



Inventory & Monitoring Program

Pacific Island Network Monitoring Plan

Supporting Documents: USS Arizona Memorial Resource Overview

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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/>

EXECUTIVE SUMMARY & INTRODUCTION

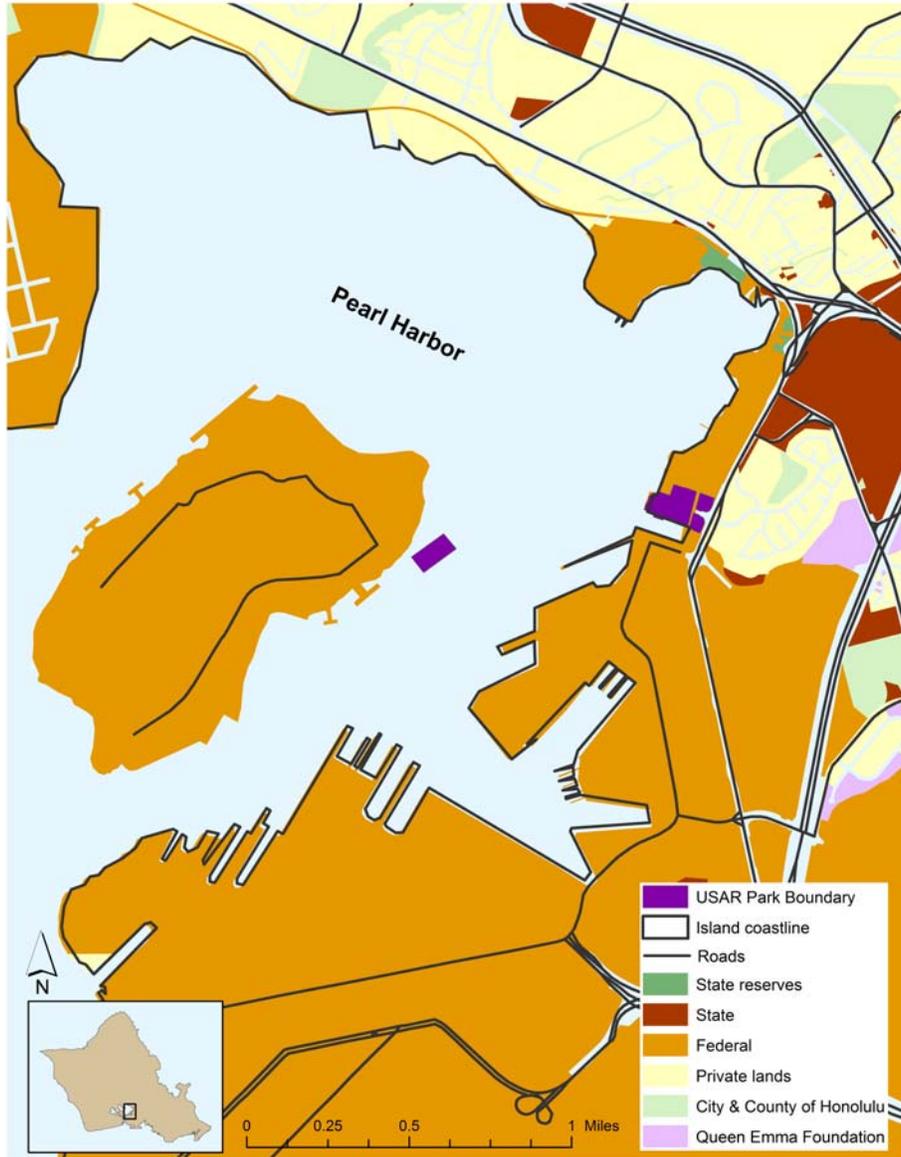
Enabling Legislation

A congressionally authorized enabling mandate does not exist for the USS Arizona Memorial (USAR). The 1978 Military Construction Authorization provides for the transfer of the operation of the USS Arizona Memorial from the United States Navy to the National Park Service (NPS) at the completion of the Visitor Center. This transfer of operation was agreed upon by the Secretary of the Navy Middendorf and Acting Secretary of the Interior Frizzell in 1975. It was finalized through an interagency agreement between the US Navy and the NPS in October 1980.

To find enabling legislation documents on-line follow the “Policy & Legislation” link from the Pacific Island Network website (www1.nature.nps.gov/im/units/pacn).

Geographic Setting

Pearl Harbor, on the south-central side of the Island of Oahu is a large estuarine environment comprised of three larger lochs, East, Middle and West; and one smaller, Southeast Loch that are all separated by a narrow channel to the open ocean. The memorial is located in the East Loch of Pearl Harbor, immediately east of Ford Island containing a wide variety of tropical marine species (see map below). Within the USAR boundary are 450 meters of coastline, 5.5 submerged acres (including 100 feet around the USS Arizona) and 11 acres on land. The surrounding area is one of the most densely populated areas in the State of Hawaii with numerous attractions drawing thousands of people per day to the area. The park is situated entirely within active US Naval Reservation boundaries, with a variety of residential and industrial uses; Ford Island, US Navy recreation facilities, and US Navy dock facilities being among these uses. Located within Pearl Harbor are the following protected and designated areas. Pearl Harbor National Wildlife Refuge, with two units, a 37 acre unit in the West Loch (Honouliuli) and 25 acre unit in Middle Loch (Waiawa) are managed by the United States Fish and Wildlife Service (USFWS). Aiea Bay State Recreation Area, located in the East Loch is managed by the State of Hawaii. Pouhala Marsh, 70 acres of wetland sanctuary in the West Loch is managed by the State of Hawaii.



Significant Natural and Cultural Resources

The primary (cultural) resource in the park is the submerged wreck of the battleship USS Arizona which entombs sailors and marines killed in the December 7, 1941 attack on Pearl Harbor. A 184’ memorial structure now spans the wreck and serves as a platform to receive visitors. These structures provide habitat to many encrusting filter-feeding organisms such as sponges, bryozoans, annelid worms, mollusks, tunicates as well as filamentous diatoms, green and red algae. Water quality is also an important or focal resource for the perpetuation of this park and its significant cultural resources (the hull of the USS Arizona itself).

Natural Resource Management Priorities

The park has come to commemorate all civilian and military personnel killed in the Pearl Harbor attack, and management efforts focus on the respectful maintenance of the memorial function. There are several hundred thousand gallons of Bunker C fuel oil encased in the hull of the USS Arizona which may potentially be catastrophic if released. Environmental management for such an event is addressed by the US Navy as part of their regular port operations. The hull is probably the best studied example of metallurgical decay in a marine environment. The NPS monitors basic marine environmental parameters as part of their ongoing hull curatory efforts. Land use and harbor practices have significantly altered the physical and chemical properties of the harbor area as well as drastically modified the flora and fauna present.

NATURAL RESOURCES

Focal Ecosystems & Processes

- Marine Landscape: The USS Arizona as habitat for fauna and flora
- Invertebrate and Algal Community Diversity
- Urbanized Streams
- Water Quality
- Threatened & Endangered Species: *Chelonia mydas* and *Monachus schauislandi*

Marine Landscape: The primary resource in USAR is the sunken WWII battleship, the USS Arizona which has come to serve as important habitat and substrate for many marine species. Additionally, the live encrusting organisms provide structural rigidity and act as reinforcement for the hull, potentially minimizing its collapse. In addition to providing substrate, the ship provides habitat for a diversity of fish. Henderson (1986) observed 25 species of fish in the vicinity of the ship. It is likely that there may be more species in the vicinity of the vessel.

Marine Invertebrate & Algal Diversity: The sunken vessel provides substrate for many encrusting filter-feeding organisms such as sponges, bryozoans, annelid worms, mollusks, tunicates as well as filamentous diatoms, green and red algae. These organisms (both live and dead) comprised over 99% cover of all vertical surface area (Henderson 1986). Hard corals were not observed in the park during the mid-late 1980s (Henderson 1986) or in recent years. There are however corals on the northeast side of Ford Island (Coles 1999).

Streams: Several highly urbanized streams flow into Pearl Harbor. Halawa stream empties into Pearl Harbor near the visitor center. Other streams that flow into the East Loch of Pearl Harbor include Kalauao and Waimalu Streams. The Waiawa is also in the watershed and empties into the Middle Loch.

Water Quality: Water quality is an important resource to this park. Water quality affects sedentary organisms and submerged structures, and their existence depends on its condition since they can not easily move if it becomes degraded. There are a number of streams that flow into Pearl Harbor, and since the quality of this water could influence both corrosion rates and the condition of the sedentary organisms existing on the hull of the ship, it is an important resource to monitor.

Threatened & Endangered Species: *Chelonia mydas* (green sea turtle) listed as endangered in the US, have been observed in park waters resting on the sunken vessel. *Monachus schauisland* (Hawaiian monk seal), listed as endangered in the US, have been also observed by park staff swimming around the sunken vessel.

Threats & Stressors

- Potential Hull Failure
- Degraded Water Quality from: Oil Spills, Land-based Runoff & Contaminants
- Alien and Invasive Species
- Litter
- Unexploded Ordinance
- Discharge of hazardous gases from the hull
- Natural Stressors

Potential Hull Failure: The compartmentalized hull contains several hundred thousand gallons of Bunker C fuel oil. Concern exists that the ship may disgorge a large quantity of fuel oil into Pearl Harbor. Depending upon environmental conditions, this oil may significantly impact most of the parks submerged resources, but a large oil leak also will have significant ramifications outside the park boundary.

Degraded Water Quality: The industrialized nature of Pearl Harbor and its adjacent land use practices are major contributors to water quality in the harbor. Two major oil spills have occurred within Pearl Harbor, one in 1987 with over 100,000 gallons of aviation fuel spilling into Middle loch and one in 1996 with 39,000 gallons of bunker fuel spilling into the East Loch (Coles et al. 1997). Both spills had an effect on marine or nearshore resources including mangroves and intertidal organisms and water quality within the park. Water quality is also affected by land based polluted run-off, sediment, and debris. Pearl Harbor receives large quantities of sediment from streams and runoff. More than 75 feet of silt sits on the bottom of the harbor. Silt can be re-suspended and settle on the hull, degrading water quality and impacting the marine life living there. Another source of degraded water quality in the marine environment is contaminants and heavy metals, leaching from land fill and dredge disposal sites.

Alien and Invasive Species: Pearl Harbor has been documented by the Bernice P. Bishop Museum as an entry point for marine invasive species to the Hawaiian Islands (Godwin 2003, DAR 2003, Coles et al. 1999). These species have been well documented, including those on the USS Arizona itself. Pearl Harbor's invasive species are a significant and currently unmanaged problem of ample magnitude. Not only are invasive species a problem in the marine environment, in the Pearl Harbor watershed, 60% of 329 estuarine and riparian species were determined to be invasive, with 19% undetermined and leaving only 21% native (Englund et al. 2000).

Litter: More than 1.5 million people visit this park each year. Litter is a significant problem at USAR. Many visitors leave coins in the water and the effect of these metal pieces on the decay rate of the sunken vessel are not known. Tourist visiting the vessels routinely loose objects over the side of the Memorial, including items such as sunglasses, cameras, and batteries. Also, large rainfall events flush litter from nearby streams onto the sunken vessel. Staff at the USAR clean litter from the deck of the USS Arizona every two weeks.

Hazardous Gases: Methane and other gases have been released from the USS Arizona. The source of these gases is unclear, but may be related to decomposition of bacteria (possibly oil-consuming bacteria) inside the hull.

Unexploded Ordinance: In addition to the primary cultural resources of the park being relic military equipment, munitions and other explosives are often found in and around the sunken vessel.

Natural Stressors: Natural stressors that could affect USAR include changes in the physical environment from sea level rise, storm surge and current dynamics. All of these could affect the sunken vessel and its inhabitants. These environmental parameters could also be heightened by global climate change. Another natural stressor that could affect USAR, but is less likely to occur includes seismic activity.

Water Quality Designations

In Hawaii, water bodies are classified by their designated use according to the Hawaii Revised Statutes, Section 11, Chapter 54 which contains definitions and water quality standards for each water body type with respect to desired uses. Waters which do not meet the criteria for their designated uses are considered non-supportive and, if certain conditions are met, may be reported as impaired to the Environmental Protection Agency as per requirements of the Clean Water Act, Section 303(d). All of Pearl Harbor is listed as impaired under 303(d). Therefore, at USAR no water bodies are listed as unique or pristine. Marine waters are classified as AA (in their natural pristine state as nearly as possible with an absolute minimum of pollution or alteration of water quality from any human-caused source or actions. To the extent practicable, the wilderness character of these areas shall be protected. No zones of mixing shall be permitted in this class) or A. Pearl Harbor is classified as A. Marine bottom ecosystems are classified as I or II (in their natural pristine state with an absolute minimum of pollution from any human-induced source. Uses of marine bottom ecosystems in this class are passive human uses without intervention or alteration, allowing the perpetuation and preservation of the marine bottom in a most natural state, such as for nonconsumptive scientific research (demonstration, observation or monitoring only), nonconsumptive education, aesthetic enjoyment, passive activities, and preservation). At USAR, marine bottom ecosystem designations are classified as II. Groundwater designations are being developed by the state of Hawaii, but are not available at this time. The Hawaii State Department of Health's water quality standards are available at <http://www.hawaii.gov/doh/rules/11-54.pdf>

CULTURAL ISSUES

- December 7, 1941 Pearl Harbor Attack
- Historic Fish and Shellfish Use

December 7, 1941 Pearl Harbor Attack: “Because the sunken hull of the USS Arizona remains in place, and its 1,177 casualties accounted for almost half of all the casualties sustained that day,

it became the symbol of commemoration and place of remembrance for the December 7, 1941 attack. Though the exact number is not known, the remains of approximately 900 to 1,000 crewmembers were never recovered and remain entombed within the ship's hull (NPS 1992).” Any management action affecting the entombed crewmembers will be given serious consideration and thought. Natural resources, including both water quality and encrusting organisms (i.e. invertebrates and algae) are important components of the sunken vessel and act to provide stability to the hull; however, the metal hull may continue to decay in its aqueous environment.

Historic Fish and Shellfish Use: Historically, Pearl Harbor is an area known for its rich fish and shell fishing grounds. One of its original names refers to it as a source of abundant shellfish, in Hawaiian, “Wai Momi” meaning “water of Pearl” or “river of Pearl.” Another historic Hawaiian name known for Pearl Harbor estuary was Pu`uloa which was regarded as the home to Ka'ahupahau (the shark goddess) and her brother Kahi'uka.

Hawaiian belief is that schooling aweoweo (Big eye – a fish deeply red in color) foretell the eminent death of a chief. Around the time that King Kalakaua died, large schooling behavior of *Heteropriacanthus cruentatus* (aweoweo) occurred in Pearl Harbor (Hoover 2003).

MANAGEMENT ISSUES

Park management

“The National Park Service manages and operates the USS Arizona Memorial under a Use Agreement with the U.S. Navy. The USS Arizona Memorial lacks specific authorizing legislation, as a unit of the National Park Service, in which its purpose is stated. Public Law 85-344, approved March 15,1958, authorized construction and maintenance of the USS Arizona Memorial and a museum. Public Law 87-201, approved September 6,1961, authorized an appropriation for the construction and maintenance of the USS Arizona Memorial and a museum "in honor and in commemoration of the members of the Armed Forces of the United States who gave their lives to their country during the attack on Pearl Harbor, Hawaii, on December 7, 1941." On March 21,1980, a Use Agreement was signed with the U.S. Navy authorizing the National Park Service to operate the USS Arizona Memorial complex. This Use Agreement did not elaborate on the Memorial's purpose (NPS 1992).” Furthermore, “under the Use Agreement with the U.S. Navy the National Park Service was given responsibility for the USS Arizona Memorial, but not the sunken hull of the USS Arizona. As the major historic resource of the area the National Park Service has, on its own initiative, assumed unofficial responsibility for the ship.” Due to the nature of this park, there are no General Management Plans in existence, there is however a statement of Management for the park

Management objectives as noted in the Statement for Management of the USS Arizona (NPS 1992) that pertain to natural resource management issues include two management objectives. The first objective was to “Preserve the USS Arizona Memorial as a tribute to the military casualties of the Pearl Harbor attack.” And another was to “provide for the

preservation of the sunken hull of the USS Arizona.” Since the USS Arizona is a sunken vessel, water quality affects its condition, as do the invertebrates and algae that have colonized and incorporated into the hull.

Other NPS natural-resource related documents include a report from a cultural study of the submerged resources in Pearl Harbor (Lenihan 1990) and a report from a resource monitoring program (Russell and Murphy 2004).

Park management documents (General Management Plan, Resource Management Plan, etc.) are available on-line at the NPS intranet site (www1.nrintra.nps.gov/im/units/pacn/parks/mgmt_docs.htm). This website is available only from NPS computer networks. Inquiries about public access should be directed to the park.

Leak Detection & Decay Rate: Management issues at USAR are focused on the preservation and management of the ship as an important archaeological resource and memorial. An important and unresolved issue is the threat of oil being discharged from the compartments of the USS Arizona; thus the need for monitoring and detection of leaks. In addition to detection of leaks, the sunken vessel also provides an opportunity to study the metallurgical decay and encrustation rates of ship wrecks in the marine environment. Future actions are geared towards monitoring the physical and chemical decay processes in the shallow marine environment.

Marine Invertebrate and Algal Communities: The sunken vessel has provided habitat for many encrusting marine organisms that have contributed to the hull's structural rigidity and face potential threats from impaired water quality, pollution, and runoff. Since the enabling legislation of USAR is to monitor and maintain as best as possible and preserve the USS Arizona, the marine environment and organisms that have attached themselves to the vessel also must be maintained and monitored. The effect of invasive or alien organisms on this community is not known.

Sedimentation: Pearl Harbor receives large quantities of sediment from streams and runoff. More than 75 feet of silt sits on the bottom of the harbor. Silt can be re-suspended and settle on the hull, degrading water quality and impacting the marine life living there.

Contaminants: Another area of concern is contamination of water quality from surrounding industrial activities and urban stream runoff.

INVENTORIES

Existing, Completed Inventories

Marine Communities - Invertebrates & Algae: In a survey of the “biofouling”, sedimentation and corrosion of the USS Arizona, Henderson (1986) created a checklist of common organisms observed on or around the hull of the sunken vessel. He found 25

taxa of encrusting organisms and 25 species of fish. Particularly abundant were sponges, *Schizoporella errata*, Annelids (*Branchiomma cingulata*., large Sabellids and *Salmacina* spp.), mollusks (Vermetids and oysters), both solitary and colonial tunicates, and filamentous red and green algae as well as diatom mats. No hard coral species were observed. Photo slides were taken with the idea that they may be used in future biological monitoring studies.

Priorities for New Inventories

Marine Communities - Invertebrates, Fish & Algae: A priority for natural resource inventories would be to complete comprehensive and updated inventories of invertebrates, algae and fish present at USAR. The only study within USAR that provides a partial checklist for a park inventory list was conducted by Henderson (1986) that included only major species present that were readily identifiable; and did not identify rare, microscopic or cryptic organisms. Some of the species included in the checklist were identified to genus.

Marine Mammals & Sea Turtles: While no formal surveys of marine mammals and sea turtles have been conducted, reliable incidental visual observations have been made.

Freshwater Communities – Fauna: The marine larval stages of native amphidromous species may also be present in the harbor waters, however, significant restoration efforts would likely be required for the streams in the East Loch watersheds to provide satisfactory adult habitat.

Buffer Zone Inventories

Marine Communities: The first comprehensive biological inventories of marine benthos in Pearl Harbor were conducted by the Navy Undersea Center during 1970-1972 (Evans et al. 1974). A shoreward piling approximately 300 feet from the USS Arizona Memorial was included in their study. This site is representative of the vicinity of the memorial, characterized as having vertical substrate with rocks, mud ledge and debris in its vicinity along with sand, mud and silt bottom approximately 30 feet below the surface. Included in this study were fish surveys, micro mollusk surveys, piling surveys of marine organisms on vertical surfaces and benthic surveys. Other data collected during this study included physical and chemical measurements of sediment, water quality, tidal movement, and runoff measurements.

A total of 388 taxa were observed in Pearl Harbor during these studies; including 23 species of algae, 278 species of invertebrates and 87 species of fish. In the benthic surveys 114 taxa were identified. Sediment samples of micromolluscs resulted in 37 species identified with *Hiatella hawaiiensis*, *Odostmia oodes* and *O. indica* and *Crepidula aculeate* being the most widely distributed within Pearl Harbor. A total of 88 genera and 113 taxa were identified in the piling surveys that were conducted at two depths (0 and 10 feet). Commonly observed species/families in Pearl Harbor included: *Hiatella*

hawaiiensis, *Syllidae*, *Cirratulidae*, *Crepidula aculeate*, *Pilumnus oahuensis*, *Styela* sp., *Vermetidae*, *Elasmopus rapax*, *Balanus amphitrite*, *Ophiactis savignyi*, and *Bugula* spp.

The study site (piling ~300 feet) closest to the USS Arizona Memorial site had 30 species identified with a mean of 185 individuals per sample. The predominant algae observed at the piling near the USS Arizona was *Caulerpa verticillata* while polychaetes and decapods were the faunal organisms most commonly observed. The USS Arizona site was described as having “very soft mud with Vermetid tube debris.”

The Bishop Museum recently conducted comprehensive marine, freshwater, and estuarine invertebrate inventories for Pearl Harbor. In these reports, Englund et al. (2000) and Coles et al. (1997) provide background and historical documentation of environmental changes and biological studies occurring throughout Pearl Harbor. The survey sites in the 1996 Bishop survey (Coles et al. 1997) included the same stations surveyed by Evans et al. (1974) during the 1970s. These sites included a station adjacent to the USS Arizona memorial and one at the northeast part of Ford Island.

Coles et al (1997) observed a total of 419 species found throughout Pearl Harbor, including 36 species of algae, 1 spermatophyte, 323 invertebrates and 59 fish species. This most recent inventory, included with past surveys give a total of 1123 taxa for Pearl Harbor (Coles et al. 1997). A significant observation in this study was that, of the species observed, 95 were either introduced or cryptogenic. Another significant finding of this study is that while 5 species of hard corals were documented at 8 sites in Pearl Harbor (Coles 1997); there were no hard coral species documented in the Evans et al. (1974) study. The most commonly observed coral was *Leptastrea pupurea*, which also occurred at the northeast end of Ford Island. *Pocillopora damicornis* was found near the Navy Shipyard, on the opposite shore of the memorial (Coles 1999). It is thought that pollution control, a reduction in non-point source runoff contribute to more favorable conditions in water quality that allow for more sensitive species such as hard corals.

Freshwater & Estuarine Communities: In October 1997 to August 1998, the Bishop Museum studied aquatic insects, fish, crustaceans and mollusks in representative major streams and wetlands that empty into Pearl Harbor. They described riparian vegetation, stream substrate, and habitat condition for each study site. In the East Loch they surveyed Halawa, Aiea , Kalauao Stream, Kalauao, Waimalu and Waimano streams and springs. In the Middle Loch they surveyed Waiawa Stream, Waiawa Refuge, Waiawa Spring and Eo Stream. They found the majority of these species identified to be alien invasive species. The majority of these species are believed to originate from aquarium, intentional biocontrol and intentional food source released species. Mangroves, an invasive species that has significantly altered the environment in Pearl Harbor, have continued to spread within the watershed. In the appendix to the report, they provide a listing of occurrences of freshwater and estuarine organisms that have ever been collected or observed in Pearl Harbor.

MONITORING

Previous & Existing Monitoring

USS Arizona Long-term Management Strategies Research Project: Currently the NPS Submerged Resources Center, along with USAR is examining how natural processes affect the structure and integrity of the sunken ship (Russell and Murphy 2004). The aims of this project are to minimize environmental hazard (in Pearl Harbor) from oil leaking and to provide baseline information that could be used to make informed management decisions in stance with historical preservation of the tomb. Many of these studies are conducted in collaboration with other departments (e.g. Department of Defense, USGS) and institutions (e.g. Medical University of South Carolina).

Hull Integrity – Corrosion potential, pH and hull thickness: The integrity of the hull is being monitored by measuring the corrosion process in situ and by using x-ray diffraction and scanning electron microscope techniques on hull “coupon” samples collected (directly from the sunken vessel) from different depths and exposures. Preliminary results indicate that corrosion rates are greatest near the top of the hull (at waterline) decreasing to below the mudline (Russell and Murphy 2004). On-going studies are now focused on assessment of corrosion and bacterial activity within the sunken vessel and below the mudline.

Water Quality – Baseline Environmental & Oceanographic Data: Baseline environmental data are being collected (by USGS scientists Drs. Mike Field and Curt Storlazzi) on oceanographic and water quality parameters by instruments placed on the seafloor near the USS Arizona (Russell and Murphy 2004). Data being collected include wave and current patterns as well as pH, temperature, salinity, dissolved oxygen, oxygen reduction potential and conductivity. Their aim is to examine (and determine patterns of) these variables in Pearl Harbor over a two-year period and see if there are any correlations with corrosion rates.

Finite Element Model (FEM) Development: Mathematical modeling of the hull life is being conducted (with NPS-SRC and USAR) with Drs. Tim Foecke and Li Ma of National Institute of Standards and Technology (NIST) in Maryland (Russell and Murphy 2004). This model will help analyze possible management scenarios that use hull stress with predictive outcomes of degree and type of stress on the hull in the areas that contain the fuel oil. They are also going to model the blast that initially sank the vessel. They also will be incorporating the parameters on hull thickness and corrosion rates into the model.

Oil and Microbiological Analysis: The possibility of using microorganisms in fuel oil degradation is being examined in collaboration with Dr. Pam Morris of Medical University of South Carolina (Russell and Murphy 2004). Samples of oil, sediment, water & concretion are all being collected as a part of this study and used to determine the state of deterioration and structural change of inaccessible oil bunkers.

GPS Structural Monitoring & Geological Studies: GPS points are being taken for detecting hull movement. Initial points were made in June 2001 with most recent resurvey in November 2003 (Russell and Murphy 2004). NPS and USGS are conducting baseline studies on geological stability around the vicinity of the USS Arizona. Four locations were chosen for geological core samples. Stratigraphy, grain size, and structural characteristics of sediment will be examined. Field data collected in these studies as well as the ship plans and photographs are being incorporated into a GIS databases.

Other Baseline Information: USAR dive staff regularly inspects the sunken hull for signs of oil seepage. The interior of the sunken vessel was also investigated with a VideoRay ROV to search for access to oil bunkers, level of interior deterioration and to collect environmental samples, including pH, temperature, salinity, dissolved oxygen, oxygen reduction potential and conductivity.

Priorities for New Monitoring

Invertebrate and Algal Communities: Invertebrate and algal community structure are a priority for natural resource monitoring, particularly because of their role in assisting with structural rigidity of the hull.

Alien & Invasive Species: The presence of invasive species, as their effect on the present community structure is not known. If these species persist, they could affect community structure and potentially disturb the organisms that have been incorporated into the hull.

Water Quality: Continued and more in depth water quality monitoring is needed for this park. Water quality is an important facet in both biological and structural facets.

Buffer Zone Monitoring

Stream Monitoring – DOH: Local streams are being monitored by the Department of Health for land-based run off and discharge into the Pearl Harbor watershed. Parameters include temperature, dissolved oxygen, pH, nitrogen, phosphorus, turbidity and flow rates.

Stream Monitoring – USGS: Halawa stream was monitored regularly by USGS from 1983 to 1999 for rainfall at two upstream locations and a water quality station was located at the mouth of the stream. The water quality station monitored streamflow, water temperature, specific conductance, pH and dissolved oxygen. Suspended sediment samples were collected at the upper reach of the stream.

Water Quality Monitoring – Outfall Monitoring by Navy Environmental: The Navy Environmental program monitors water quality at the outfall from the Fort Kamehameha Wastewater Treatment Facility for temperature, ammonia, nitrate/nitrite, totally nitrogen, total phosphorus, turbidity, chlorophyll a, salinity, dissolved oxygen and pH. After

qualifying rainfall events, storm water run-off is monitored at eight sites around the Pearl Harbor Naval Base.

Water Quality Monitoring – Leeward Community College: Pearl Harbor Watershed Environmental Restoration Projects contracted water quality studies by Leeward Community College (LCC) from April 18, 2000 - December 31, 2001. From 1979 to 1994, LCC students of Donald G. Klim studied water quality parameters at different locations throughout Pearl Harbor from Waiawa stream to West Loch.

Marine Monitoring – Brock Surveys: Brock (1994, 1995) monitored fish and epibenthic fouling organisms on or near Hawaii Electric Company Waiiau discharge on the West side of Ford Island and at the head of Aiea Bay.

CONCLUSIONS

Designated as a national memorial, management efforts focus on the respectful maintenance of the memorial function. Primary natural resources include the benthic marine community (comprised primarily of invertebrates and algae) on the ship hull as well as water and water quality. Primary threats to resources include increasing urbanization, invasive species, and chemical water and soil contamination. The sunken hull provides an excellent example of *in situ* observation for ship wrecks and decay. Future management at USAR is aimed towards continued monitoring of the sunken hull and simultaneous development of strategies (i.e. will preserve without endangering the tomb) to avoid major catastrophic release of fuel oil.

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