Section 305b Water Quality Report to Congress. 56 pp.

Guam Environmental Protection Agency. 2001. Revised Guam Water Quality Standards. Public Law 26-32. 122 pp.

Guam EPA. Notice to the Public: 303(d) List for 2003-2004

Guam EPA. Status of the Reefs of Guam: Draft Report - March 30, 2004

Guam EPA. 2000. Management of Contaminated Harbor Sediments in Guam; Coastal Zone Management Act Section 309; Guam Harbors Sediment Project, Phase III, Final Report.

Jackson, William L., Rosenlieb, Gary. 1989. Anchialine pond water concerns Kaloko-Honokohau National Historical Park, North Kona, Hawaii.

Kauahikaua, Ji, Takasaki, Kiyoshi, Jackson, Dallas B. 1985. An evaluation of ground water resources in Kailua-Kona, Hawaii using electric geophysical measurements, U S Geological Survey Open file report: OF 85-0033.

Kay, E. Alison, Lau, L. Stephen, Stroup, Edward D., Dollar, Stephen J., Fellows, David P., Young, Reginald H. F. 1977. Hydrologic and ecologic inventories of the coastal waters of west Hawai`i Technical Report No. 105, Sea Grant Cooperative Report UNIHI-SEAGRANT-CR-77-02: Water Resources Research Center, University of Hawaii.

Kikuchi, William K. 1976. Prehistoric Hawaiian fishponds. Science: 193:4250, p.295-299.

Kikuchi, William K., Belshe, J. 1971. Examination and evaluation of fishponds on the leeward coast of the Island of Hawai`i.

Kimura International. 1996. Kaloko Town Center, North Kona, Hawai`i : final environmental impact statement: Kaloko International Inc.

Loomis, Harold G. 1975. Normal modes of oscillation in Honokohau Harbor, Hawai`i Report No. HIG-75-20.

MacDonald, G. A., and A. T. Abbott. 1970. Volcanoes in the sea; the geology of Hawaii. University of Hawaii Press, Honolulu, Hawaii.

Mink, John F. investigato, Kay, E. Alison investigator, Bowles, Stephen P. investigator, Gee, Henry K. investigator. 1982. Land disposal by injection wells of ocean water effluent at seacoast test facility, Keahole Point, Island of Hawaii. No Title: p.51-52.

Moore, R. B., D. A. Clague, M. Rubin, and W. A. Bohrson. 1987. Hualalai volcano: a preliminary summary of geologic, petrologic, and geophysical data. Pp. 571-585 in R. W.

Decker, T. L. Wright, and P. H. Stauffer (editors). Volcanism in Hawaii, Vol. 1. U. S. Geological Survey Professional Paper 1350. U. S. Government Printing Office, Washington, DC.

Mueller-Dombois, D., and F. R. Fosberg. 1998. Vegetation of the tropical Pacific islands. Springer-Verlag, New York.

National Park Service Water Resources Division. 2000. Baseline water quality data inventory and analysis Kaloko-Honokohau National Historic Park Technical Report NPS/NRWRD/NRTR-99/247: United States Department of the Interior, National Park Service, Water Resources Division.

National Park Service, Honokohau Study Advisory Commission. 1974. Draft environmental statement Proposed Kaloko, Honokohau National Cultural Park, Hawai`i: U.S. National Park Service.

National Park Service Water Resources Division. 2000. Baseline water quality data inventory and analysis Kaloko-Honokohau National Historic Park Technical Report NPS/NRWRD/NRTR-99/247: United States Department of the Interior, National Park Service, Water Resources Division.

National Park Service, Honokohau Study Advisory Commission. 1974. Draft environmental statement Proposed Kaloko, Honokohau National Cultural Park, Hawai`i: U.S. National Park Service.

Oconnor, Paul Alelele, HALE stream assessment report

Oki, Delwyn S., Tribble, Gordon W., Souza, William R., Bolke, E. L. 1999. Ground-water resources in Kaloko-Honokohau National Historical Park, Island of Hawaii, and numerical simulation of the effects of ground-water withdrawals U.S. Geological Survey Water-Resources Investigations Report 99-4070: U.S. Geological Survey.

Paulay, G., L. Kirkendale, C. Meyer, P. Houk, T. Rongo, R. Chang. 2001 Marine biodiversity resource survey and baseline reef monitoring survey of the Southern Orote Peninsula and North Agat Bay area, COMNAVMARIANAS.

PCR Environmental, Inc. 2002.a. Sampling of Tumon Bay springs for chemical analysis. Guam Environmental Protection Agency. 125 pp.

PCR Environmental, Inc. 2002.b. Sampling of Tumon Bay springs for chemical and bacterial analysis. Guam Environmental Protection Agency. 145 pp.

PCR Environmental, Inc. 2002.c. Summary Report of Tumon Bay springs sampling for chemical analysis. Guam Environmental Protection Agency. 141 pp.

Polhemus, Dan A., Maciolek, John, Ford, John. 1992. An ecosystem classification of inland waters for the tropical Pacific Islands. Micronesica: 25:2, p.155-173.

Rosenlieb, Gary W., Long, Barry A., Martin, Larry, Hagemann, Matt, Irwin, Roy J., Tilmant, Jim. 1998. Potential influences of wastewater discharges on Aimakapa Pond and nearby anchialine pools, Kaloko-Honokohau National Historic Park: U.S. National Park Service, Water Resources Division.

Sansone, Francis J, Smith, S. V., Price, James M., Walsh, Ted W., Daniel, Thomas H., Andrews, Christine C. 1988. Long-term variation in seawater composition at the base of the thermocline. Nature (London): 332:6166, p.714-717.

Stone, D.B, Stone, D.B., Stone, D.B. 1989. Hawai`i's wetlands, streams, fishponds and pools, Conservation Biology in Hawai`i: Univ. of Hawai`i Press, p.125-136.

Stromquist, C. Dale. 1996. Untitled: Well completion reports, Honokohau-NPS, monitor wells.

U.S. Army Corps Of Engineers. 1983. A decade of ecological studies following construction of Honokohau small boat harbor, Kona, Hawai`i Special report, Honolulu District.

U.S. Navy (USN). 2002. Draft work plan for the phase II investigation at the South Orote Peninsula Operable Unit. Report prepared for the Pacific Division, Naval Facilities Engineering Command by AMEC Earth and Environmental Inc.

U.S. Navy (USN). 2003. Draft site work plan ground water monitoring, phase II investigation, South Orote Peninsula Operable Unit, COMNAVMARIANAS, Guam. Report prepared for the Pacific Division, Naval Facilities Engineering Command by Shaw Environmental Inc.

Whistler, W. A. 1992. Botanical inventory of the proposed Tau unit of the National Park of American Samoa. Cooperative National Park Resources Studies Unit Technical Report 83.University of Hawaii at Manoa, Department of Botany, Honolulu, Hawaii

Whistler, W. A. 1994. Botanical inventory of the proposed Tutuila and Ofu units of the national Park of American Samoa. Cooperative National Park Resources Studies Unit Technical Report 87. University of Hawaii at Manoa, Department of Botany, Honolulu, Hawaii.

Work, Thierry. personal communication 2004

Work, Thierry M. and George H. Balazs. 1997. Causes of Green Turtle (Chelonia mydas) Morbidity and Mortality in Hawaii. Proceedings of the Seventeenth Annual Symposium on Sea Turtle Biology and Conservation, Orlando, Florida, March 4-8, 1997.

Wyban, Carol A. 1996. Feasibility study for Kaloko fishpond-Kaloko-Honokohau National Historical Park, Island of Hawai`i.

APPENDIX A: SURFACE WATER BODIES IN THE PACN

Table 2 Partial list of non-marine aquatic resources associated with PACN parks. Resources may not be within authorized park boundaries, but are within desired water quality monitoring boundaries. List includes most of the named waterbodies, but not many smaller resources like seeps and springs.

Table 2. Partial list of non-marine aquatic resources associated with PACN parks

Park	Name	Type	Location	Other
WAPA	Maina	Spring	possibly: Fonte Plateau Unit	
	Asan	River	mouth & part of body	
	Asan	Spring	possibly: Asan Unit	
	Matgue	River	mouth & part of body	
	Taguag	River	part of body, Piti Unit	
	Masso	River	possibly: part of body, Piti Unit	
	Namo	River	mouth, Agat Unit	
	Togcha	River	mouth & headwaters, Agat/Mt. Alifan Unit	
	Salinas	River	mouth & headwaters, Agat/Mt. Alifan Unit	
	Finile	Creek	mouth & possibly headwaters, Agat/Mt. Alifan Unit	
	Finile	Spring	possibly: 2 of 3 springs, Mt. Alifan Unit	
	Gaan	River	mouth, possibly headwaters, Agat/Mt. Alifan Unit	
	Auau	Stream	mouth, Agat Unit	
	Ylig	River	possibly: headwaters, Mt. Chachao/Mt. Tenjo Unit	

Park	Name	Type	Location	Other
	(several)	Wetland	upland areas	
	(several)	Wetland	coastal areas	
AMME	(unnamed?)	Stream	on border	in Garapan
	"AMME"	Wetland	within park	
NPSA	Agaputuputu	Stream	mouth, Ofu	
	Tafe	Stream	mouth, Ofu	
	Ulafala	Stream	mouth, Ofu	
	Vainuulua	Stream	mouth, Ofu	
	Alei	Stream	Olesega	
	Vaaui	Stream	Olesega	
	Sinapoto	Stream	Olesega	
	Talaisina	Stream	Olesega	
	Topea	Stream	Olesega	
	Etemuli	Stream	Olesega	
	Papausi	Stream	Olesega	
	(unknown)	Stream	upland stream, Tutuila	possibly intermittent
	(unknown)	Stream	possibly: on border, Ta`u	possibly intermittent
	Laufuti	Stream	whole stream, Ta`u	
	Leua	Stream	possibly on border, headwaters, Tutuila	
	(unknown)	Stream	several, Tutuila	possibly intermittent
	Nu`utogo	Stream	Tutuila	
	Vaisa	Stream	Tutuila	
	Gaoa	Stream	Tutuila	
	Lausaa	Stream	Tutuila	
	Faatafe	Stream	Tutuila	
	Mulivai	Stream	Tutuila	
	Vaiola	Stream	Tutuila	
	Tiaiu (Falls)	Stream	at least headwaters, Tutuila	
USAR	Halawa	Stream	not within park	
	Kalauao	Stream	not within park	
	Waimalu	Stream	not within park	
	Waiawa	Stream	not within park	
	others?	Stream	not within park	possibly intermittent
KALA	Waikolu	Stream	not headwaters	
	Wailea	Stream	not headwaters	
	Waihanau	Stream	not headwaters	intermittent
	Pelekunu	Stream	possibly headwaters	
	Kauhako	Lake	within park	
HALE	Waiho`i	Bog	below park boundary, upper Hana	
	State	Bog	below park boundary, upper Hana	
HALE	Big	Bog	upper Hana	
	Mid-Camp	Bog	upper Hana	
	Greensword	Bog	upper Hana	
	New	Bog	upper Hana	
	Flat Top	Bog	upper Hana	
	Wai`ele`ele	Lake	upper Hana	
	Wai`anapanapa	Lake	upper Hana	
	"Wai Nene"	Lake	upper Hana	not perennial

Park	Name	Type	Location	Other
	Kalepa	Stream	Ka`apahu tract	forms west boundary
	`Alelele	Stream	Ka`apahu tract	
	Leleka	Stream	Ka`apahu tract	
	(unnamed)	Stream	Ka`apahu tract	intermittent (lower reaches)
	Kukuiula	Stream	Ka`apahu tract, upstream section	forms east boundary?
	Pipiwai	Stream	Kipahulu tract (`Oheo)	Pipiwai/Palikea join in `Oheo Gulch
	Palikea	Stream	Kipahulu tract (`Oheo)	Pipiwai/Palikea join in `Oheo Gulch
	Pua`alu`u	Stream	Kipahulu tract	
	Kalena	Stream	Kipahulu tract, only upper portion	
	Kalena	Stream	Kipahulu tract, only upper portion	
	(seasonal)	Stream	Kaupo Gap ?	
ALKA	?	? [1]	resources have yet to be identified	
PUHE	Makahuna	Stream	mouth & part of body	upper reaches intermittent
KAHO	Kaloko	Fishpond	within park	
	Kaloko	wetland	within park	
	`Aimakapa	Fishpond	within park	
	Anchialine	Ponds	several	
	`Aimakapa	Wetland	yes: associated w. `Aimakapa Pond	
PUHO	"Royal"	Fishpond	within park	
	(no name)	Wetland	within park	
	Anchialine	Ponds	several	4 ponds + 2 waterholes
	Ki`ilae	Stream	mouth	intermittent
HAVO	(ephemeral)	Streams	Ka`u region	intermittent
	(several)	Ponds	several anchialine ponds	
WAPA	Maina	Spring	possibly: Fonte Plateau Unit	
	Asan	River	mouth & part of body	
	Asan	Spring	possibly: Asan Unit	
	Matgue	River	mouth & part of body	
	Taguag	River	part of body, Piti Unit	
	Masso	River	possibly: part of body, Piti Unit	
	Namo	River	mouth, Agat Unit	
	Togcha	River	mouth & headwaters, Agat/Mt. Alifan Unit	
	Salinas	River	mouth & headwaters, Agat/Mt. Alifan Unit	
	Finile	Creek	mouth & possibly headwaters, Agat/Mt. Alifan Unit	
	Finile	Spring	possibly: 2 of 3 springs, Mt. Alifan Unit	
	Gaan	River	mouth, possibly headwaters, Agat/Mt. Alifan Unit	
	Auau	Stream	mouth, Agat Unit	
	Ylig	River	possibly: headwaters, Mt. Chachao/Mt. Tenjo Unit	

[1] Multiple aquatic resources exist along the trail route, including coastal wetlands, anchialine ponds, inland Hawaiian fishponds, and streams.

Park	Name	Type	Location	Other
	(several)	Wetland	upland areas	
	(several)	Wetland	coastal areas	
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	"AMME"	Wetland	within park	
NPSA	Agaputuputu	Stream	mouth, Ofu	
	Tafe	Stream	mouth, Ofu	
	Ulafala	Stream	mouth, Ofu	
	Vainuulua	Stream	mouth, Ofu	
	Alei	Stream	Olesega	
	Vaaui	Stream	Olesega	
	Sinapoto	Stream	Olesega	
	Talaisina	Stream	Olesega	
	Topea	Stream	Olesega	
	Etemuli	Stream	Olesega	
	Papausi	Stream	Olesega	
	(unknown)	Stream	upland stream, Tutuila	possibly intermittent
	(unknown)	Stream	possibly: on border, Ta`u	possibly intermittent
	Laufuti	Stream	whole stream, Ta`u	
	Leua	Stream	possibly on border, headwaters, Tutuila	
	(unknown)	Stream	several, Tutuila	possibly intermittent
	Nu`utogo	Stream	Tutuila	
	Vaisa	Stream	Tutuila	
	Gaoa	Stream	Tutuila	
	Lausaa	Stream	Tutuila	
	Faatafe	Stream	Tutuila	
	Mulivai	Stream	Tutuila	
	Vaiola	Stream	Tutuila	
	Tiaiu (Falls)	Stream	at least headwaters, Tutuila	
USAR	Halawa	Stream	not within park	
	Kalauao	Stream	not within park	
	Waimalu	Stream	not within park	
	Waiawa	Stream	not within park	
	others?	Stream	not within park	possibly intermittent
KALA	Waikolu	Stream	not headwaters	
	Wailea	Stream	not headwaters	
	Waihanau	Stream	not headwaters	intermittent
	Pelekunu	Stream	possibly headwaters	
	Kauhako	Lake	within park	
HALE	Waiho`i	Bog	below park boundary, upper Hana	
	State	Bog	below park boundary, upper Hana	
HALE	Big	Bog	upper Hana	
	Mid-Camp	Bog	upper Hana	
	Greensword	Bog	upper Hana	
	New	Bog	upper Hana	
	Flat Top	Bog	upper Hana	
	Wai`ele`ele	Lake	upper Hana	
	Wai`anapanapa	Lake	upper Hana	
	"Wai Nene"	Lake	upper Hana	not perennial

Park	Name	Type	Location	Other
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	Leleka	Stream	Ka`apahu tract	
	(unnamed)	Stream	Ka`apahu tract	intermittent (lower reaches)
	Kukuiula	Stream	Ka`apahu tract, upstream section	forms east boundary?
	Pipiwai	Stream	Kipahulu tract (`Oheo)	Pipiwai/Palikea join in `Oheo Gulch
	Palikea	Stream	Kipahulu tract (`Oheo)	Pipiwai/Palikea join in `Oheo Gulch
	Pua`alu`u	Stream	Kipahulu tract	
	Kalena	Stream	Kipahulu tract, only upper portion	
	Kalena	Stream	Kipahulu tract, only upper portion	
	(seasonal)	Stream	Kaupo Gap ?	
ALKA	?	? 2	resources have yet to be identified	
PUHE	Makahuna?	Stream	mouth & part of body	upper reaches intermittent
KAHO	Kaloko	Fishpond	within park	
	Kaloko	wetland	within park	
	`Aimakapa	Fishpond	within park	
	Anchialine	Ponds	several	
	`Aimakapa	Wetland	yes: associated w. `Aimakapa Pond	
PUHO	"Royal"	Fishpond	within park	
	(no name)	Wetland	within park	
	Anchialine	Ponds	several	4 ponds + 2 waterholes
	Ki`ilae	Stream	mouth	intermittent
HAVO	(ephemeral)	Streams	Ka`u region	intermittent
	(several)	Ponds	several anchialine ponds	

[1] Multiple aquatic resources exist along the trail route, including coastal wetlands, anchialine ponds, inland Hawaiian fishponds, and streams.

APPENDIX B: PACN MONITORING AND ISSUES

Table 3 indicates the status of current water quality monitoring for each parks resources and their associated stressors. “Long term” programs are marked with a C if they are comprehensive and complement our resource monitoring goals for the park, while an X indicates that it is limited in scope or sampling location. “Short term” projects have a set completion date and generally focus on a specific resource or issue. Some projects are considered “suspended” due to lack of funding although they may have been collecting important data for some time. “In prep” describes studies that are pending or being implemented at this time. Most resource stressors are “unaddressed” in regards to water quality monitoring as shown below.

Table 3. Water quality monitoring for park resources & associated stressors

PARK	RESOURCE	STRESSOR(S)	ACTIVITY STAGE				
			long-term	short-term	in-prep	suspended	unaddressed
WAPA	Streams	Climate Change				X	
		Erosion				X	
		Hydrology		X			
		Invasives					X
		Microbial Contamination				X	
		Organic Enrichment		X		X	
		Sedimentation		X			
		Toxics		X		X	
	Groundwater	Hydrology		X	X		
		Microbial Contaminants					X
		Organic Enrichment					X
		Toxics		X			
	Wetlands	Atmosheric Deposition					X
		Climate Change		X			
		Erosion		X			
		Hydrology		X			
		Invasives					X
		Microbial Contaminants					X
		Organic Enrichment		X			
		Sedimentation		X			
		Toxics		X			
	Beaches	Climate Change					X
		Erosion					X
		Hydrology					X
		Invasives					X
		Microbial Contaminants	X				
		Organic Enrichment					X
		Toxics					X
	Nearshore/coastal	Climate Change		X	X		
		Hydrology		X			
		Invasives			X		
		Microbial Contaminants					X
		Organic Enrichment			X		
		Sedimentation	C		X		
		Toxics		X	X		

PARK	RESOURCE	STRESSOR(S)	ACTIVITY STAGE				
			long-term	short-term	in-prep	suspended	unaddressed
AMME	Streams	Climate Change					X
		Erosion		X			
		Hydrology		X	X		
		Invasives					X
		Microbial Contaminants					X
		Organic Enrichment		X			
		Sedimentation					X
		Toxics		X			
	Groundwater	Hydrology		X	X		
		Microbial Contaminants					X
		Organic Enrichment		X			
		Toxics		X			
	Wetlands	Atmosheric Deposition					X
		Climate Change					X
		Erosion					X
		Hydrology		X	X		
		Invasives					X
		Microbial Contaminants					X
		Organic Enrichment					X
		Sedimentation					X
		Toxics		X			
	Beaches	Climate Change					X
		Erosion					X
		Hydrology					X
		Invasives					X
		Microbial Contaminants	C				
		Organic Enrichment	C				
		Toxics					X
	Nearshore/coastal	Climate Change	C				
		Hydrology					X
		Invasives					X
		Microbial Contaminants	C				
		Organic Enrichment	C				
		Sedimentation	C				
		Toxics			X		

PARK	RESOURCE	STRESSOR(S)	ACTIVITY STAGE				
			long-term	short-term	in-prep	suspended	unaddressed
NPSA	Streams	Climate Change		X			
		Erosion					X
		Hydrology		X	X		
		Invasives					X
		Microbial Contaminants		X	X		
		Organic Enrichment		X	X		
		Sedimentation					X
		Toxics			X		
	Groundwater	Hydrology				X	
		Micobial Contaminants					X
		Organic Enrichment					X
		Toxics					X
	Beaches	Climate Change					X
		Erosion					X
		Hydrology					X
		Invasives					X
		Microbial Contaminants					X
		Organic Enrichment					X
		Toxics					X
	Nearshore/coastal	Climate Change	X	X			
		Hydrology					X
		Invasives					X
		Microbial Contaminants					X
		Organic Enrichment		X			
		Sedimentation					X
		Toxics					X
	Tide Pools	Climate Change					X
		Micobial Contaminants					X
		Organic Enrichment					X

PARK	RESOURCE	STRESSOR(S)	ACTIVITY STAGE				
			long-term	short-term	in-prep	suspended	unaddressed
USAR	Streams	Climate Change					X
		Erosion					X
		Hydrology				X	
		Invasives					X
		Microbial Contaminants				X	
		Organic Enrichment				X	
		Sedimentation					X
		Toxics				X	
	Groundwater	Hydrology				X	
		Micobial Contaminants				X	
		Organic Enrichment				X	
		Toxics				X	
	Beaches	Climate Change					X
		Erosion					X
		Hydrology					X
		Invasives					X
		Microbial Contaminants					X
		Organic Enrichment					X
		Toxics					X
	Nearshore/coastal	Climate Change					X
		Hydrology		X			
		Invasives					X
		Microbial Contaminants					X
		Organic Enrichment	C	X			
		Sedimentation		X			
		Sedimentation	C				
		Toxics	C	X			

PARK	RESOURCE	STRESSOR(S)	ACTIVITY STAGE				
			long-term	short-term	in-prep	suspended	unaddressed
KALA	Streams	Climate Change					X
		Erosion					X
		Hydrology				X	
		Invasives					X
		Microbial Contaminants					X
		Organic Enrichment					X
		Sedimentation					X
		Toxics					X
	Groundwater	Hydrology				X	
		Microbial Contaminants				X	
		Organic Enrichment				X	
		Toxics				X	
	Beaches	Climate Change					X
		Erosion					X
		Hydrology					X
		Invasives					X
		Microbial Contaminants					X
		Organic Enrichment					X
		Toxics					X
	Nearshore/coastal	Climate Change					X
		Hydrology					X
		Invasives					X
		Microbial Contaminants					X
		Organic Enrichment					X
		Sedimentation					X
		Toxics					X
	Kahakau Crater	Organic Enrichment					X
		Toxics					X
		Hydrology					X

PARK	RESOURCE	STRESSOR(S)	ACTIVITY STAGE				
			long-term	short-term	in-prep	suspended	unaddressed
HALE	Sub-alpine Lakes	Atmospheric Deposition					X
		Climate Change					X
		Erosion					X
		Hydrology					X
		Invasives					X
		Organic Enrichment					X
		Sedimentation					X
		Toxics					X
	Streams	Climate Change					X
		Erosion					X
		Hydrology				X	
		Invasives					X
		Microbial Contaminants				X	
		Organic Enrichment				X	
		Sedimentation					X
		Toxics					X
	Groundwater	Hydrology				X	
		Micobial Contaminants				X	
		Organic Enrichment				X	
		Toxics				X	
	Anchialine Pools	Atmosheric Deposition					X
		Climate Change					X
		Hydrology					X
		Invasives					X
		Microbial Contaminants					X
		Organic Enrichment					X
		Sedimentation					X
		Toxics					X
	Beaches	Climate Change					X
		Erosion					X
		Hydrology					X
		Invasives					X
		Microbial Contaminants					X
		Organic Enrichment					X
		Toxics					X
	Nearshore/coastal	Climate Change					X
		Hydrology					X
		Invasives					X

		Microbial Contaminants					X
		Organic Enrichment					X
		Sedimentation					X
		Toxics					X
	Coastal Springs	Hydrology					X
		Organic Enrichment				X	
		Toxics					X
		Microbial Contaminants				X	

PARK	RESOURCE	STRESSOR(S)	ACTIVITY STAGE				
			long-term	short-term	in-prep	suspended	unaddressed
ALKA	Streams	Climate Change					X
		Erosion	X				
		Hydrology	X			X	
		Invasives					X
		Microbial Contaminants					X
		Organic Enrichment					X
		Sedimentation	X				
		Toxics					X
	Groundwater	Hydrology			X	X	
		Microbial Contamination	X			X	
		Organic Enrichment	X		X	X	
		Toxics				X	
	Anchialine Pools	Atmosheric Deposition					X
		Climate Change					X
		Hydrology	X		X		
		Microbial Contamination	X				
		Organic Enrichment	X		X		
		Sedimentation					X
		Toxics					X
	Fish Ponds	Atmosheric Deposition					X
		Climate Change					X
		Erosion					X
		Hydrology			X		
		Invasives			X		
		Microbial Contamination		X			
		Organic Enrichment		X	X		
		Sedimentation			X		
		Toxics					X

PARK	RESOURCE	STRESSOR(S)	ACTIVITY STAGE				
			long-term	short-term	in-prep	suspended	unaddressed
	Wetlands	Atmosheric Deposition					X
		Climate Change					X
		Erosion					X
		Hydrology					X
		Invasives					X
		Microbial Contaminants					X
		Organic Enrichment					X
		Sedimentation					X
		Toxics					X
	Beaches	Climate Change					X
		Erosion					X
		Hydrology					X
		Invasives					X
		Microbial Contamination	X				
		X					
		Toxics					X
	Nearshore/coastal	Climate Change					X
		Hydrology			X		
		Invasives					X
		Microbial Contamination	X	X			
		Organic Enrichment	X	X			
		Sedimentation			X		
		Toxics					X

PARK	RESOURCE	STRESSOR(S)	ACTIVITY STAGE				
			long-term	short-term	in-prep	suspended	unaddressed
PUHE	Streams	Climate Change					X
		Erosion	C				
		Hydrology	C			X	
		Invasives					X
		Microbial Contaminants				X	
		Organic Enrichment					X
		Sedimentation	C				
		Toxics				X	
	Groundwater	Hydrology				X	
		Micobial Contaminants				X	
		Organic Enrichment				X	
		Toxics				X	
	Fish Ponds	Atmospheric					X

PARK	RESOURCE	STRESSOR(S)	ACTIVITY STAGE				
			long-term	short-term	in-prep	suspended	unaddressed
		Deposition					
		Climate Change					X
		Erosion					X
		Hydrology					X
		Invasives					X
		Microbial Contamination		X			
		Organic Enrichment		X			
		Sedimentation					X
		Toxics					X
	Beaches	Climate Change					X
		Erosion					X
		Hydrology					X
		Invasives					X
		Microbial Contamination	X				
		Organic Enrichment	X				
		Toxics					X
	Nearshore/coastal	Climate Change					X
		Hydrology			X		
		Invasives					X
		Microbial Contamination		X			
		Organic Enrichment		X			
		Sedimentation			X		
		Toxics					X

PARK	RESOURCE	STRESSOR(S)	ACTIVITY STAGE				
			long-term	short-term	in-prep	suspended	unaddressed
KAHO	Groundwater	Hydrology				X	
		Hydrology			X		
		Microbial Contamination	X			X	
		Organic Enrichment	X		X	X	
		Toxics				X	
	Anchialine Pools	Atmospheric Deposition					
		Climate Change					X
		Hydrology			X		
		Invasives					X
		Microbial Contamination	X				
		Organic Enrichment	X		X		

PARK	RESOURCE	STRESSOR(S)	ACTIVITY STAGE				
			long-term	short-term	in-prep	suspended	unaddressed
	Fish Ponds	Sedimentation					X
		Toxics					X
		Atmospheric Deposition					X
		Climate Change					X
		Erosion					X
		Hydrology			X		
		Invasives			X		
		Microbial Contaminants					X
	Wetlands	Organic Enrichment			X		
		Sedimentation			X		
		Toxics					X
		Atmospheric Deposition					X
		Climate Change					X
		Erosion					X
		Hydrology					X
		Invasives					X
		Microbial Contaminants					X
	Beaches	Organic Enrichment					X
		Sedimentation					X
		Toxics					X
		Climate Change					X
		Erosion					X
		Hydrology					X
		Invasives					X
	Nearshore/coastal	Microbial Contamination	X				
		Organic Enrichment	X				
		Toxics					X
		Climate Change					X
		Hydrology					X
		Invasives					X
		Microbial Contamination	X				
		Organic Enrichment	X				
		Sedimentation					X
		Toxics					X

PARK	RESOURCE	STRESSOR(S)	ACTIVITY STAGE				
			long-term	short-term	in-prep	suspended	unaddressed
PUHO	Streams	Climate Change					X
		Erosion					X
		Hydrology				X	
		Invasives					X
		Microbial Contamination				X	
		Organic Enrichment				X	
		Sedimentation					X
		Toxics				X	
	Groundwater	Hydrology				X	
		Micobial Contaminants				X	
		Organic Enrichment				X	
		Toxics				X	
	Anchialine Pools	Atmospheric Deposition					X
		Climate Change					X
		Hydrology					X
		Invasives					X
		Microbial Contaminants					X
		Organic Enrichment					X
		Sedimentation					X
		Toxics					X
	Fish Ponds	Atmosheric Deposition					X
		Climate Change					X
		Erosion					X
		Hydrology					X
		Invasives					X
		Microbial Contaminants					X
		Organic Enrichment					X
		Sedimentation					X
		Toxics					X
	Beaches	Climate Change					X
		Erosion					X
		Hydrology					X
		Invasives					X
		Microbial Contaminants					X
		Organic Enrichment					X
		Toxics					X
	Nearshore/coastal	Climate Change					X
		Hydrology					X

PARK	RESOURCE	STRESSOR(S)	ACTIVITY STAGE				
			long-term	short-term	in-prep	suspended	unaddressed
		Invasives					X
		Microbial Contaminants					X
		Organic Enrichment					X
		Sedimentation					X
		Toxics					X
	Submerged Spring	Hydrology					X
		Microbial Contamination					X
		Organic Enrichment					X
		Toxics					X
		Sedimentation					X

PARK	RESOURCE	STRESSOR(S)	ACTIVITY STAGE				
			long-term	short-term	in-prep	suspended	unaddressed
HAVO	Streams	Climate Change					X
		Erosion					X
		Hydrology				X	
		Invasives					X
		Microbial Contamination				X	
		Organic Enrichment				X	
		Sedimentation					X
		Toxics				X	
	Groundwater	Hydrology				X	
		Micobial Contaminants				X	
		Organic Enrichment				X	
		Toxics				X	
	Anchialine Pools	Atmosheric Deposition					X
		Climate Change			X		
		Hydrology			X		
		Invasives			X		
		Microbial Contaminants					X
		Organic Enrichment			X		
		Sedimentation					X
		Toxics					X
	Wetlands	Atmosheric Deposition					X
		Climate Change					X
		Erosion					X

PARK	RESOURCE	STRESSOR(S)	ACTIVITY STAGE				
			long-term	short-term	in-prep	suspended	unaddressed
		Hydrology					X
		Invasives					X
		Microbial Contaminants					X
		Organic Enrichment					X
		Sedimentation					X
		Toxics					X
	Beaches	Climate Change					X
		Erosion					X
		Hydrology					X
		Invasives					X
		Microbial Contaminants					X
		Organic Enrichment					X
		Toxics					X
	Nearshore/coastal	Climate Change					X
		Hydrology					X
		Invasives					X
		Microbial Contaminants					X
		Organic Enrichment					X
		Sedimentation					X
		Toxics					X

APPENDIX C: PROPOSED WATER QUALITY BOUNDARIES

The following is the link to the maps showing proposed boundaries for water quality monitoring within each PACN park: http://www1.nature.nps.gov/im/units/pacn/monitoring/plan/2003-pre/waterq/index.htm

APPENDIX D: POTENTIAL PARTNERS

- EPA (Guam, American Samoa, United States)
- NPS
- NPS-WRD (Baseline Water Quality Data Inventory and Analysis for the Hawaiian Parks)
- USGS-WRD
- State of Hawaii (Department of Land and Natural Resources, Department of Aquatic resources, Seagrant-both state and NOAA, DOH)
- Universities (Hawaii at Manoa and Hilo, Guam, California at Santa Cruz, American Samoa Community College, North Carolina)
- Bureau of Coastal Zone Management (Guam)

- NOAA-NMS
- United States Fish and Wildlife Service
- Molokai Community Watershed Coalition
- Bishop Museum
- Non-Governmental Organizations – e.g. The Nature Conservancy
- UG-WERI
- American Samoa DMWR
- USDA-NRCS (MKSWCD)
- US NAVY
- Department of Environmental Quality, Commonwealth of the Northern Mariana Islands