MAMALA BAY STUDY

PROJECT MB-10
ENVIRONMENTAL IMPACTS ON RECEPTORS AND RESOURCES

Part I

MANAGEMENT ALTERNATIVES AND MANAGEMENT MEASURES FOR WASTE DISCHARGES TO THE MAMALA BAY ECOSYSTEM

Principal Investigators:

Joseph M. O'Connor
Kinnetic Laboratories, Inc.
Santa Cruz, CA 94547

Katherine Courtney
PRC Environmental Management, Inc.
Honolulu, HI

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MANAGEMENT ALTERNATIVES AND MANAGEMENT MEASURES FOR WASTE DISCHARGES TO THE MAMALA BAY

Executive Summary

Point source and nonpoint source discharges in the Mamala Bay watershed each year transports large masses of pollutants to Mamala Bay and adjacent enclosed and semi-enclosed waterbodies (Pearl Harbor, Kewalo Basin, Keehi Lagoon, and the Ala Wai Canal). Water quality in Mamala Bay would, in all likelihood, improve, if the masses of pollutants discharged to and transported throughout Mamala Bay and its ecosystem were reduced. The greatest direct discharge volumes to Mamala Bay arise from WWTP effluents. For most pollutant constituents, the greatest masses of pollutants come from nonpoint source discharges to the semi-enclosed waterbodies bordering the Bay.

The State of Hawaii has many programs in effect to reduce pollutants in nonpoint waste streams. These waste streams include nonpoint sources and activities such as:

- domestic use and disposal of pesticides and herbicides
- domestic use and disposal of paints, oils and other household chemicals
- industrial use and disposal of solvents, paints, and oils
- illegal discharge of industrial chemicals to storm drains
- agricultural use and disposal of pesticides, herbicides and fertilizers
- stormwater discharges from urban and suburban highways
- stormwater discharges from industrial properties
- stormwater discharges from agricultural properties
- oil spills in coastal waters
- waste disposal in coastal waters.

Despite the masses of pollutants discharged from point sources and nonpoint sources, the waters of Mamala Bay continue to support a productive and diverse flora and fauna. Damage to the reef and reef flat ecosystems in Mamala Bay that has occurred has come about more from habitat alteration (in-water construction and the dredging and building of islands)

as from wastes disposed into the system. Public use of the beach resources on the shoreline of Mamala Bay do not appear to be threatened by point source and nonpoint source discharges. Nonetheless, the masses and types of pollutants discharged to the Bay, and their long-term impacts, if any, are not clearly defined by the knowledge that we have at the present time.

Specific recommendations have been made for improving the efficiency of suspended solids and BOD removal from the Honouliuli and Sand Island WWTPs. These include:

- Implementation of DAF and CEPT at the Sand Island WWTP;
- Implementation of CEPT at the Honouliuli WWTP.

A specific recommendation has been made to improve the bacteriological quality of water at the Sand Island and Honouliuli WWTPs, should it be found that indicator bacteria concentrations in Mamala Bay exceed acceptable limits:

- Implementation of UV disinfection of the Sand Island and Honouliuli WWTP effluents.

Specific recommendations exist for improving the water quality of the Ala Wai Canal (and the Ala Wai Canal discharge if it is determined that Ala Wai Canal water quality poses a threat to human health on the beaches, or if Ala Wai Canal water quality poses a threat to maintaining water quality in the nearshore zone of Mamala Bay). These include:

- Increased flushing of the canal with freshwater and/or saltwater flow, or
- The use of salt water barriers, or
- UV disinfection of the Manoa stream prior to entry into the Ala Wai Canal.

We specifically recommend investigation of the use of floating wetlands as the only method suggested that might improve Ala Wai Canal water quality while preserving the action of the Canal as a settling basin for TSS and pollutants entering from the drainage basin.. The problem of the Ala Wai Canal is complex; to recover beneficial uses by increased flushing would result in the increased discharge of suspended solids - and their associated pollutants - into Mamala Bay. To optimize the use of the Ala Wai Canal as a detention basin would result in maintaining low water quality in the waterbody, which is already the site for fishing and recreational boating.

Specific recommendations are made to continue to reduce the mass of pollutants discharged to the Bay with nonpoint source waste water. These include implementation of existing legislation calling for waste minimization, pollution prevention, and nonpoint source pollution.

- Existing and successful programs on waste minimization, pollution prevention, and nonpoint source control in the State of Hawaii must be maintained at existing levels;
- Pollution prevention and waste minimization programs that are in place, and as yet undeveloped or unenforced must be enforced; i.e., programs must be funded at levels sufficient to support adequate staff and materials for rule promulgation, development of field presence, and enforcement;
- Nonpoint source programs that are in place and as yet undeveloped or unenforced must be enforced; i.e., existing programs must be funded at levels that are sufficient to support adequate staff and materials for rule promulgation, development of field presence, and enforcement.
- Additional government support is encouraged for the support of existing programs in public and industrial education on the principles of pollution prevention, source reduction and waste minimization.

We recommend a long-term monitoring program to be carried out to gather data on living resources, habitats, and pollutant levels, such that future conditions can be compared with existing conditions, allowing regular evaluation of the ecological status of the Mamala Bay ecosystem. The objective of the monitoring program would be to measure trends in various indicators of ecosystem health (water quality, habitat integrity, population structure, ecosystem function, maintenance of marine resources) and to allow the custodians of the ecosystem to determine whether additional management and treatment alternatives for the control of pollution must be implemented.

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1.0 Introduction

The waters of Mamala Bay support typical reef, hard-bottom and soft-bottom communities. Offshore waters support an abundant pelagic and benthic community. The generally favorable tropical climate and the high quality of beaches on the Mamala Bay shoreline provide recreation to thousands of beach goers, swimmers, and surfers, and support a large and vigorous tourist industry.

The recreational and aesthetic appeal of the beaches, the coral reefs and other marine communities, and the general quality of the Mamala Bay aquatic environment may face degradation due to pollutants that enter the Bay. The pollutants are discharged from three wastewater treatment plants, numerous industrial facilities, and an unknown number of ill-defined sources such as rainfall runoff from urban streets, erosion from exposed soils, discharge from boats and boaters, and discharge from agricultural land.

This report is part of the Mamala Bay Study. The objective of this report is to evaluate and list waste management alternatives that are available for use in reducing the overall load of pollutants entering Mamala Bay. The report is organized to provide:

1. Identification of the Pollutants of Concern in Mamala Bay
2. An overview of the sources of wastes entering Mamala Bay;
3. A review of the treatment given to waste streams entering Mamala Bay
4. A review of waste management strategies and Management Measures (MMs) suitable for application to discharges entering Mamala Bay; and
5. Recommendations for waste treatment alternatives.

2.0 Pollutants of Concern

The identity of all pollutants entering Mamala Bay is not known. Permits to dischargers releasing wastes to Mamala Bay under the National Pollutant Discharge Elimination System (NPDES) require periodic analysis for conventional pollutants (nutrients such as nitrogen [N], phosphorous [P], and ammonia [NH_4], suspended solids [TSS], dissolved solids [TDS], oil and grease [O&G], biochemical oxygen demand [BOD]), and certain pollutants typical of the industry from which each waste arises. Required measurements for toxicants in wastes discharged to Mamala Bay are generally for toxic metals (lead [Pb], mercury [Hg], arsenic [As], copper [Cu], zinc [Zn], other metals, and a suite of organic pollutants including insecticides, herbicides, PCBs, industrial solvents, petroleum, and petroleum waste products; [see Stevenson et al., 1995; O'Connor et al., 1995]). Most analyses of storm water runoff and other indicators of nonpoint source pollution are limited to measurements such as TSS, TDS, BOD, and Oil and Grease.

Water quality standards for pollutants in Hawaii are contained in Hawaii Administrative Rules, Title 11, Chapter 54 (Table 1).Acute toxicity (saltwater) standards exist for 52 pollutants listed in the Hawaii Administrative rules. Of the 52 pollutants that have saltwater acute standards, 12 are metals, and the remainder are primarily chlorinated pesticides, chlorinated industrial compounds, and solvents. These compounds are monitored because they are considered potentially harmful, by the State of Hawaii (O'Connor et al., 1995). This report does not deal directly with the effects of any pollutant or class of pollutants on the Mamala Bay ecosystem.

3.0 Sources of Pollutants Entering Mamala Bay

There are three sources of pollutants entering Mamala Bay: point sources, land-based nonpoint sources, and water-based nonpoint sources. Each of these categories is described below.

3.1 Point Sources of Pollutants

Point source pollutant discharges are defined as "... discharges that enter a body of water from a specific, identifiable point such as a pipe, ditch, tunnel, channel, or similar discrete conveyance." (Hawaii DPW/DOH, 1990). By this definition, storm water discharges from urban environments may be point sources because they discharge through conveyances. However, to maintain consistency between the present report, general industry categorization, and other reports in this study (Stevenson et al., 1995), storm water discharges will be treated as nonpoint source discharges. The case of the Ala Wai Canal will be treated separately.

The major point sources of pollutants to Mamala Bay are three municipal wastewater treatment plants (WWTPs): Sand Island WWTP, Honouliuli WWTP and the Fort Kamehameha Sewage Treatment Plant. Secondary point sources of pollutants include 33 industrial and agricultural discharges to Mamala Bay or contiguous waters of Pearl Harbor, Keehi Lagoon, and the Ala Wai Canal (Stevenson et al., 1995; see Appendix Tables A1-A5). Other than the three WWTPs, permitted discharges to Mamala Bay and contiguous waters include sugar processing plants, oil refineries, drydocks, a desalination plant, power plants, and small WWTPs associated with the Waikiki Aquarium, and residential complexes.

3.2 Land-Based Nonpoint Sources of Pollutants

Land-based nonpoint pollutant sources include land-based activities likely to discharge pollutants to Mamala Bay directly, and sources likely to increase the load of pollutants to storm water runoff and groundwater flowing to Mamala Bay. Nonpoint sources are regulated under Section 319 of the Clean Water Act and Water Quality Act of 1978 and Section 6217 of the Coastal Zone Act Reauthorization Amendments of 1990. Section 6217 requires states to implement Management Measures (MMs) to restore and protect coastal waters; MMs must conform with guidance issued by EPA and NOAA (EPA and NOAA, 1993). A list of land-based nonpoint pollutant sources to Mamala Bay includes:

- Urban and non-urban storm water runoff;
- Runoff from industrial plant surfaces;
- Onsite sewage disposal (septic tanks, sumps and cesspools);
- Illicit disposal of hazardous household materials;
- Construction and development;
- Illicit waste discharges to storm sewers;
- Farmland fertilization;
- Irrigated agriculture;
- Open uses of insecticides, herbicides and fertilizers in agriculture

- Confined animal areas;
- Rangeland; and
- Erosion and weathering of soils.

3.3 Water-Based Nonpoint Sources of Pollutants

Water-based nonpoint sources of pollutants include any water-based activities likely to increase the load of pollutants entering Mamala Bay. A list of water-based nonpoint sources of pollutants to Mamala Bay includes:

- Catastrophic spills at sea;
- Spills or losses of cargo containing pollutants during loading and lightering;
- Marinas and recreational boating;
- In-water servicing of hulls;
- In-water servicing of marine engines;
- Bilge- and head-pumping at sea; and
- Toxicant losses from anti-fouling paints.

3.4 A Special Case: The Ala Wai Canal

The Ala Wai Canal is a narrow canal constructed between 1921 and 1928 to drain marshy areas around Waikiki and to serve as a sedimentation basin (Miller, 1975; Stevenson, 1994). The Canal receives runoff from the Manoa Stream, the Palolo Stream and the Makiki Stream, as well as runoff from urbanized areas in the lower watersheds of the streams. Annual average flow in the Ala Wai Canal is estimated to be from 30.3 to 79.5 million liters per day (MLD)(eight to 21 million gallons per day [MGD]), with a residence time of from 40 to 60 hours.

Because the Ala Wai Canal drains a substantial portion of the eastern end of the Mamala Bay watershed and integrates the flow of three streams draining more than 405 hectares (1,000 acres), it can be considered one of the few major point sources of pollutants entering Mamala Bay proper. However, since the Canal serves primarily as a conduit for the transport of baseflow and storm water runoff from the drainage basin to Mamala Bay, it may also be considered a major, integrated source of nonpoint source runoff. Nonpoint pollutant sources to the Ala Wai Canal include: mountainous conservation areas of the Waianae Mountains; urban runoff; and groundwater discharge. Several permitted point sources also discharge into the southern portions of the Ala Wai Canal (Table A5; Stevenson et al., 1995).

The Ala Wai Canal plays three roles in pollutant loading to Mamala Bay These roles are 1) as a heavily impacted waterway (a designated water-quality limited segment under EPA Section 316 rules, heavily contaminated with bacteria, yet used extensively for recreational boating and fishing), 2) as a receiving water body (receiving point and nonpoint pollutant loads), and 3) as a source of pollutants to Mamala Bay (discharging water to Mamala Bay that is contaminated with nutrients and measurable concentrations of bacteria, trace elements, and organic contaminants) (Miller, 1975; DOH, 1982; Edward K. Noda and Associates, 1992; Stevenson, 1994; Stevenson et al., 1995). While studies are underway to determine the best management measures to be applied to improve water quality in the Ala Wai Canal (Harleman et al., 1995), it is also true that the Ala Wai Canal is a settling basin that is quite effective in removing about 50 percent of the solids (and associated pollutants; Table 2) that enter the Canal from upstream sources (Stevenson, 1994; Stevenson et al., 1995).

Special Studies carried out on the Ala Wai Canal, and recommendations for treatment of the Canal for reduction of pollutant levels have been prepared by personnel from the Parsons Laboratory of Chemical and Environmental Engineering (Harleman et al., 1995). Those reports are part of the Mamala Bay Study, and are included in this report in summary form. The full reports on Special Studies of the Ala Wai Canal have been issued separately.

3.5 Other Sources of Pollutants to Mamala Bay

Other sources of wastes must eventually be included in an overall evaluation of the impact on Mamala Bay. The two most readily identifiable minor sources of wastes are:

- The direct deposition of waste material on Mamala Bay from atmospheric sources, including dry fallout (dust and dirt), and wet fallout (rainfall containing wastes in condensation nuclei, or wastes in solution in rainfall as the result of rainfall scavenging wastes from the atmosphere); and

- Wastes from other sources in ocean waters (e.g., metals-enriched deep waters from upwelling) transported into Mamala Bay with ambient ocean waters.

Since wastes in the atmosphere and in ocean waters are not amenable to treatment, they will not be evaluated in this report.

4.0 Estimates of Pollutant Loading to Mamala Bay

An understanding of pollutant discharge to Mamala Bay has, until very recently, been limited to information available in NPDES self-monitoring reports submitted by dischargers to the State of Hawaii Department of Health. Pollutant concentrations in the Ala Wai Canal have been measured previously, but have not previously been incorporated into pollutant loading estimates.

4.1 Estimates of Pollutant Loading from Point Sources

There are only six point source discharges to Mamala Bay. The three WWTPs (Sand Island, Honouliuli, and Fort Kamehameha) together discharge about 141 x 10^6 cubic meters (m^3) of wastewater (115,000 acre-feet) per year. The three remaining discharges (Waikiki Aquarium, Hawaiian Milling Corp., and AES Barber's Point) discharge about 88,776 m^3 (72 acre-feet) of wastewater per year. Other point source discharges enter confined waters such as the Ala Wai Canal, Keehi Lagoon-Honolulu Harbor, or Pearl Harbor.

Estimates of pollutant loads from point sources were based upon self-monitoring data from 1989 to 1993. The majority of the data available were for total suspended solids (TSS), biochemical oxygen demand (BOD), oil and grease (O&G), and concentrations of "indicator bacteria" (*Clostridium perfringens, Escherichia coli,* and fecal coliforms) in effluent streams. Some data are available for making estimates of loading of nutrients and toxic metals to Mamala Bay (Table 3). The reader is referred to Stevenson et al. (1995) for a full discussion of the quality of the data available for analysis and the manner in which analyses were undertaken.

Average flows of wastewater to Mamala Bay and adjacent waters from point source discharges were about 151 x 10^6 m^3 (122,400 acre feet) per year. The majority of that flow

($141.7 \times 10^6\ m^3$) was from Sand Island, Honouliuli, and Fort Kamehameha WWTPs. On average, 7,584 metric tons (tonnes; 8,360 short tons) of sediment (as TSS) per year was discharged into Mamala Bay (1991 to 1993; Table 4), along with an average of 14,143 tonnes (15,590 tons) of BOD, 67,677 tonnes (74,600 tons) of COD, and 3,744 tonnes (4,127 tons) of oil and grease (Table 4). The majority of the discharged load was from the three WWTPs.

Microbiological loading data are presented in Table 5. The data showed that the Sand Island and Honouliuli WWTPs were the only significant point sources of microbiological pollutants to Mamala Bay. The Loads of microbiological pollutants from the Fort Kamehameha WWTP were extremely small compared to the loads reported from Sand Island and Honouliuli (Table 5). Sand Island and Honouliuli are primary sewage treatment plants; they do not chlorinate their effluent before discharge to Mamala Bay. Fort Kamehameha is a secondary treatment plant where sludge undergoes digestion prior to discharge, a process that removes a portion of the bacteria in the sludge. The Fort Kamehameha effluent is chlorinated before discharge to the Bay.

4.2 Estimates of Pollutant Loading from Land-Based Nonpoint Sources

Estimates of pollutant loads to Mamala Bay from land-based nonpoint sources were derived from available data on land drainage and surface runoff throughout the drainage basin (Stevenson et al., 1995). Nonpoint source pollutant load calculations included:

- Base flow from seeps and groundwater discharge throughout the basin, but most especially in upland regions and mountainous areas;
- Surface runoff to streams from rainfall impinging upland forests and undeveloped land;
- Groundwater flow to surface streams from agricultural areas;
- Surface runoff to streams from rainfall impinging agricultural land;
- Groundwater flow to streams from septic tanks and cesspools;
- Surface runoff and direct discharge from rural/suburban residential areas; and
- Surface runoff to streams and direct discharges to the Bay from urban and urban/industrial areas.

Nonpoint source estimates were made based upon evaluation of rainfall, runoff and groundwater-to-surface flows within sub-basins of the Mamala Bay watershed (Stevenson et al., 1995). With the exception of the Ewa Plain and conduits draining to the beaches, runoff from all the sub-basins drains into water quality limited segments (Stevenson et al., 1995).

The volume of water from runoff that enters Mamala Bay each year from the watershed is about 299.6 x 10^6 m^3 (243,000 acre-feet). About 80% of the volume comes from rainfall events, and the rest comes from baseflow. About 100,699 tonnes (111,000 tons) of sediment per year are washed from the Mamala Bay watershed into receiving water (Table 6). The largest contributor of sediment is natural erosion from mountainous forest conservation areas. About 5 percent of the nonpoint source sediment load is from urban areas; however, it is the sediments from urban areas (including industrial plants) that most often carry high concentrations of conventional pollutants and potentially toxic metals and organic compounds. Sediment concentrations in runoff were estimated as ranging between 39 mg/L from the heavily urbanized Kewalo Basin watershed, to 453 mg/L from the largely forested and agricultural areas draining into the Middle Loch of Pearl Harbor.

Urban runoff was the primary source of nutrients and potentially toxic metal loading from land-based nonpoint sources (on a "per acre" basis). The largest metal loads and bacterial loads were discharged from the urbanized Keehi Lagoon/Honolulu Harbor and West Loch Pearl Harbor watersheds (Table 6 and Table 7).

4.3 Estimates of Pollutant Loading from Water-Based Nonpoint Sources

There are no quantitative estimates available for pollutant loading from water-based, nonpoint sources in Mamala Bay. Oceangoing vessels and pleasure craft both add chemical wastes from anti-fouling paints, hull corrosion, sacrificial anodes, and illegal discharges of sanitary wastes. Shoreside activities at shipyards and marinas may add metals from hull scrapings (and anti-fouling paint), petrochemicals from fuel spills and bilge water, and sanitary wastes from misuse of marine heads and marine head pump-out facilities. Metals and hydrocarbons come from ship works and dry docks. Waterside activities can add wastes from fuel spills, cargo spills, bilge washing, and illegal pumping of sanitary wastes.

4.4 Estimates of Pollutant Loading from the Ala Wai Canal

Numerous surveys have been conducted to identify pollutants in the sediments, water and biota of the Ala Wai Canal (Edward K. Noda and Associates, 1992; Schultz et al., 1975; Hawaii Dept. of Health, 1978, 1990; Fox and Freeman, 1992). The Canal has been identified as a source of metals and bacterial pollutants to Mamala Bay (Hawaii Dept. of Health, 1978; Noda and Associates, 1992; Harleman et al., 1995). Blumberg and Connolly (1995) are modeling the loading of pollutants from the Ala Wai Canal to Mamala Bay.

Estimates of pollutant loading from the Ala Wai Canal to Mamala Bay were: 4,694 tonnes (5,175 tons) per year of suspended sediment, 232 tonnes (256 tons) of BOD, and 1,438 tonnes (1,585 tons) of COD. Discharge from the Ala Wai Canal contributes about 52 tonnes (57 tons) of nitrogen to Mamala Bay, while phosphorous loading is almost 6.4 tonnes (7 tons) per year. Loading of four potentially toxic metals from the Ala Wai Canal to Mamala Bay was 2 tonnes (4,400 pounds) of zinc per year, 0.42 tonnes (920 lb) of copper, 33 kilograms (kg; 72 lb) per year of lead, and 14 kg (31.2 lb) per year of cadmium.

Stevenson (1994) conducted a special study to estimate loading of bacteria (*Escherichia coli, Enterococcus* and *Clostridium*) from the Ala Wai Canal under high-flow conditions and low-flow conditions in 1994. He found that fecal coliform concentrations were greatest in surface waters, ranging between 4,000 and 12,000 colony-forming units (CFUs) per 100 ml of sample. Such concentrations are well in excess of State of Hawaii standards for bacteria in waters. Mean annual bacterial loading from the Ala Wai Canal to Mamala Bay was estimated at 11,119 CFU/100 ml for fecal coliforms, 13,417 CFU/100 ml for *Enterococci,* and 182 CFU/100 ml for *Clostridium perfringens.*

4.5 Estimates of Pollutant Loading from Other Sources

To the best of our knowledge, no attempt has been made to estimate the masses of pollutants entering Mamala Bay from either atmospheric deposition of from transport into the Bay from the Pacific Ocean, or the contribution of these sources to pollutant concentrations in Mamala Bay.

5.0 Current Levels of Treatment of Waste Water and Nonpoint Source Water

With very few exceptions, the wastewater and nonpoint source water entering Mamala Bay from land receives treatment of some kind. Primary treatment is given to wastes entering the Sand Island and Honouliuli WWTPs, while secondary treatment is given to wastewater processed at the Fort Kamehameha WWTP. A *de facto* settling treatment is afforded urban runoff and storm water flowing from landside to basins such as Pearl Harbor, Keehi Lagoon, and the Ala Wai Canal.

5.1 Wastewater

Honouliuli WWTP provides primary treatment for wastewater flowing from the western portion of Honolulu. Effluent from Honouliuli is not chlorinated prior to discharge into Mamala Bay. Primary treatment includes screening to remove larger particles and the removal of suspended material (and some associated organic material) in settling tanks. The discharge permit for Honouliuli carries numerous limitations, including requirements for:

- influent monitoring and enforcement of industrial pre-treatment programs and public programs for reduction of pollutant loads;
- monitoring and reporting on the concentrations of selected pollutants in the primary sludge generated by the plant;
- monitoring of plant effluent and monitoring of receiving water to assure mandated BOD and suspended solids removal, and compliance with Hawaii water quality standards;
- monitoring effluent toxicity using standard techniques and test organisms;
- monitoring biota in the vicinity of the effluent to assess potential impacts; and
- monitoring receiving waters and beaches to assure compliance with State and federal limitations on bacteriological indicator organisms.

Sand Island WWTP is a primary treatment facility that discharges wastewater to Mamala Bay. Wastewater from the Sand Island WWTP is not chlorinated prior to discharge into Mamala Bay. A modified section 301(h) permit was granted in January 1990, and is subject to pre-treatment conditions, influent monitoring, sludge monitoring, toxicity testing, biological monitoring and water quality monitoring similar to that required of the Honouliuli plant.

Fort Kamehameha WWTP is run by the US Navy and provides waste treatment for domestic and industrial waste streams from throughout the Pearl Harbor Naval Base. Fort Kamehameha is a secondary treatment plant providing biological treatment which accomplishes 1) a reduction in the amount of organic matter (BOD) in the waste stream; 2) the degradation of some organic chemicals; and 3) the inactivation of some pathogenic bacteria and viruses. The effluent of the Fort Kamehameha WWTP is chlorinated before discharge to Mamala Bay waters.

The effluent flows from the three WWTPs make up over 90% of the point source flow in the study area. A full list of other permitted treatment facilities and their characteristics is included in the pollutant loading study (MB-3; Stevenson et al., 1995); and in Appendix Tables A1 through A5 of this report.

5.2 Runoff Water - Land-Based Nonpoint Source Water

Rather than describing "storm water," *per se*, we consider runoff from three different sources: 1) Runoff from upland, mountainous conservation areas; 2) Runoff from agricultural and non-urban areas; and 3) Runoff from urban and suburban areas, including those portions of the Mamala Bay watershed that include industry. None of the runoff water in the Mamala Bay watershed receives treatment for removal of solids or potential pollutants in any of the three WWTPs present in the watershed.

5.2.1 Runoff from Conservation Areas

Runoff and drainage from upland, mountain conservation areas comprise baseflow during dry periods and flash-flow during storms. The topography of Oahu results in high, nearly vertical cliffs, and few natural upland lakes and reservoirs (Masa Fujioka and Associates, 1995). Runoff from the mountainous areas in the watershed is not retained or treated in any natural or man-made basins in the distance between the stream origins and their entry into watershed areas where suburban or urban influences contribute to the stream flow.

5.2.2 Runoff from Agricultural and Non-urban Areas

Runoff from agricultural and non-urban areas in the Mamala Bay watershed may receive some treatment prior to entry into the several major streams that discharge to Pearl Harbor, the Ala Wai Canal, or directly into Mamala Bay. Treatment in agricultural areas consists primarily in the diversion of runoff into settling basins to accomplish the removal of some of the TSS. The solids retained in the settling basin probably contain significant concentrations of toxic metals and organic compounds such as pesticides. While some settling basins intercept runoff flow, the major basins for runoff from the agricultural region of the Ewa Plain are the Middle and Western Lochs of Pearl Harbor.

Runoff from the drainage sub-basins of the Manoa Stream and the Palolo Stream receives settling treatment in the Ala Wai Canal. Stevenson et al. (1995) estimated that the Ala Wai Canal retains about 50 percent of solids introduced to it from the Manoa-Palolo streams, and from urban storm drains feeding into the canal.

5.2.3 Runoff From Urban and Suburban Areas

Storm sewers from urban and suburban areas in the watershed discharge to drainage conveyances that direct the stormwater flow to the following locations:

- Ala Wai Canal
- Keehi Lagoon and tributary streams
- Kewalo Basin and tributary streams
- Pearl Harbor and tributary streams
- Mamala Bay

With the exception of the settling that occurs in the Ala Wai, Keehi Lagoon, Kewalo Basin and Pearl Harbor, none of the stormwater runoff from urban areas in the Mamala Bay watershed receives treatment for the removal of solids or potentially toxic chemicals.

5.3 Water-Based Nonpoint Sources

Pollutant discharges from water-based non point sources receive no treatment prior to entry into the Bay or waters contiguous with Mamala Bay. Water-based nonpoint source discharges that occur in Pearl Harbor, Honolulu Harbor, Keehi Lagoon and Ala Wai Boat Harbor are subject to settling due to the slow movement of water in these basins (Table 2).

6.0 Alternatives for the Reduction of Wastes Discharged to Mamala Bay

All the waste streams entering Mamala Bay and its sub-embayments contain chemical and biological pollutants. Neither the identity nor the concentrations of many of the chemical pollutants entering Mamala Bay are known; NPDES self-monitoring reports provide few data, and the data base for many pollutants contained in stormwater and other nonpoint sources are sparse. What is known is that many toxic pollutants are associated with suspended particulate matter in the waste stream. For that reason, efforts to reduce the particulate matter entering receiving water bodies are well known to cause a reduction in pollutant loading (Table 2). The identity and concentrations of biological pollutants (bacteria) are known to the extent that NPDES self-monitoring reports require sampling and analysis for fecal coliforms, *E. coli,* and enterococci. Some data are available for the bacterium *Clostridium perfringens.*

While additional treatment for all waste streams may not be practical, there are alternatives available whereby chemical pollutants and indicator bacteria in the waste streams can be systematically reduced to a minimum. The alternatives available for reducing pollutants in wastewater and other permitted point sources involve increased treatment, pollution prevention, and source reduction for chemical pollutants, and disinfection for biological pollutants. The treatment alternatives available for pollutants entering the system from nonpoint sources involve the construction of treatment facilities (including possible disinfection) as well as MMs for the reduction of nonpoint source pollution. The following sections describe a number of options related to decreasing waste constituents in the various flows entering Mamala Bay. Each description provides a waste treatment alternative or a MM, the probable impact of that alternative/MM on pollutant loads entering Mamala Bay, and an evaluation of the options presented.

6.1 Alternatives for the Reduction of Waste Constituents Entering Mamala Bay from Permitted Point Source Discharges

The majority of waste constituents entering Mamala Bay from permitted point sources come from WWTPs. Waste constituents in WWTP discharges could be reduced by one of three methods:

1) enhanced waste treatment (tertiary treatment, secondary treatment, or enhanced primary treatment)
2) flow reduction; and/or
3) pollution prevention.

Indicator bacterial loads (and, presumably, pathogens) in WWTP discharges from Honouliuli and Sand Island could be reduced by disinfection.

6.1.1 Waste Constituent Reduction Through Enhanced Waste Treatment

Enhanced treatment is the application of an alternative method for wastewater treatment resulting in increased efficiency of removal of waste constituents. Enhanced treatment may take one of several forms, and must be viewed in relative terms. Compared to no treatment (raw sewage discharge), primary treatment (filtration and settling) is an enhancement; compared to primary treatment, secondary treatment is an enhancement, and so forth.

6.1.1.1 Tertiary Treatment

The most straightforward approach to reducing suspended solids, BOD, COD, Oil and Grease, nutrients, indicator bacteria (and some toxic substances) in WWTP discharges is to construct new plants capable of providing tertiary waste treatment to the full volume of wastes. Construction of "State-of-the-Practice" tertiary plants would result in a reduction of overall pollutant loads to masses equivalent to the current discharge at Fort Kamehameha (e.g., Tables 3 - 5). Of greatest significance would be the reduction in bacterial loading to Mamala Bay. Bacterial load, alone, could be accomplished by the use of disinfection at the Honouliuli and Sand Island WWTPs.

Tertiary Treatment - Evaluation and Recommendation

Positive aspects of implementing tertiary treatment of domestic/industrial wastes in the Mamala Bay Watershed are:

- Large reduction in bacterial loads to Mamala Bay;
- Large reduction in loading of TSS, BOD, COD, and Oil and Grease;
- Substantial reduction in loading of nutrients; and
- Substantial reduction in loading of metallic and organic toxicants.

Negative aspects of tertiary treatment of domestic/industrial wastes in the Mamala Bay watershed are:

- Available space for the construction of tertiary treatment plant(s);
- Prohibitive cost of tertiary treatment for the City and County of Honolulu;
- Removal of only point source pollutant loadings from Mamala Bay; and
- Large volumes of chemical and biological sludge for disposal.

Unless it is shown that Mamala Bay is under severe stress from the loading of pollutants from permitted point sources, implementation of tertiary treatment of domestic and/or industrial wastes cannot be recommended as an option at this time.

6.1.1.2 Secondary Treatment

Another approach to reducing pollutant discharges to Mamala Bay would be to upgrade Sand Island and Honouliuli to provide secondary treatment to the full volume of wastes in the waste stream. Construction of secondary plants would result in a reduction of overall conventional pollutant loads. Disinfection of the waste stream prior to discharge to Mamala Bay would accomplish a very large reduction in the loading of bacteria.

Secondary Treatment - Evaluation and Recommendation

The Fort Kamehameha WWTP is presently providing secondary treatment (with chlorine disinfection) for waste from the US Navy complex at Pearl Harbor. The Fort Kamehameha WWTP will switch from chlorine disinfection to UV disinfection in the near-future when the UV disinfection facilities that are under construction have been completed.

Comparison of the pollutant loading from Fort Kamehameha with pollutant loading from Honouliuli and Sand Island (Stevenson et al., 1995) shows that secondary treatment at the efficiency of the Fort Kamehameha plant could accomplish the removal of substantial portions of the conventional waste load currently entering Mamala Bay (Table 3). However, secondary treatment has little effect on metals; Fort Kamehameha discharges proportionately the same loads of Cd, Cu and Zn as Honouliuli, but only about 20 percent of the lead.

Positive aspects of implementing secondary treatment (with disinfection) of domestic and industrial wastes at Sand Island and Honouliuli on pollutant loading to Mamala Bay are:

- Large reduction in bacteria loads to Mamala Bay;
- Significant reductions in loading of TSS (60%), BOD (94%), and Oil and Grease contamination (89%); and
- Substantial reduction in loading of N (53%) and P (54%).

Negative aspects of secondary treatment of domestic/industrial wastes in the Mamala Bay watershed are:

- Prohibitive cost of upgrading to secondary treatment;
- Minor impact on the removal of toxic metals from the discharges;
- Removal of only point source pollutant loadings from Mamala Bay; and
- Large volumes of biological sludge for disposal.

Unless it can be demonstrated that Mamala Bay is under severe stress from the present loading of pollutants from permitted point sources, upgrading of the Sand Island and Honouliuli treatment plants from primary to secondary for the treatment of domestic/industrial wastes from the City and County of Honolulu cannot be recommended as an option at this time.

6.1.1.3 Enhanced Primary Treatment

A variety of engineering solutions have been proposed to upgrade treatment and expand capacity at Sand Island and Honouliuli. Five options were included in the West Mamala Bay Wastewater Facilities Plan - Final Environmental Impact Statement. These were:

- No action;

- Achieve optimum operation of existing facilities;
- Expand primary treatment to meet the 30 percent BOD removal;
- Convert to secondary treatment; and
- Eliminate or reduce the volume of the discharge to the ocean.

Harleman et al. (1995) carried out a six-month long special project: *Point Source Characterization and Control Options for Mamala Bay.* Their report has been finalized as a chapter in this collection; *Wastewater Management Strategies in an Integrated Coastal Management Plan for Mamala Bay* (Project MB-11). The study was undertaken to examine engineering and economic aspects of reducing point source pollution levels in discharges to Mamala Bay by reducing inputs from the Honouliuli and Sand Island WWTPs. The study team evaluated step-wise changes in treatment plant flow capacity and removal efficiency of identified pollutants that are technically and economically feasible over the next two-to-three decades. The study also considered steps that might be taken to improve the water quality of the Ala Wai Canal discharge. A summary of their results follows.

Loading rates calculated by the MB-11 team for TSS, BOD and fats, oil and grease (FOG = Oil and Grease) were similar to values calculated in Project MB-3 (*Pollutant Source Identification;* Stevenson et al., 1995). Evaluation of six years of data from the Sand Island WWTP showed that monthly average 30% BOD removal efficiency has not been achieved in 1994 and early 1995, but that monthly average TSS removal efficiency (>70%) has not declined. The average daily flow at the Sand Island Plant has increased since May 1992, from 269 million liters per day (MLD) to 276 MLD (71 to 73 MGD), and fats oils and greases have increased by almost 50% since 1992. Chemical data (chloride concentrations and pH values) suggest seawater intrusion into the influent waste stream at Sand Island.

The Honouliuli WWTP has achieved TSS removal efficiencies of about 77 percent, and BOD removal efficiencies of about 47 percent, over the six-year period from 1988 through November 1993. Monthly average BOD removal efficiency has been below 30% since late 1994. In general, TSS and BOD removal efficiencies at Honouliuli were much higher than would be expected for conventional primary treatment until 1994, when BOD removal began to decline. The average daily flow at Honouliuli has increased over the past six years, as have effluent concentrations of BOD. Effluent TSS and FOG have remained fairly constant.

The population of the East Mamala Bay service area (Sand Island) is predicted to increase to 412,000 by the year 2015. This will increase the average daily flow at Sand Island WWTP from its current level of 276 MLD (73 MGD) to between 295 and 325 MLD (78 MGD to 86 MGD); design flow for the plant is about 310 MLD (82 MGD). According to the general plan of the City and County of Honolulu, the population of the area serviced by the Honouliuli plant will increase to 269,000 by 2005. This population growth will cause an increase in average daily flow from 87 to 132 MLD (from 23 MGD to 35 MGD); design capacity for Honouliuli is 193 MLD (51 MGD).

The options recommended by the City and County of Honolulu and Belt Collins Hawaii were to either expand primary treatment to meet the 30 percent BOD removal requirement, or go to secondary treatment in the form of selector-activated sludge or roughing filter/activated sludge.

Harleman et al. (1995) concluded that additional options existed, namely, to upgrade the Sand Island and Honouliuli WWTPs using chemically-enhanced primary treatment (CEPT). Laboratory-scale tests were carried out at the Sand Island plant to determine the impact of low doses of chemical coagulants on plant performance. The principal finding of the study was that CEPT would be a simple and cost-effective way to upgrade the quality of the effluents and increase flow capacity. Implementation of CEPT at the Sand Island WWTP would improve BOD removal from 30 percent to 50 percent, and would improve solids removal from 65 percent to 80 percent.

6.1.1.3.1 Sand Island Treatment Evaluations

6.1.1.3.1.1 Dissolved Air Flotation

Performance of the primary clarifiers in terms of the relative efficiency of dissolved air flotation (DAF) *vs* conventional gravity settling at Sand Island WWTP was required by the 1992 Consent Decree. The efficacy of dissolved air flotation (DAF) was evaluated in two studies; one by GMP Associates, Inc. / Carpenter Environmental Associates, Inc., the other by the Project MB-11 Team (Harleman et al., 1995). The GMP/Carpenter evaluation recommended continued use of the DAF because "... of the two processes (conventional primary settling and DAF, only DAF consistently meets the minimum removal requirement of 30% for BOD"(as cited in Harleman et al., 1995). Harleman et al. (1995) evaluated data from a longer time base and showed that conventional primary clarification attained BOD removal comparable with DAF, and that TSS removal with conventional clarification was better than with DAF (Table 8). Because the Sand Island WWTP did not show improved performance with DAF in 1994 and 1995, Harleman et al. (1995) do not believe that DAF is superior to conventional clarification.

6.1.1.3.1.2 Chemically Enhanced Primary Treatment (CEPT)

Tests with CEPT at the Sand Island WWTP showed that chemical addition is a simple means to achieve improved BOD removal performance, and that performance improvement gets better with polymer additions in the range of 1 to 3 mg/L. Further, DAF with polymer addition gave better performance than polymer addition followed by gravity settling. Harleman et al. (1995) recommended the use of polymers on a continuous basis in order to optimize the performance of the existing WWTP at Sand Island, and to allow the plant to accommodate disinfection if it is decided that disinfection is needed.

6.1.1.3.2 Honouliuli Treatment Evaluations

Bench-scale and full-scale CEPT testing was carried out with the objective of determining the efficacy of COD, TSS, phosphorus, nitrogen and fecal coliform removal at the Honouliuli WWTP. Bench-scale tests showed that TSS removal of 80%, and COD removal of about 60% could be expected using any of several cationic polymers, including chitosan and various synthetic polymers. Full-scale testing was carried out in 1994 and 1995. The results of the full-scale tests (Table 9) showed a significant increase in TSS and BOD removal (7% and 10% improvement, respectively). Harleman et al. (1995) recommend use of CEPT at the Honouliuli WWTP with proper choice of coagulants and treatment times.

Enhanced Primary Treatment - Evaluation and Recommendation

Positive aspects of implementing enhanced primary treatment of domestic/industrial wastes at Sand Island and Honouliuli on pollutant loading to Mamala Bay are:

- Enhanced primary treatment could provide compliance with EPA requirements for BOD removal;
- Improved BOD, TSS, Oil and Grease, and nutrient removal; and
- The suitability of effluent transmissivity for disinfection by UV irradiation.

Negative aspects of enhanced primary treatment of domestic/industrial wastes at Sand Island and Honouliuli are:

- The cost of upgrading to enhanced primary treatment for the City and County of Honolulu;
- Minor impact on the removal of toxic metals from the discharges;
- Minor impact on removal of bacteria from the discharges; and
- Removal of only point source pollutant loadings from Mamala Bay.

Upgrading Sand Island and Honouliuli WWTPs from primary treatment to enhanced primary treatment, or some other method for improving the removal of BOD from the waste discharges, is required. Bacterial loading to Mamala Bay from the Sand Island and Honouliuli WWTPs could be reduced by employing disinfection. Although upgrading to enhanced primary treatment will not have a significant impact on the removal of toxics from the waste discharges, and although any degree of treatment of domestic and industrial waste ignores the loading of pollutants from nonpoint sources, Harleman et al. (1995) recommended that wastes from the Sand Island and Honouliuli WWTPs be upgraded to enhanced primary treatment conditions.

6.1.1.4 Disinfection at Waste Water Treatment Plants

The Mamala Bay study has as one of its objectives to determine the potential impact of point source and nonpoint source discharges on the health of human populations (see Fujioka and Loh, 1995; Cooper and Olivieri, 1995). The primary exposure for humans to potential pathogens in Mamala Bay waters is during swimming. Identification of pathogens other than "typical" indicator bacteria in Mamala Bay water is part of the Mamala Bay study (Fujioka and Loh, 1995; Hill et al., 1995; Landry et al., 1995).

Sources of bacterial and viral pathogens in the inshore waters of Mamala Bay are:

- shedding from swimmers themselves (Cooper and Olivieri, 1995; Landry et al., 1995);
- shoreline transport of pathogens from nonpoint sources (Stevenson, 1994; Stevenson et al., 1995); and
- onshore transport from discharge areas into the shore zone by ocean currents (Gerba and Pepper, 1995; Blumberg and Connolly, 1995).

The State of Hawaii (1992) has published standards for bacterial indicators in water at beach areas for full-contact recreation; not more than 7 enterococci communities / 100 ml sample in not less than five samples equally spaced over a 30-day period. This standard for enterococci is the most restrictive standard of any state.

The Sand Island and Honouliuli WWTPs are a major source of bacterial indicator loadings to Mamala Bay (Stevenson et al., 1995; O'Connor et al., 1995). Mean calculated concentrations of enterococci in the Sand Island and the Honouliuli WWTP effluents were 4.8 x 10^5 and 3.95 x 10^5 CFU/100 ml, respectively (from Table 5). Estimated enterococci concentrations after initial dilution of the effluent (factor of 400; Roberts et al., 1995) are 1.2 x 10^3/100ml and 1 x 10^3 /100 ml for Sand Island and Honouliuli, respectively; these concentrations are well in excess of the existing Hawaii water quality standard. If it is determined through hydrodynamic modeling that bacterial contamination of WWTP effluent discharges to Mamala Bay poses a problem (Blumberg and Connolly, 1995), then indicator bacteria loading (and, presumably, pathogen loading) from Sand Island and Honouliuli could be greatly reduced by disinfection; the Fort Kamehameha WWTP disinfects their wastewater discharge with chlorine at present (July 1995), and indicator bacteria loads from Fort Kamehameha are vanishingly small (10^{-6}) in proportion to the loads from Sand Island and Honouliuli (see above; Stevenson et al., 1995; Fujioka and Loh, 1995).

As reported by Harleman et al. (1995), both Sand Island and Honouliuli have facilities to process liquid chlorine into chlorine gas for injection into the wastewater outflow;

however, the systems to inject the chlorine are entirely corroded. In order for chlorination to be implemented as a disinfection method, there would have to be a complete rebuilding and replacement of piping. Furthermore, there is no chlorine contact chamber at either plant, and neither plant has facilities for dechlorination.

Neither Sand Island nor Honouliuli chlorinate because chlorination is not required under their respective NPDES permits. The primary reason is that chlorine poses a serious threat to aquatic organisms.

Harleman et al. (1995) listed disinfection alternatives for the Sand Island and Honouliuli WWTPs. These included:

- chlorination/dechlorination;
- chlorine-based alternatives with other than chlorine gas; and
- ultraviolet (UV) irradiation.

The toxicity of chlorine to aquatic species mitigates against chlorination for disinfection at the Sand Island and Honouliuli WWTPs (Isaacs, 1995). After reviewing the requirements for disinfection with UV irradiation, Harleman et al. (1995) concluded that UV was a viable alternative and deserves consideration if disinfection is required (UV irradiation for disinfection will soon be implemented at the Fort Kamehameha WWTP).

6.1.1.4 Treatment for Discharges from the Ala Wai Canal

As noted, the Ala Wai Canal plays a role in pollutant loading to Mamala Bay. On the one hand the polluted Ala Wai Canal (a water-quality limited segment) discharges to Mamala Bay and is a source of pollutants to the Bay (Stevenson, 1994). Harleman et al. (1995) have supposed that the Ala Wai Canal is a primary source of bacterial pollution to beaches; Blumberg and Connolly (1995) are modeling pollutant fate and transport in Mamala Bay using the Ala Wai Canal as a "point source" of pollutants to the system.

On the other hand the Ala Wai Canal also serves as a settling basin for suspended solids entering the canal from the several streams in the eastern portion of the Mamala Bay watershed. Stevenson et al. (1995) have estimated that approximately 50% of the suspended solids entering the Canal with stormwater and urban runoff are retained therein, along with large fractions of some of the pollutants associated with stormwater and urban sources. Whatever treatment may be applied to the Ala Wai Canal for purposes of restoring beneficial uses to the human population, the Canal should also be maintained in a condition wherein it serves as a settling basin for suspended solids and pollutants in storm water and urban runoff.

Harleman et al. (1994) evaluated four engineering alternatives for improvement of the Ala Wai Canal. The options included those presented by the Hawaii Dept. of Land and Natural Resources (1992) as well as by investigators from the MB-11 Team. The options are:

1. Groundwater Injection with the objective of maintaining freshwater flow in order to flush sediments, bacteria, nutrients, and other pollutants from the Canal, thus improving water quality for recreation and fishing.
2. Sea Water Injection. The objective is the same as that cited above, for groundwater injection.
3. Chemical coagulation with the objective of removing suspended solids and pollutants associated with suspended solids, as well as organic matter (BOD) and phosphorus, resulting in an overall improvement of water quality in the Canal.
4. Erecting a salt water barrier to create a "one-way flow" of saltwater into the canal. The effect would be to improve water quality with the increased circulation and flushing in the canal.
5. UV disinfection of the Manoa-Palolo Stream to reduce indicator bacterial populations in stream water by directing the flow of the stream through UV-irradiation chambers before discharge to the Ala Wai Canal.
6. Placement of artificial constructed wetlands in the Ala Wai Canal for biological removal of nutrients, metals, and bacterial contaminants.

Treatment for Discharges from the Ala Wai Canal - Evaluation and Recommendation

Freshwater injection to the Ala Wai canal using deep wells from the Ala Wai Golf Course may not be practical since the 0.5 to 0.9 m^3/sec (20 to 30 ft^3/sec) volume of freshwater required may have a negative impact on nearby land. Dr. Ed Noda (personal communication to D. Harleman) has stated that pumping could cause subsidence of the land around Waikiki. Seawater injection, as an alternative to freshwater injection, is still a viable alternative within the Ala Wai Task Force. New wells located off Kalakaua Avenue have recently (October 1994) been tested and have shown promising hydrogeology. The alternative of freshwater injection is still being considered.

Coagulation would result in the removal of suspended solids. Harleman et al. (1995) evaluated the potential for chemical coagulation to cause the formation of flocs in the Ala Wai Canal, and to reduce COD and TSS. They concluded 1) that the nature of wet-weather events in Hawaii (intermittent and intense) would pose engineering obstacles to treating the Ala Wai Canal with chemical flocculents. Moreover, Harleman et al. (1995) have noted that coagulation with cationic polymers is not recommended since cationic polymers would have an adverse effect on aquatic biota in the Canal.

The salt water barrier concept has been tested in a similar system in American Samoa and has been found to be successful; the idea is under consideration by the Ala Wai Task Force.

Disinfection of the Manoa-Palolo Stream by UV irradiation has been tested in concept; that is, tests of UV disinfection of the Fort Kemhameha effluent, combined with the fact that water from the Ala Wai Canal and Manoa Stream has similar UV light transmission characteristics as the Fort Kemhameha effluent, suggest that UV disinfection might be applied at the mouth of the Manoa-Palolo stream. If it is determined from pathogen monitoring studies and hydrodynamic modeling that disinfection of Ala Wai Canal effluent water is needed, then this alternative should be discussed further.

The placement of artificial, constructed wetlands in the Ala Wai Canal has been proposed (Harleman et al., 1994) as an alternative that might be combined with chemical coagulation and increased flushing of the Canal. The artificial wetlands have been shown to result in improved water quality in another confined coastal system (Flax Pond, Long Island) and hold promise as a treatment alternative. At the present time the artificial constructed wetland for the Ala Wai Canal has only been proposed in concept; to our knowledge there have been no bench-scale tests of this treatment alternative. If such a treatment alternative were found to be effective for the Ala Wai Canal situation, it could well lead to a substantial reduction in discharge of solids, nutrients and bacteria from the Ala Wai to Mamala Bay at the same time that it served to increase the water quality in the Canal and assisted in the restoration of beneficial uses.

Positive aspects of implementing Ala Wai Canal treatment options are associated primarily with improvement of the water quality in the Canal. The coagulation option holds the potential for removing pollutants from the Canal and reducing loadings to Mamala Bay; however, the coagulation alternative has been noted as having a potentially negative impact on aquatic biota in the Canal.

The artificial wetland holds promise for improving water quality in the Ala Wai Canal while reducing pollutant loads to the Bay. With the exception that constructed wetlands in the Canal could interfere with boating and fishing, the authors find little in the concept that objectionable.

The other options (freshwater injection, saltwater injection, seawater barrier) proposed to solve the water quality problem in Ala Wai Canal by flushing the Canal more rapidly, thereby maintaining or increasing the loading of pollutants to Mamala Bay. All these alternatives have the potential to reduce pollutant concentrations in the Ala Wai Canal effluent. Reduced concentrations of pollutants in the discharge would be beneficial if it were true that discharges from the Ala Wai were causing acute and/or chronic toxicity to marine biota, or if indicator bacterial loading from the Ala Wai Canal were found to pose a problem on the beaches.

Negative aspects of implementing treatment of the Ala Wai Canal are:

- Changing the nature of the canal from a small estuary into a predominantly freshwater system (freshwater injection) or a predominantly saltwater system (seawater injection);
- No impact on the removal of nutrients, toxic metals, or toxic organics from the discharge (freshwater injection, seawater injection, seawater barrier);
- No impact on removal of bacteria from the discharges (freshwater injection, seawater injection, seawater barrier); and

- Elimination of the Ala Wai Canal as a settling basin for the removal of suspended solids and toxic materials the Canal discharge.

Care must be taken to evaluate carefully the purpose for treating the waters of the Ala Wai Canal. Any decision must include consideration of not only improved water quality and restored beneficial uses, but also the value of the Canal as a settling basin for nonpoint source pollutants entering Mamala Bay. The two objectives are not apparently compatible; i.e., restoring water quality using acceptable options will not reduce pollutant loading, and optimizing the function of the Canal as a settling basin will not help to improve water quality.

If it can be demonstrated that discharges from the Ala Wai Canal are affecting Mamala Bay, or that bacterial loading from the Ala Wai Canal affect the quality of water on bathing beaches, then action in the Ala Wai Canal should be directed toward optimizing the function of the Canal as a settling basin. If the discharges from the Ala Wai Canal have no apparent impact on Mamala Bay, and if the bacterial loads from the Ala Wai Canal do not play a significant role in bacterial loading on the beaches, then action in the Ala Wai should be directed toward restoration of water quality in the Canal, and optimization of beneficial uses. The alternative of floating artificial wetland has been proposed but not evaluated in bench-scale. We recommend that the option be given consideration as the only potential treatment alternative that holds the promise of reducing pollutant loads from the Ala Wai Canal at the same time that water quality in the Canal is reduced, and beneficial uses might be restored.

6.1.2 Waste Constituent Reduction by Reducing Flows to Point Source Discharges

Pollutants from the point sources that enter Mamala Bay are transported in waste streams that discharge directly to the Bay or to its contiguous waters. Other pollutants from numerous industrial sources are pre-treated and conveyed to WWTPs for additional treatment, along with domestic and urban wastes. One MM for reducing pollutant discharge to Mamala Bay and its contiguous waters is to reduce the volume of flows entering receiving waters and the volume of industrial flows conveyed to WWTPs for "finishing" prior to discharge.

6.1.2.1 Flow Reduction from WWTPs and Point Source Discharges

Reduction in the volume of wastewater flows can be accomplished in most industries after an evaluation of wastewater flow to determine minimum flows necessary to the process under consideration. In some cases wastewater flows can be minimized using conservation plans that include recycling of wastes, concentration of flows, or elimination of pollutants for inclusion in wastewater flows. For industries discharging directly to surface waters minimization of wastewater flows will depend upon the ability of treatment facilities to handle a lower volume of flow and, possibly, waste flows containing higher concentrations of pollutants. For industries discharging to WWTPs, minimization of flows will depend upon the ability of the source in question to minimize flow and, under conditions where waste flows are concentrated, to still meet pre-treatment criteria for waters discharged to the WWTP.

Reduction in the volume of wastewater flows from domestic sources can be accomplished through water conservation. That is to say, fewer gallons of water discharged to WWTPs can result in a smaller volume of discharge from the WWTP. Proper operation of the WWTPs discharging to Mamala Bay can easily be maintained under conditions of reduced flows amounting to 10 to 20 percent. Simple arithmetic shows that if a given WWTP receives a 10 percent reduced flow containing the same or similar concentrations of pollutants, then the mass of pollutant discharged to Mamala Bay could be reduced by 10 percent. In the case of suspended solids a 10 percent reduced flow could result in a reduction of more than 75 tonnes (83 tons) per year (roughly equivalent to the mass of sediment released from the Ala Wai Canal in eight years). In the case of total phosphorus, a 10 percent reduction in flow could result in a reduction of four tonnes (4.5 tons) per year, or roughly one-half the total P discharged to the Ala Wai Canal each year.

Flow Reduction from Point Source Discharges - Evaluation and Recommendation

Positive aspects of flow reduction from point source discharges to Mamala Bay are:

- Reduced masses of conventional pollutants, potentially toxic metals, and organic compounds discharged to Mamala Bay and contiguous waters of Pearl Harbor, Keehi Lagoon, Kewalo Basin, and the Ala Wai Canal;

- Reduced volume of freshwater entering Mamala Bay and adjacent waters;
- More rapid dilution of freshwater flow after discharge at sea and in the estuarine waters of Pearl Harbor and the Ala Wai Canal; and

Flow reduction would not accomplish any change in the concentration of pollutants entering Mamala Bay; however, since concentrations of toxic materials entering Mamala Bay appear not to be a major problem at present (O'Connor et al., 1995), maintenance of existing pollutant concentrations at *status quo* would pose no problem.

Negative aspects of flow reduction from point source discharges to Mamala Bay are few. If flows were reduced drastically, there could be a reduction in the efficiency of the WWTP diffusers; such a drastic reduction of flow is unlikely to occur. The authors are aware of only one significant potential negative impact, that being a possible increase in the concentration of some pollutants in discharge flows and pretreatment flows. Under conditions where some pollutants become more concentrated in wastewater flows, it is possible that their increased concentrations could have an adverse impact on the operation of existing treatment processes.

We conclude that, regardless of the apparent impact or lack of impact of point source discharges on Mamala Bay, reductions in wastewater flow from all sources to Mamala Bay and its contiguous waters would have a positive impact. We recommend that the State of Hawaii take action as follows: 1) to require industries to evaluate MMs to reduce the volume of wastewater flow currently discharged to receiving waters or to pretreatment facilities and to implement reduction in wastewater flows where feasible; and 2) to encourage further water conservation in the home and in the workplace with the objective of reducing the amount of wastewater discharged to WWTPs for treatment and eventual release to Mamala Bay.

6.1.2.2 Flow Reduction from the Ala Wai Canal

Flows in the Ala Wai Canal are driven by stream discharges, rainfall, groundwater seepage, stormwater runoff in non-urban areas, stormwater runoff in urban areas, and the daily cycling of tides. Only a small volume of permitted, point source wastewater flow is discharged directly into the Ala Wai Canal. The Canal acts as a conveyance for water from three streams in the eastern portion of the Mamala Bay watershed; the Manoa Stream, the Palolo Stream, and the Makiki Stream. Under present circumstances it is unlikely that flows in the Ala Wai Canal could be reduced to any measurable extent by reduced flow from permitted point source discharges to the Ala Wai Canal. It is further unlikely that reduction of flows in the Ala Wai Canal would have any positive impact on the reduction of pollutant loading to Mamala Bay.

Flow Reduction from the Ala Wai Canal - Evaluation and Recommendation

Flow reductions from the Ala Wai Canal are unlikely; it is impossible to provide evaluations or recommendations based upon such considerations.

6.1.3 Waste Constituent Reduction Through Pollution Prevention - Point Sources

Pollution prevention and source reduction of pollutants by dischargers is required under the Pollution Prevention Act of 1990 (PL 101-508). Pollution prevention is a process whereby pollutants are either partially or fully eliminated from specified domestic or industrial applications. Elimination of a pollutant from some uses reduces the mass of the pollutant discharged to treatment plants and, hence, reduces the load discharged to surface waters. Some examples of pollution prevention in waste discharges would be the elimination of phosphates from domestic and industrial detergents, the elimination of a specific solvent from household and/or industrial applications, or the elimination of metal-based pigments in soaps and toilet tissue.

We believe that pollution prevention and waste minimization are reasonable processes to espouse to domestic and industrial waste generators in the Mamala Bay watershed. We are of the opinion that, regardless of the apparent impact, or lack of impact, of point source discharges on Mamala Bay, reduction in the uses of all pollutants in the Mamala Bay watershed is a reasonable policy to pursue, and would have a positive impact on the quality of surface waters. We recommend that the State of Hawaii take action as follows:

1. To support public education programs to inform residents of the means whereby uses of pollutants can be reduced in the household;

2. To require businesses and industries to undertake inventories of their uses of toxic pollutants, and to institute, where possible, MMs aimed at reducing the use of toxic pollutants where feasible; and

3. To require manufacturers to undertake inventories of their uses of toxic materials, and to minimize the uses of such materials wherever possible, whether by reduction in the amounts of toxic and potentially toxic materials are used, or by the substitution of non-toxic materials for those that are known to be toxic.

All of these activities are required by the Pollution Prevention Act of 1990, and funds have been available from EPA to accomplish the reduction of pollutant discharges.

6.2. Alternatives for the Reduction of Waste Constituents from Nonpoint Sources

Numerous alternatives exist to assist in the reduction of waste constituents from nonpoint source discharges into Mamala Bay. Some alternatives involve the construction of facilities for direct treatment of nonpoint source flow. Most alternatives represent MMs that may be applied to existing practices that will result in the minimization of pollutants in nonpoint source flows. Indeed, states now have the requirement under the Coastal Zone Act Reauthorization Amendments (CZARA) to examine and implement appropriate MMs in order to protect and preserve the integrity of biological resources and coastal ecosystems. A full listing of potential MMs may be found in the US EPA-NOAA publication *Guidance Specifying Management Measures for Sources of Nonpoint Pollution in Coastal Waters* (1993; see also Masa Fujioka and Associates, 1995).

Evaluation and implementation of MMs under the US EPA guidance document have been addressed in reports from state organizations (Washington State Department of Ecology, 1990; Camp Dresser and McKee et al.,1993; Freeman et al, 1994). Not all such MMs are practical for application to the Mamala Bay watershed (Masa Fujioka and Associates, 1995). The following sections discuss two kinds of MMs that could be implemented in the Mamala Bay watershed. The first MM deals with constructed facilities for the treatment of nonpoint source water for the removal of pollutants (Best Management

Technology). The second MM deals with modification of human behaviour at the point where pollutants become available to nonpoint source flows preventing the introduction of pollutants into nonpoint source flows, or minimizing or eliminate the movement of pollutants from their site of origin into surface waters and eventual transport into Mamala Bay.

6.2.1 Best Management Technology for Waste Reduction at Nonpoint Sources

Treatment to reduce waste constituents in nonpoint sources involves treatment of nonpoint sources prior to discharge into Mamala Bay. MMs useful in treating nonpoint source flows for pollutant removal include 1) direct treatment of nonpoint source flows for removal of particulate matter and associated pollutants, and 2) construction of settling ponds (retention basins, canals, impoundments, and so forth) to allow the settling of particulate material and associated pollutants. Direct treatment of nonpoint source flows has been proposed only for the Ala Wai Canal (Harleman et al., 1995; see above).

6.2.1.1 Best Management Practice for Treatment of Nonpoint Source Flows

Most of the runoff within the Mamala Bay drainage basin enters the Bay indirectly, flowing first through permanent and temporary streams, canals, and storm sewers into sub-embayments, and then into Mamala Bay. The sub-embayments provide *de facto* treatment; that is to say, embayments such as Pearl Harbor and the Keehi Lagoon receive drainage and runoff water from the drainage basin and, by virtue of their physical structure, allow for the settling and the removal of suspended solids (and some pollutants) from runoff . The Ala Wai Canal acts as a settling basin for solids carried in drainage and runoff from the eastern portion of the Mamala Bay drainage Basin. Stevenson et al. (1995) provided estimates of the proportion of nonpoint source pollutants associated with solids and, therefore, subject to settling in natural or constructed basins (Table 2). They estimated that about 50 percent of the settleable solids that enter the Canal should be retained due to deposition; Pearl Harbor, Kewalo Basin, and Keehi Lagoon had sufficient depth and retention time relative to the annual average volume of nonpoint source inflow that 95%of the suspended solids entering those basins would be retained.

Pearl Harbor, Kewalo Basin, Keehi Lagoon and the Ala Wai Canal are ideal for the removal of suspended solids and particle-associated pollutants because of their position at the seaward end of runoff flow. Based upon the fraction of pollutant classes associated with suspended material, existing structures in the Mamala Bay watershed will accomplish the removal of most TSS, a measurable quantity of nutrients, and proportions of potentially toxic heavy metals ranging from 40 percent (zinc) to 90 percent (lead) (Table 2). A significant question remains as to whether additional settling basins in the Mamala Bay Watershed would serve to improve significantly the existing proportion of particle trapping and particle-associated pollutant removal (State of Hawaii, Department of Land and Natural Resources, 1980).

Several factors limit the locations where effective settling basins could be placed. The mountainous conservation areas are unsuitable for the placement of settling basins for at least two reasons: 1) the steepness of the slopes; and 2) the extreme degree of "flashiness" of the flow from storms. The plains of the eastern side of the Mamala Bay watershed are unsuitable for the construction of settling basins for at least three reasons: 1) the intense development of the region; 2) poor infiltration characteristics of the alluvial soils (Masa Fujioka and Associates, 1995); and 3) the high cost of the land, which limits the amount of land available for set-asides in new development.

The quantity of pollutants removed from nonpoint source flows in the Mamala Bay watershed by natural and constructed settling basins is substantial. Under current conditions, it is unlikely that additional solids removal could be accomplished by the construction of new settling basins. However, nonpoint source treatment is not only a matter of solids removal; as can be seen from Table 2, several of the classes of contaminants listed as present in nonpoint source flow remain virtually unaffected by the natural and constructed settling basins that exist at present (BOD, Total P). The small percentage of particles that are assumed to escape the existing settling basins will, in all likelihood, be the finer particles and colloidal matter that have a very high affinity for adsorbing a variety of pollutants, including metals, nutrients, pesticides, and sparingly soluble industrial chemicals. It is quite possible, therefore, that additional pollutant removal could be accomplished by the construction and placement of additional settling basins upstream of Pearl Harbor, Keehi Lagoon, Kewalo Basin, and the Ala Wai Canal.

The states of Washington and California evaluated Best Management Practices for stormwater pollution control (Washington Dept. of Ecology, 1990; Camp Dresser McKee et al., 1993). Their evaluations, as well as evaluations performed in the State of Hawaii (Freeman et al., 1994) provide documentation of potential MMs that might be constructed for the removal of suspended material and pollutants from nonpoint source flow. Those included:

- Infiltration basins
- Infiltration trenches
- Vegetated filter strips
- Grassed swales
- Porous pavement and permeable surfaces
- Concrete grid pavement
- Water quality inlets
- Extended detention dry ponds
- Wet Ponds
- Constructed wetlands
- Filtration basins and sand filters.

Where possible, these management practices are being implemented in the Mamala Bay watershed, especially with regard to ordinances covering new development and construction in the watershed. Masa Fujioka and Associates have provided a discussion of each of these alternatives in their draft report on *Urban Nonpoint Source Pollution Control in the Hawaiian Islands* (1995). Certain of the practices listed above may also be effective in particle/pollutant removal for runoff from agricultural areas. On the whole, additional efforts to reduce suspended solids in nonpoint source runoff should be concentrated on control of erosion, especially in areas under development and in agriculture. The Hawaii Soil Conservation effort is active in erosion control activities, including advocating the planting of cover crops, revegetation, grassing dirt roads in agricultural areas, and other measures.

6.2.2 Non-Construction MMs for the Control of Pollutants in Nonpoint Sources

If one assumes that the existing settling basins remain in place, in their present configuration in the Mamala Bay Watershed (volume/depth and retention time characteristics), the question that must be asked is: "What additional alternatives can be proposed and implemented that will serve to significantly reduce the load of solids and pollutants discharged to Mamala Bay from the watershed?"

The answer to that question is in a wealth of activities, initiatives, and ordinances that have been put in place in the State of Hawaii, the City and County of Honolulu, and in many communities seeking to comply with EPA and NOAA directives under the Clean Water Act and the Coastal Zone Management Act to put in place MMs to prevent nonpoint source pollution and to protect and restore the coastal environment from the effects of nonpoint source pollution. A full review of nonpoint source management efforts in the State of Hawaii has been published recently (Freeman et al., 1994).

Most MMs, other than those involving the new construction of settling basins, infiltration ponds, and the like, focus on activities aimed at pollution prevention or reduction of the amount of pollution at sources likely to contribute to pollutant concentrations in nonpoint source runoff. In the paragraphs that follow we highlight MMs that are applicable to a variety of conditions and pollutant sources. The discussion of each pollution prevention activity presented below is by no means exhaustive; rather, it represents MMs that can have a direct and meaningful impact on the amount of pollution in nonpoint source flows and which, if followed, can result in an overall decrease in the load of pollutants discharged to Mamala Bay from nonpoint sources, including the Ala Wai Canal.

The principles of pollution prevention and source reduction are that if pollutants introduced into the waste stream are minimized, the mass (and, possibly, the concentration) of pollutants transported to surface waters can be reduced. Parity between pollutant load and pollutant concentration entering surface waters cannot be maintained because many pollutants are introduced into nonpoint source streams in slugs or boluses (e.g., waste crankcase oil poured into a storm drain). The result is that loads calculated on a daily or monthly basis do not reflect the instantaneous concentration of a pollutant in the waste stream.

Pollution prevention or source reduction to minimize pollution in nonpoint waste streams takes several forms in Hawaii and in other states. The following paragraphs deal with activities aimed at accomplishing pollutant source reduction in 1) the urban environment, 2) industry, 3) construction, 4) transportation, 5) agriculture, and 6) domestic situations. While many of the source reduction programs in the State of Hawaii are in the early stages of implementation (Freeman et al., 1994), several programs are active and have been highly successful in reducing nonpoint source pollution (for example, in the strict rules governing new development and construction of roadways).

6.2.2.1 Source Reduction of Nonpoint Pollution - Urban Environments

Nonpoint source pollution in urban environments arises from discarded wastes and trash, pollutant deposition from the atmosphere to impermeable surfaces such as roadways, improperly disposed chemicals, including paints, solvents, waste oils, cooking wastes, leaking storage tanks, fluids leaking from automobiles and other equipment, and so forth. Typical urban environments have a high proportion of impermeable surface; hence, a high proportion of nonpoint source pollutants are transported from urban surfaces to storm drains and, thence, to surface waters.

Much of the Honolulu urban environment is immediately adjacent to the waters of Mamala Bay. Most urban storm drains in the Mamala Bay watershed drain into Pearl Harbor, Keehi Lagoon, Kewalo Basin, or the Ala Wai Canal. Some nonpoint source wastes from metropolitan Honolulu are transported in storm drains directly to Mamala Bay without first passing through one of the natural or constructed settling basins. Appropriate available MMs that can be applied to nonpoint source pollution control in urban Honolulu include:

- Improved street sweeping and trash removal;
- Improved operation of existing treatment facilities (infiltration basins, recharge canals, and the like);
- Reformulation of products known to contribute pollutants;
- Improved maintenance of known mechanical sources of nonpoint source pollution;

- Public education regarding impacts of improper waste disposal; and
- An increased number of training and education programs for persons in the urban environment who routinely handle waste materials.

Hawaii's Water Pollution Control Program has made strides toward management of nonpoint source pollution in the urban environment. For example, the NPS program has received grant money for public education on a statewide basis. Further, erosion control programs for road cut areas and public education related to the Pearl Harbor sub-basins have been implemented. On a grass-roots level, government agencies and citizen groups have been conducting *ad hoc* public education programs and public awareness programs, such as stenciling storm drains (*"Drains to Bay"*) throughout the urban environment. Statewide programs exist for the identification of leaking fuel tanks and storage tanks, pollution related to spills of transported wastes and toxicants, and an active program for the control of soil erosion at new construction/development sites (Freeman et al., 1994).

Several programs should be expanded in order to further reduce nonpoint source pollution loading in the urban environment. These include expansion and acceleration of the rehabilitation of leaking fuel and waste storage tanks, the utilization of non-polluting products (for example, brake linings - a source of zinc and lead), increased street sweeping and trash removal, and public education and consciousness-raising programs with a higher profile.

6.2.2.2 Source Reduction of Nonpoint Pollution - Industrial Environment

Nonpoint source pollution in the industrial environment may arise from waste product materials in and around the plant, the loss of dust and debris to the surrounding environment during manufacture and processing, the inadvertent discharge of waste product and cleaning solutions in storm drains, and frank illegal disposal of waste product material, debris and cleaning solutions in storm drains. The greater number of industrial operations in the City and County of Honolulu are located primarily in the vicinity of the Pearl Harbor Naval Station, and in the industrial areas near Honolulu Harbor. Nonpoint source runoff from industrialized portions of the City is directed primarily to Pearl Harbor, Keehi Lagoon and the Kewalo Basin.

The types of materials in nonpoint waste from industrial operations are varied; metal plating and tooling factories discharge metals, acids, and organic cleaning solvents to the environment; the plastics industry, boat manufactories, and household product manufactories discharge metals and organics wastes, as well as solvents and other materials. Since the amount of impermeable land surface in industrial areas is high, pollutants on paved surfaces in industrial areas can easily be transported with stormwater runoff into coastal waters.

Pollutant source reduction in the industrial environment can take one of two forms. First, pollutant source reduction can be accomplished by employing good-housekeeping practices throughout the industrial environment; tailings and slag from processes can easily be collected for recycling or disposal; air from manufacturing and finishing can be filtered for the removal of pollutant-containing dust; solvents used for processing, cleaning, and finishing can be better managed by recycling; disposal of any liquid waste to storm drains can be eliminated, and illicit discharges to storm drains can be stopped.

There is, at present, no national program for the monitoring of nonpoint source pollution from industry. Permits for nonpoint source discharges issued to industries under the National Pollutant Discharge Elimination System (NPDES) require sampling and analysis of site-runoff for a small number of conventional pollution measures; total suspended solids (TSS), acidity (pH), and oil and grease. Some municipalities, such as the Alameda County in California, maintain aggressive programs to identify and fine illicit dischargers. To the best of our knowledge, there are no programs in the State of Hawaii aimed at minimizing nonpoint source pollution from industrial facilities and adjacent sites (Freeman et al., 1994).

6.2.2.3 Source Reduction of Nonpoint Pollution - Construction Industry

Nonpoint source pollution in construction arises from erosion of topsoil, subsequent transport of eroded soil from the construction site to streams and, thence, to coastal waters. Toxic chemicals associated with construction may be petrochemicals, paints, solvents, and other, similar chemicals. Any toxic chemicals spilled, sprayed, or otherwise placed on bare topsoil at constructions sites will, in all likelihood, become associated with soil particles, and will be transported from the site along with soils. Toxic and potentially toxic materials buried at construction sites have the potential to migrate from the point of burial and be transported to coastal waters with surface water flow, or with groundwater flow.

The State of Hawaii has strict ordinances in place for the control of erosion at construction sites throughout the state, as well as in the City and County of Honolulu (Freeman et al., 1994). Ordinances strive to reduce the transport of suspended materials (soils) from all construction sites by 80 percent during the construction phase, and to maintain subsequent suspended material losses below losses that occurred prior before construction.

6.2.2.4 Source Reduction of Nonpoint Pollution - Transportation

The Mamala Bay watershed supports much land-based and water-based transportation. The land-based transportation supports the domestic and industrial activities carried out by a population of about one million people. Water-based transportation includes both defense, merchant, and recreational activity. Defense activity is centered on Pearl Harbor, one of the largest bases operated by the US Navy. Water-based transportation activity involves commercial fisheries as well as providing the link between Honolulu and major ports on the Pacific Rim. There is, in addition, active inter-island merchant activity linking Honolulu, Hawaii's major port, with other ports and the other populated islands of the archipelago. Recreational water-based transportation activity is centered on recreational fishing, cruise vessels, touring boats, and other recreational boating related to the very active visitor industry centered in Honolulu. Reduction in nonpoint source pollution for land-based and water-based transportation involves rather different approaches, each of which will be addressed in the following sections.

Reduction in nonpoint source pollution from land-based transportation involves reduction in pollution from the following:

- Pollution from construction of roadways and bridges (erosion, construction pollution);
- Pollution from discharges from vehicles (petroleum waste, exhaust waste, metals, paints, fibrous products of wear, and corrosion wastes); and
- Pollution from spills of fuel and goods and materials in transport.

Hawaii ordinances provide for effective control of pollution from spills of fuel and materials in transport. Freeman et al. (1994) report effective and nearly complete cooperation between officials of the state Dept. of Transportation and truckers regarding prevention of spills and management of the spills that do occur.

Pollution from construction of roadways and bridges in the State of Hawaii is addressed in ordinances that address the problem of erosion and runoff control from new development and construction projects. As noted previously, such measures are enforced strictly, with the result that erosion and construction site pollution are managed effectively.

Land-based transportation pollution arising from vehicular discharges involves urban streets and parking lots, freeways, interstate highways, and parking areas for automobiles, trucks, buses, and construction equipment. Land-based transportation nonpoint source pollution includes leaking underground storage tanks in the watershed.

As noted in numerous studies in Hawaii and throughout the US, nonpoint source pollution of rainfall runoff water with lead has declined substantially since the changeover to unleaded fuels. Such an effect is evidence that efforts to reduce pollutant discharge to roadway surfaces can be beneficial in the control of nonpoint source pollution.

The experience with lead shows that efforts aimed at reducing pollutant loss to roadway surfaces from mechanical wear, brake pad wear, and petroleum leakage can have a positive impact on pollutant loads in rainfall runoff from road surfaces. Programs in the State of Hawaii can focus on several MMs to accomplish this objective:

- Encourage development of non-polluting brake materials for automobiles;
- Educate automobile owners to maintain vehicles properly, minimizing wear of metal parts and leakage of petroleum products on roadways;
- Require frequent maintenance of public transportation vehicles to minimize wear of metal parts and leakage of petroleum products on roadways; and
- Promote the use of public mass transportation to minimize the numbers of private vehicles on roads.

Leaking underground storage tanks (LUSTs) pose a problem throughout metropolitan Honolulu and the rest of the State of Hawaii. The State of Hawaii has an active program aimed at underground tank testing and rehabilitation of tanks and soils where leaks occur. It is expected that the LUST program will result in a reduction in the amount of gasoline and other fuel products in groundwater and in groundwater discharges to Mamala Bay.

Reduction in pollution of Mamala Bay from nonpoint sources due to water-based transportation includes reduction of pollutant inputs from:

- Spills and discharges from marine fueling facilities;
- Fuel spills and discharges from vessels;
- Spills and discharges of cargoes with hazardous or toxic materials;
- Catastrophic spills and illicit discharges of toxic cargoes at sea;
- Illicit pumping of bilges and ballast tanks;
- Illicit discharges of marine heads;
- Leaching of toxicants from anti-fouling paints; and
- Input of toxic and potentially toxic chemicals from in-water hull maintenance and scraping.

The greatest potential impacts on Mamala Bay from water-based transportation activities are 1) catastrophic spills of cargoes in harbors or in the nearshore zone at sea, especially petroleum and petroleum products, 2) spills of petroleum cargoes or break-up of vessels and emptying of fuel bunkers, and 3) the leaching of toxicants from anti-fouling paints used on the hulls of small vessels in crowded anchorages with poor water circulation.

The State of Hawaii has enacted numerous control ordinances aimed at minimizing nonpoint source pollution from water-based transportation activities. As pointed out by Freeman et al. (1994), most of the legislated programs are under funded and/or understaffed; however, shoreline marine facility operators in the State of Hawaii have demonstrated a responsibility for controlling pollution of marine facilities due to dockside spills and discharges. Local yacht clubs and boating organizations have done much to educate operators and the public to the adverse effects of marine pollution discharges in port facilities. Such organizations should be encouraged to maintain their activities.

The most effective MMs that can be undertaken at the present time to reduce nonpoint source pollution due to water-based transportation are as follows:

- To establish and train a rapid-response team able to contain and/or neutralize the impact of catastrophic spills or discharges in harbors or at-sea;
- To encourage development of anti-fouling agents and paints for small vessels that have no substantial impact on nearby marine ecosystems; and
- To establish and maintain education programs that will inform the water-going public that discharges of harmful and potentially harmful substances in marine waters near anchorages, and in marine coastal waters, will result in a long-term, irretrievable loss of resources.

6.2.2.5 Source Reduction on Nonpoint Pollution - Agriculture

Nonpoint source pollution from agriculture includes soil erosion, discharge of nutrients to surface waters with rainfall runoff, discharge of pesticides to surface waters with rainfall runoff, discharge of pesticides to the atmosphere with spray-drift, and the potential contamination of the water table and ground water with nutrients and pesticide chemicals carried deep into the soil by deep irrigation.

The State of Hawaii and the US Soil Conservation Service have long recognized the potential adverse impacts of soil erosion from farmland on local streams and on coastal waters and ecosystems. There exist numerous programs and demonstration project throughout the State aimed at minimizing soil erosion from agricultural areas, and developing new and better techniques to prevent soil loss from open ground. Such techniques focus on physical structures and land grading to prevent erosion, and the use of irrigation techniques that do not contaminate groundwater with pesticides and nutrients. Given the high affinity of many pesticides for fine particulate matter, it is probably very true that the control of soil erosion in Hawaiian agricultural areas will have a positive effect, reducing the transport of pesticides from agricultural lands to Mamala Bay.

The same cannot be said for nutrients which, after application, are readily soluble, and can be transported from fields dissolved in either surface runoff or in groundwater. Heavy nutrient loading to the coastal zone in Mamala Bay has the potential to cause enrichment and, possibly, to contribute to eutrophication in coastal water. Because tropical marine waters are, typically, very low in nutrient concentrations, the discharge of rather small concentrations of nutrients to the coastal zone could have a potentially harmful impact.

6.2.2.6 Source Reduction of Nonpoint Pollution - Domestic Activities

The "domestic activities" refereed to in this section includes household maintenance (cleaning, painting, vermin control) lawn and garden maintenance (erosion control, fertilization, pest control, weed control - including residential parks, golf courses and greenbelts), *in situ* waste disposal systems (septic tanks and cesspools), and vehicle maintenance carried out in the home arena. Nonpoint source pollution problems from domestic sources includes:

- Improper use and disposal of solvents, paints and cleaning chemicals;
- Improper use and disposal of lawn and garden herbicides and insecticides;
- Improper use of vermin control chemicals;
- Over-use of fertilizers and vermin control chemicals; and
- Improper disposal of waste chemicals from automotive maintenance.

There are no structural measures that can be implemented to control the majority of nonpoint source pollution from household and garden use of chemicals. Erosion control structures can be applied to the control of nonpoint source pollution from the use of chemicals in parks, greenbelts and public land areas like golf courses.

Household, lawn and garden use of chemicals for pest control, weed control, and vermin control is almost invariably greater, on an area/use basis, than use of the same chemicals in industrial situations, or when the chemicals are being applied by licensed personnel. The major reasons for this over use are lack of education on the part of homeowners and private citizens regarding the proper use of the chemicals, and the absence of any significant financial gain to be got from application of the chemicals according to strict labeling limitations. As an example, a homeowner treating a lawn with a chemical such as diazinon, will often buy the chemical in quantities that are more than sufficient to treat the lawn, even according to labeling instructions. In application, the homeowner almost invariably over applies the chemical, in the mistaken belief that "more is better." Or, alternatively, if a relatively small amount of a chemical is left over from application, he or she will apply it, simply to get rid of it. In such cases the chemical is applied in excess of labeling instructions, and has a strong likelihood of being washed from the treated surface in rain, with the ultimate fate being transport to and contamination of surface waters. In cases where application is performed properly, the homeowner often has excess chemical remaining that must be stored and, at some point, disposed. In such instances it is not unusual for excess chemicals to be included in household garbage (for eventual transport to and deposition in a landfill), or to be poured into a storm drain, especially if the chemical is well-labeled as not for disposal in household waste for landfills.

Similar situations apply to the disposal of waste paint, paint solvents, cleaning solvents, varnishes, and finishes. Such pollutants are often disposed in household drains for eventual transport to and contamination of WWTPs. Equally likely is the disposal of such wastes in storm drains or on waste land, in which case the pollutants are eventually entrained with storm water runoff, transported to storm drains, and eventually deposited in surface waters and Mamala Bay.

The most important and effective MM for the control of nonpoint source pollution from households and gardens is public education. Education regarding nonpoint source control of pollutants can be done in the public schools, adult education classes, and extension classes. Education about the hazards of improper chemical use can be carried out in neighborhood and service club settings, through the media, as well as through effective labeling programs that not only spell out proper use and disposal of pollutant chemicals, but also present the labels in a manner in which they will be noticed easily. Such public education programs have enjoyed great success in other parts of the nation, and have been recommended in most communities as a means for effecting a substantial reduction in nonpoint source pollution in stormwater runoff from residential urban and suburban areas.

The State of Hawaii has an active public education program underway, making use of local public interest groups, schools, and organizations such as yacht clubs and service clubs to inform residents of the hazards posed by improper use and disposal of chemicals. While a substantial part of the public education activity is carried out on a volunteer basis, federal and state funds have been used for education programs in parts of the Mamala Bay watershed (Freeman et al., 1994).

7.0 Conclusions and Recommendations

7.1 Conclusions

Point source and nonpoint source discharges in the Mamala Bay watershed each year transports large masses of pollutants to Mamala Bay and adjacent enclosed and semi-enclosed waterbodies (Pearl Harbor, Kewalo Basin, Keehi Lagoon, and the Ala Wai Canal). Water quality in Mamala Bay would, in all likelihood, improve, if the masses of pollutants discharged to and transported throughout Mamala Bay and its ecosystem were reduced. The greatest direct discharge volumes to Mamala Bay arise from WWTP effluents. For most pollutant constituents, the greatest masses of pollutants come from nonpoint source discharges to the semi-enclosed waterbodies bordering the Bay.

The State of Hawaii has many programs in effect to reduce pollutants in nonpoint waste streams. These waste streams include nonpoint sources and activities such as:

- domestic use and disposal of pesticides and herbicides
- domestic use and disposal of paints, oils and other household chemicals
- industrial use and disposal of solvents, paints, and oils
- illegal discharge of industrial chemicals to storm drains
- agricultural use and disposal of pesticides, herbicides and fertilizers
- stormwater discharges from urban and suburban highways
- stormwater discharges from industrial properties
- stormwater discharges from agricultural properties
- oil spills in coastal waters
- waste disposal in coastal waters.

Despite the masses of pollutants discharged from point sources and nonpoint sources, the waters of Mamala Bay continue to support a productive and diverse flora and fauna. Damage to the reef and reef flat ecosystems in Mamala Bay that has occurred has come about more from habitat alteration (in-water construction and the dredging and building of islands) as from wastes disposed into the system. Public use of the beach resources on the shoreline of Mamala Bay do not appear to be threatened by point source and nonpoint source discharges. Nonetheless, the masses and types of pollutants discharged to the Bay, and their long-term impacts, if any, are not clearly defined by the knowledge that we have at the present time.

7.1 Recommendations

Specific recommendations have been made for improving the efficiency of suspended solids and BOD removal from the Honouliuli and Sand Island WWTPs. These include:

- Implementation of DAF and CEPT at the Sand Island WWTP;
- Implementation of CEPT at the Honouliuli WWTP.

A specific recommendation has been made to improve the bacteriological quality of water at the Sand Island and Honouliuli WWTPs, should it be found that indicator bacteria concentrations in Mamala Bay exceed acceptable limits:

- Implementation of UV disinfection of the Sand Island and Honouliuli WWTP effluents.

Specific recommendations exist for improving the water quality of the Ala Wai Canal (and the Ala Wai Canal discharge if it is determined that Ala Wai Canal water quality poses a threat to human health on the beaches, or if Ala Wai Canal water quality poses a threat to maintaining water quality in the nearshore zone of Mamala Bay). These include:

- Increased flushing of the canal with freshwater and/or saltwater flow, or
- The use of salt water barriers, or
- UV disinfection of the Manoa stream prior to entry into the Ala Wai Canal.

We specifically recommend investigation of the use of floating wetlands as the only method suggested that might improve Ala Wai Canal water quality while preserving the action of the Canal as a settling basin for TSS and pollutants entering from the drainage basin.. The problem of the Ala Wai Canal is complex; to recover beneficial uses by increased flushing would result in the increased discharge of suspended solids - and their associated pollutants -

into Mamala Bay. To optimize the use of the Ala Wai Canal as a detention basin would result in maintaining low water quality in the waterbody, which is already the site for fishing and recreational boating.

Specific recommendations are made to continue to reduce the mass of pollutants discharged to the Bay with nonpoint source waste water. These include implementation of existing legislation calling for waste minimization, pollution prevention, and nonpoint source pollution.

- Existing and successful programs on waste minimization, pollution prevention, and nonpoint source control in the State of Hawaii must be maintained at existing levels;
- Pollution prevention and waste minimization programs that are in place, and as yet undeveloped or unenforced must be enforced; i.e., programs must be funded at levels sufficient to support adequate staff and materials for rule promulgation, development of field presence, and enforcement;
- Nonpoint source programs that are in place and as yet undeveloped or unenforced must be enforced; i.e., existing programs must be funded at levels that are sufficient to support adequate staff and materials for rule promulgation, development of field presence, and enforcement.
- Additional government support is encouraged for the support of existing programs in public and industrial education on the principles of pollution prevention, source reduction and waste minimization.

7.3 Long-Term Monitoring Program

We recommend a long-term monitoring program to be carried out to gather data on living resources, habitats, and pollutant levels, such that future conditions can be compared with existing conditions, allowing regular evaluation of the ecological status of the Mamala Bay ecosystem. The objective of the monitoring program would be to measure trends in various indicators of ecosystem health (water quality, habitat integrity, population structure, ecosystem function, maintenance of marine resources) and to allow the custodians of the ecosystem to determine whether additional management and treatment alternatives for the control of pollution must be implemented.

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List of Tables

Table 1. List of pollutant chemicals for which the State of Hawaii, Department of Health, maintains freshwater or saltwater acute or chronic standards, or human health Standards. From Hawaii Department of Health, 1992.

Acenaphthene	DDT and metabolites	Hexachlorocyclohexane	Pentachlorophenol
Acrolein	Dichlorobenzene	Hexachlorocyclopenta-diene	2,4 dimethylphenol
Aldrin	Dichlorobenzidine	Hexachloroethane	Phthalate esters
Aluminum	Dichloroethane	Isophorone	PCBs
Antimony	Dichloroethylene	Lead	PAHs
Arsenic	Dichlorophenol	Lindane	Selenium
Benzene	Dichloropropane	Malathion	Silver
Benzidine	Dichloropropene	Mercury	Tetrachloroethanes
Beryllium	Dieldrin	Methoxychlor	Tetrachlorobenzene
Cadmium	Dinitro-o-cresol	Naphtalene	Tetrachloroethane
Carbon tetrachloride	Dinitrotoluene	Nickel	Tetrachloroethylene
Chlordane	Dioxins	Nitrobenzene	Tetrachlorophenol
Chlorine	Diphenylhydrazine	Nitrophenols	Thallium
Chloroethers	Endosulfan	Nitrosamines	Toluene
Chloroform	Endrin	Nitrosodibutylamine	Toxaphene
Chlorophenol	Ethylbenzene	Nitrosodiethylamine	Tributyltin
Chlorpyrofos	Fluoranthene	Nitrosodimethylamine	Trichloroethanes
Chromium	Guthion	Parathion	Trichloroethylene
Copper	Heptachlor	Pentachloroethanes	Trichloro phenol
Cyanide	Hexachlorobenzene	Pentachlorobenzene	Vinyl chloride
	Hexachlorobutadiene		Zinc

Table 2. Percentage of various pollutants entering Mamala Bay from four retention basins based upon proportion of the pollutant in the suspended fraction and percent solids retained in each basin. From Stevenson et al., (1995)

Pollutant	Percent Suspended	Ala Wai Canal (50% Retained)	Pearl Harbor (95% Retention)	Kewalo Basin (95% Retention)	Keehi Lagoon (95% Retention
BOD	0	100	100	100	100
COD	0	100	100	100	100
TSS	100	50	5	5	5
TDS	0	100	100	100	100
TP	40	80	62	62	62
DP	0	100	100	100	100
TKN	20	90	81	81	81
NO_2/NO_3	50	75	52	52	52
Pb	90	15	10	10	10
Cu	60	70	43	43	43
Zn	40	80	62	62	62
Cd	70	65	34	34	34

BOD = Biochemical Oxygen Demand; COD = Chemical Oxygen Demand; TSS = Total Suspended Solids; TDS = Total Dissolved Solids; TP = Total Phosphorus; DP = Dissolved Phosphorus; TKN = Total Kjeldahl Nitrogen.

Table 3. Annual average load estimates for nutrients and trace metals discharged to Mamala Bay and adjacent waters from point source discharges. Loading data given as metric tons per year for nutrients, and kg per year for the metals. From data in Stevenson et al. (1995)

Water Body Receiving Point Source Discharge	**Flow $m^3 \times 10^6$**	**NH_4-N (Tonnes)**	**Total N (Tonnes)**	**Total P (Tonnes)**	**Cd (kg)**	**Cu (kg)**	**Pb (kg)**	**Zn (kg)**
Ala Wai Canal	3.59							
Kewalo Basin	0					0.082	9.1	
Keehi Lagoon	1.04							
Pearl Harbor	4.14	0.24				1.2		
Coastal Mamala Bay	0.09							
Sand Island WWTP	99.4	1,923	1,951	345	272	1,633	4,173	5,897
Honouliuli WWTP	33.2	613	799	122	84.4	998	6,169	2,540
Ft. Kam WWTP	9.53	16.3	109	16.3	36.3	163	263	998
Totals	**151**	**2,553**	**2,859**	**483**	**393**	**2,795**	**10,614**	**9,435**

Table 4. Annual average load estimates for suspended solids, BOD, COD and Oil and Grease discharged to Mamala Bay and adjacent waters from point source discharges. From Stevenson et al. (1995).

Water Body Receiving Point Source Discharge	Flow $m^3 \times 10^6$	TSS (Tonnes/yr)	BOD (Tonnes/yr)	COD (Tonnes/yr)	Oil and Grease (Tonnes/yr)
Ala Wai Canal	3.59	10			9.1
Kewalo Basin	0				
Keehi Lagoon	1.04	3			1.4
Pearl Harbor	4.14	1.1	17.2		0.044
Coastal Mamala Bay	0.09	1.4	6.9		
Sand Island WWTP	99.4	5,567	10,026	26,127	2,649
Honouliuli WWTP	33.2	1,812	4,014	41,550	1,050
Ft. Kam WWTP	9.53	190	75.3		34.5
Totals	**151**	**7,584**	**14,139**	**67,677**	**3,744**

Table 5. Annual average load estimates for microbiological pollutants discharged to Mamala Bay from point source discharges. All microbiological data presented as CFU (Colony forming units) X 10^{15}. Data from Stevenson et al. (1995)

Water Body Receiving Point Source Discharge	Flow ($m^3 \times 10^6$)	*Clostridium perfringens*	*Eschericia coli*	Enterococci	Fecal coliforms
Ala Wai Canal	3.59				
Kewalo Basin	0				
Keehi Lagoon	1.04				
Pearl Harbor	4.14				
Coastal Mamala Bay	0.09				0.00003
Sand Island WWTP	99.4	29	30,675	476	17,205
Honouliuli WWTP	33.2	13	8,533	131	5,074
Ft. Kam WWTP	9.53			0.00037	
Totals	**151**	**42**	**39,208**	**607**	**22,280**

Table 6. Annual average load estimates for conventional pollutants and microbiological pollutants discharged to Mamala Bay and adjacent waters from nonpoint source discharges. All loading data for TSS, BOD, COD and Oil and Grease given as metric tons (Tonnes) per year. Loading data for microbiological pollutants given as CFU X 10^{15} per year. See Stevenson et al. (1995) for description of drainage basins for each waterbody.

Water Body Receiving Nonpoint Source Discharge	**Flow ($m^3 \times 10^6$)**	**TSS**	**BOD**	**COD**	***Clostridium perfringens***	**Enterococci**	**Fecal Coliform**
Ala Wai Canal	20.8	9,389	232	1,438	0.052	3.9	3.2
Kewalo Basin	4.6	576	39.9	232	0.016	1.2	0.9
Keehi Lagoon	62.4	19,777	518	3,195	0.13	9.6	7.9
Pearl Harbor (E. Loch)	47.3	20,593	366	2,193	0.043	3.2	23.9
Pearl Harbor (M. Loch)	45.6	20,639	351	2,105	0.031	2.3	2.2
Pearl Harbor (W. Loch)	100.3	27,443	746	4,125	0.13	10	8.5
Ewa Plain	5.5	2,694	78.9	406	0.0098	0.73	0.66

Table 7. Annual average load estimates for nutrients and trace metals discharged to Mamala Bay and adjacent waters from nonpoint source discharges. Nutrient loading data given as metric tonnes (T)per year. Metal loading given as kg per year. From data in Stevenson et al. (1995)

Water Body Receiving Nonpoint Source Discharge	Flow ($m^3 \times 10^6$)	Nitrate/ Nitrite (T)	Total N (T)	Total P (T)	Cd (kg)	Cu (kg)	Pb (kg)	Zn (kg)
Ala Wai Canal	20.8	19	61	7.8	2.18	590	218	2,449
Kewalo Basin	4.6	2.6	8	0.99	0.73	136	72	1,179
Keehi Lagoon	62.4	41	125	15	56.3	1,361	562	7,802
Pearl Harbor (E. Loch)	47.3	40	101	11	18.1	671	181	2,540
Pearl Harbor (M. Loch)	45.6	39	113	13	12.7	508	127	1,996
Pearl Harbor (W. Loch)	100.3	118	303	34	58.1	1,270	572	8,981
Ewa Plain	5.5	9.1	29	3.4	4.54	82	40	526

Table 8. Summary of removal efficiencies for BOD and TSS at the Sand Island WWTP for DAF *vs* conventional gravity settling. From Harleman et al. (1995).

	GMP/Carpenter Study		MB-11 Performance Analysis
	Conventional Settling (1/94-5/94)	**DAF (4/93-7/93)**	**Conventional Settling (3/92-3/93)**
BOD Removal	27	36	36
TSS Removal	73	63	69

Table 9. BOD and TSS removal efficiencies and calculated BOD and TSS loading at the Honouliuli WWTP under conventional treatment and CEPT. NPDES requirements for removal and loading under Section 301(h) waiver conditions are presented for comparison.

	BOD % Removal	BOD Monthly Loading (kg/day)	TSS % Removal	TSS Monthly Loading (kg/day
NPDES Requirements	30% (301[h])	15,200	--	9,000
Conventional Primary Treatment	30	15,100	73	5,500
CEPT Tests	40	16,300	80	6,200

APPENDIX

TABLES A1 THROUGH A5
LOCATION AND NATURE OF EXISTING PERMITTED INDUSTRIAL DISCHARGERS

MAMALA BAY AND CONTIGUOUS WATERS

Table A.1 Location and nature of existing (as of 12/93) permitted industrial dischargers direct to Mamala Bay

Discharger (NPDES Permit Number)	Latitude	Longitude	Type of Discharge	Receiving Water
AES Barbers Point Inc 91-086 Kaomi Loop Ewa Beach, HI 96707 (HI 0021130)	001 21 °18' 16" 002 21 °17' 56"	 158 °06'38" 158 °06'22"	 Overflow from settling basins Coal or limestone pile runoff	 Pacific Ocean
DLNR Demonstration Desal Plant (HI 0021148)	001 21 °19' 45"	 158 °05'30"	 Brine from desalinization process	 Unnamed ditch to Pacific Ocean/groundwater recharge
Hawaii Milling Corporation Hawaii Meat Company Feedlot Campbell Industrial park (HI 0020656)	21 °18 "30'	158 °06"00'	Stormwater runoff (greater than 8 inches in 24 hours)	Pacific Ocean
Waikiki Aquarium University of Hawaii (HI 0020630)	21 ° 16" 17'	156 ° 49" 31'	Overflow water from aquatic animal exhibits through an outfall	Pacific Ocean

Table A.2 Location and nature of existing (as of 2/13/93) permitted industrial dischargers to Keehi Lagoon

Discharger (NPDES Permit Number)	Latitude	Longitude	Type of Discharge	Receiving Water
AMERON HC&D, Ltd. 811 Middle Street Honolulu, HI 96820 (HI 0021075)	21 °19'30"	157 °53'40"	Treated process water, storm water runoff, and conveyer belt tunnel seepage	Keehi Lagoon
Hawaii Fueling Facilities 3181 and 3201 Aolele Street Honolulu, HI (HI 0020354)	21 °20"08'	157 °55"00'	Stormwater runoff from an aviation turbine fuel storage facility	Keehi Lagoon
Keehi Marine Inc. 24 Sand Island Access Rd. Honolulu, HI (HI 0020664)	21 °19"08'	157 °53"50'	Wash water from a marine railway facility	Keehi Lagoon

Table A.3 Location and nature of existing (as of 2/13/93) permitted industrial dischargers to Honolulu Harbor

Discharger (NPDES Permit Number)	Latitude	Longitude	Type of Discharge	Receiving Water
Chevron USA Inc. Honolulu Distribution Center 933 North Nimitz Highway Honolulu, HI (HI 0020923)	21 °19'01"	157 °52'37"	Stormwater runoff from discharge recovery pad Loading rack washdown Fire hydrant test water	Honolulu Harbor
Chevron USA Inc. Honolulu MarineTerminal 777 North Nimitz Highway Honolulu, HI (HI 0020931)	21 °18'49"	157 °52'39"	Tank water draws, loading rack/pier wash down, fire hydrant test water and storm water runoff from fuel storage facility	Honolulu Harbor
Chevron USA Inc. Kapalama Terminal (HI 0020940)	001 21 °19'21" 002 21 °19'21"	 157 °52'43" 157 °52'46"	Tank water draws, yard storm water runoff and fire hydrant testing waters	Honolulu Harbor
Hawaiian Electric Company Honolulu Generating Station (HI 0000027)	21 °18 "33'	157 °52"01'	Cooling water 70 mgd (002) Low volume waste 0.06 mgd (002/003) Metal Cleaning Wastes 0.065 mgd (002/003)	Honolulu Harbor
Hawaiian Cement Pier 34 Distribution Center (HI 0021083)	21 °19 "04'	157 °52"42'	Stormwater runoff from a cement receiving, storage and distribution facility (001 and 002)	Honolulu Harbor (via ditch)

Table A.3 Location and nature of existing (as of 2/13/93) permitted industrial dischargers to Honolulu Harbor

Discharger (NPDES Permit Number)	Latitude	Longitude	Type of Discharge	Receiving Water
Honolulu Shipyard	001			
	21 °19 "20'	157 °53"07'	Harbor water flowing off docks after lifting/lowering	Honolulu Harbor
Pier 41	002			
(HI 0020753)	21 °19 "13'	157 °53"09'	Marine Railway	
	003			
	21 °19 "10'	157 °53"10'	Kekaulana Floating Drydock	
Pacific Resources Terminals 739 North Nimitz Highway Honolulu HI 96817 (HI 0000663)	21 ° 18" 50'	157 ° 52" 30'	Stormwater runoff from petroleum bulk station and terminal	Honolulu Harbor
Shell Oil Company - Marketing Dist. Plant 789 North Nimitz Highway Honolulu Plant (HI 0000582)	21 ° 19" 00'	157 ° 52" 30'	Stormwater runoff for plant	Honolulu Harbor
Shell Oil Company (Mike's Vineyard Shell) 225 South Vineyard Boulevard Nov 91 Permit (HI 0021211)	21 ° 19" 06'	157 ° 52" 20'	Treated petroleum-contaminated ground water	Nuuanu Stream

Table A.4 Location and nature of existing (as of 2/13/93) permitted industrial dischargers to Pearl Harbor

Discharger (NPDES Permit Number)	Latitude	Longitude	Type of Discharge	Receiving Water
California & Hawaiian Sugar Company Aiea Refinery Aiea, HI 96701 (HI 0000281)	(Position estimated)		Sugar refinery process water	Aiea Stream tributary to Pearl Harbor (East Loch)
Hawaiian Electric Company Waiau Generating Station 559 Kamehameha Highway Pearl City, HI (HI 0000604)	21 °23 "30'	157 °57"56'	Cooling water 133 mgd (002) 162 mgd (003) 217 mgd (004) Low volume waste 0.350 mgd (003) 0.350 mgd (004) Metal cleaning waste 0.200 mgd (003) 0.200 mgd (004)	Pearl Harbor (East Loch)
Hawaiian Cement Halawa Batch Plant (HI 0000558)	21 °22 "44'	157 °54"44'	Treated process water (001)	Halawa Stream
Oahu Sugar Company Limited Waipio Peninsula Field Facilities (HI 0020699)	21 ° 21"55'	157 ° 59 "30'	Excess irrigation water for the purpose of mosquito control	Pearl Harbor (West Loch)
Navy Public Works Center Building No. 826 Navy Public Works Center Pearl Harbor, HI (HI 1120907)	21 ° 21" 12'	157 ° 56" 47'	Cooling water from the air compressor facility	Pearl Harbor

Table A.4 Location and nature of existing (as of 2/13/93) permitted industrial dischargers to Pearl Harbor

Discharger (NPDES Permit Number)	Latitude	Longitude	Type of Discharge	Receiving Water
Pearl City Fuel Annex Naval Supply Center (HI 0000647)	001 21 ° 23" 16'	157 ° 58" 38'	Stormwater runoff and tank draw down water	Kaiapo Canal to Pearl Harbor
	002 21 ° 23" 12'	157 ° 58" 37'		
Pearl Harbor Naval Shipyard U.S. Naval Base Pearl Harbor (HI 0110230)	001 21 ° 21" 15'	157 ° 57" 30'	Wet sandblasting water, hydroblasting water, cooling water, drydock seepage water and stormwater from Drydocks 1-4	Pearl Harbor
	002 21 ° 21" 00'	157 ° 57" 30'		
	003 21 ° 20" 45'	157 ° 58" 00'		
	004 21 ° 20" 45'	157 ° 58" 00'		
U.S. Navy Submarine Base Floating Drydock AFDM-6 (HI 1121032)	21 ° 21" 37'	157 ° 56" 51'	Discharge from floating drydock outfall 001 and cooling water from air compressors (002 and 005) and emergency generators (007 and 008)	Pearl Harbor
Navy Public Works Center Pearl Harbor, Hawaii Building no. 177 (HI 1121105)	21 ° 21" 05'	157 ° 58" 11'	Discharge noncontact cooling water from the air compressor facility at Building No. 177	Pearl Harbor

Table A.4 Location and nature of existing (as of 2/13/93) permitted industrial dischargers to Pearl Harbor

Discharger (NPDES Permit Number)	Latitude	Longitude	Type of Discharge	Receiving Water
Pearl Harbor, Naval Shipyard Dockside Chlorinator Units (HI 1121172)	no precise location		Discharge chlorinated, once-through, non-contact, cooling water from its vessel berthed in Drydock Nos. 1,2,3&4 and at piers B1-B21	Pearl Harbor
Pearl Harbor, Naval Submarine Base Dockside Chlorinators (HI 1121181)	no precise location		Discharge chlorinated, non-contact, cooling water from vessels berthed at the piers, from S1 to S21	Pearl Harbor

Table A.5 Location and nature of existing (as of 2/13/93) permitted industrial dischargers to the Ala Wai Canal

Discharger (NPDES Permit Number)	Latitude	Longitude	Type of Discharge	Receiving Water
Super Hawaii Ala Wai Marine, Ltd. 1651 Ala Moana Blvd. Honolulu, HI 96815 (HI 0020711)	21 °17'26"	157 °50'37"	Wash water from marine railway facility	Ala Wai Canal
Yacht Harbor Towers 1600 Ala Moana Honolulu, HI 96815 (HI 0020346)	21 °17 "37'	157 °50"48'	Air conditioning cooling water	Ala Wai Canal