APPENDIX I

HONOLULU MBR FEASIBILITY STUDY

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EXECUTIVE SUMMARY

A study was conducted to examine possible applications of membrane bioreactors (MBRs) for decentralized production of recycled water on the island of Oahu. The objectives of this study were to identify potential reuse and treatment facility sites and to develop costs to build and operate these facilities. This work is a follow-up to MBR pilot testing conducted at the Honouliuli Wastewater Treatment Plant from 2003 to 2006.

More than 90% of Oahu's current water supply is naturally filtered underground fresh water that floats on seawater and is held in place by relatively impermeable sediment called caprock. These aquifer systems are susceptible to seawater intrusion when drafted at a rate greater than the recharge rate. With the water demand on the island growing along with the population, its aquifer systems are in danger of exceeding sustainable yield. The use of MBRs to produce R-1 recycled water from wastewater was proposed to alleviate the strain on Oahu's aquifer systems and reduce the volume of wastewater to be conveyed, treated, and discharged into the ocean from Oahu's centralized treatment facilities. Decentralized or satellite MBR facilities were recommended due to site constraints at most of the island's centralized treatment facilities and to reduce the amount of distribution piping for the recycled water.

A list of the top 100 water users on Oahu was obtained from the Honolulu Board of Water Supply (BWS)'s record of service holders for 2005. The list was narrowed by removing service holders that failed to meet all of the following criteria:

1. The user has a nonpotable water demand.
2. The user's nonpotable water demand is greater than 0.1 million gallon per day (MGD), or the user is near another user or other users with a cumulative nonpotable demand greater than 0.1 MGD.
3. The user is not currently receiving or anticipating recycled water service from other water recycling facilities (WRF).
4. The user is within a mile of a significant wastewater source.

Ten sites were preliminarily identified from the potential top 100 water users list as potential locations for MBR WRF:

- Central Oahu Regional Park
- Public Baths Wastewater Pump Station
- Sand Island Wastewater Treatment Plant
- Moana Park Wastewater Pump Station
- Kailua Beach Park
- Kamehameha Highway Wastewater Pump Station
- Fort DeRussy Wastewater Pump Station
- University of Hawaii at Manoa

Cost estimates were developed for 0.1-, 0.25-, 0.5-, and 1.0-MGD installations to help bracket anticipated flow rates. These estimates include capital and operational costs for the MBR process and UV disinfection. For the decentralized systems, the facilities are strategically located near the wastewater source and the sludge is returned to the sewer. Therefore, cost for conveyance piping and sludge disposal are not included. Also, a storage tank is assumed to be provided by the user, and storage is not considered in the costs. A summary of the costs for an MBR facility is presented in Table ES-1.

Table ES.1. Summary of costs

Items	Installation capacity (in MGD)			
	0.1	**0.25**	**0.5**	**1.0**
Capital costs [a]				
Preliminary treatment	$194	$389	$518	$751
MBR system	$406–$688	$713–$1000	$1251–$1281	$1625–$2288
Process tanks/structures	$655	$1064	$1389	$2181
UV system	$156	$214	$214	$281
Pumping system	$20	$35	$50	$75
Subtotal	$1431–$1713	$2415–$2702	$3422–$3452	$4913–$5576
Electrical/instrumental (15%)	$215–$257	$362–$405	$513–$518	$737–$836
Mechanical (10%)	$143–$171	$242–$270	$342–$345	$491–$558
Site work (15%)	$215–$257	362–$405	$513–$518	$737–$836
Subtotal	$2004–$2398	$3381–$3783	$4790–$4833	$6878–$7806
Contractor OH&P [b] (15%)	$301–$360	$507–$567	$719–$725	$1032–$1171
Contingency (25%)	$501–$600	$845–$946	$1198–$1208	$1720–$1952
Total capital cost	$2804–$3357	$4733–$5296	$6707–$6766	$9630–$10,029
Annualized capital cost [c]	$204–$244	$344–$385	$487–$492	$700–$794
O&M costs [a]				
Energy	$17–$31	$37–$43	$74–$84	$141–$168
Chemicals	$0.20	$0.30	$0.70	$1.40
Manpower	$23	$23	$45	$45
Membrane replacement [d]	$8–$12	$14–$21	$28–$42	$111–$166
UV equipment replacement	$10	$25	$50	$100
Total O&M cost	$58–$76	$99–$112	$198–$222	$398–$480
Annualized cost	$262–$320	$443–$497	$685–$714	$1098–$1274

[a] All capital and operation and maintenance (O&M) costs are in thousands of dollars based on ENR Construction Cost Index value of 8092.
[b] OH&P is overhead and profit.
[c] Capital costs are amortized on a 6%, 30-year basis.
[d] Membrane replacement based on an 8-year life

CHAPTER 1

INTRODUCTION

Membrane bioreactors or MBRs are a relatively new wastewater treatment technology that has become commercially viable in the past 10 years. MBRs combine multiple unit processes from traditional wastewater treatment into a single process. This approach reduces the overall footprint of the treatment facility and produces a higher-quality effluent than do traditional approaches. These advantages are the primary reasons for the rise in popularity of this technology.

A comparison of a traditional tertiary treatment facility and an MBR treatment facility is presented schematically in Figure 1.1.

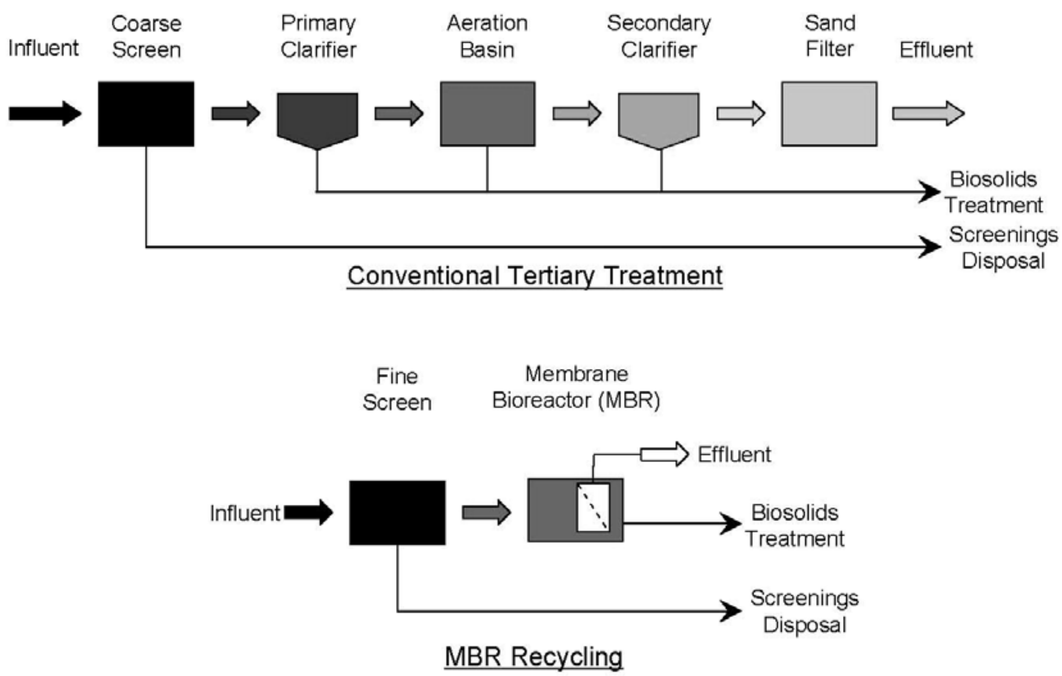


Figure 1.1. Comparison of traditional tertiary treatment and MBR treatment.

The MBR process essentially replaces the primary clarifier, secondary aeration basin, secondary clarifier, and sand filtration with the MBR tank. In addition, MBR systems are operated at significantly higher mixed liquor concentrations—typically 5 to 10 times higher. This practice results in a smaller aeration tank. Fine screens (with perforated openings typically ranging from 0.5 to 3 mm) are used in place of traditional bar screens (with bars typically spaced from 15 to 75 mm apart) for MBR applications. This increase in screening requirements is necessary to safeguard the membranes, which are the most expensive part of the MBR system, from damage.

The first municipal MBR unit was installed in 1995, and today there are over 220 units installed in the United States (over 2200 worldwide). The bulk of these units are 1 million gallons per day (MGD) or less in capacity. The largest MBR facility currently operating in the United States has a capacity of 9 MGD.

1.1 HONOLULU MBR PILOT STUDY

Dr. Roger Babcock of the University of Hawaii, supported by Kennedy/Jenks Consultants, Engineering Solutions, and Aqua Engineers, initiated a study with the City and County of Honolulu (CCH)'s Department of Environmental Services and the Honolulu BWS (Board of Water Supply) to pilot test several MBR units in 2002. The goal of the project was to demonstrate the viability of MBR as a treatment train in Hawaii and to offer the opportunity for the local engineering community to gain firsthand experience in operating these systems. Testing was performed on three waste streams at the Honouliuli wastewater treatment plant (WWTP) in Ewa Beach, HI—influent wastewater; primary effluent; and a high-strength, highly colored centrate recycling flow.

MBR units from Enviroquip, Huber, Ionics, US Filter–Jet Tech, and Zenon were tested. Each of the MBR units performed satisfactorily on the influent and primary effluent streams and was capable of producing R-1 quality recycled water with the inclusion of suitable disinfection (which was not studied as part of this project). Biochemical oxygen demand levels (BOD_5) and total-suspended-solid levels (TSS) of the effluent were both generally less than 2 mg/L, and turbidity was less than 0.15 NTU.

The MBR units did not perform as well on the centrate recycling flow, due primarily to the higher organic loads in this waste stream. The pilot units were not designed with adequate oxygen transfer capacity to deal with this high-strength waste stream (BOD_5 ranging from 3200 to 4250 mg/L; TSS ranging from 1250 to 3740 mg/L, and color ranging from 2240 to 4100 color units). As a result, the influent flows were diluted 10:1, while secondary effluent and flux rates were reduced by 50% in order to facilitate treatment and testing. In spite of the dilution, the centrate waste proved difficult on the membranes themselves and the ancillary equipment (pumps and seals). BOD_5 and TSS were both generally reduced to less than 4 mg/L, but the MBR units were unable to reduce the color of the waste stream to an acceptable level. The color was attributed to recalcitrant organic matter consisting of either dissolved substances and/or a very fine suspension of colloidal matter. The pilot units were judged as marginal on this waste stream, but it is possible that a full-scale system could be designed to overcome some of the difficulties, in particular the lack of sufficient process air.

1.2 OAHU MBR FEASIBILITY STUDY

Following the start of the project, the WateReuse Foundation was approached regarding the availability of grant monies to expand the project scope. A collaborative proposal was submitted on behalf of the project and was accepted. In addition to the goal of finishing the piloting effort, a feasibility study was added that would determine where satellite reclamation might be feasible on Oahu. Cost information will also be presented to help agencies estimate capital and operational costs. This report summarizes the findings of this effort.

1.3 ACKNOWLEDGMENTS

The Honolulu MBR Pilot and Feasibility Study owes its success to a number of individuals and organizations. The following alphabetical listing attempts to acknowledge all of the work that these individuals have contributed to the project.

- CCH, Department of Environmental Services
    - Nic Musico
    - Pat Roberts
    - Ross Tanimoto
- CCH, BWS
    - Barry Usagawa
    - Erwin Kawata
- WateReuse Foundation, Project Advisory Committee
    - Dr. Samer Adham, MWH Americas, Inc.
    - Dr. Jörg Drewes, Colorado School of Mines
    - Robert Jurenka, U.S. Bureau of Reclamation
    - Dr. David Stensel, University of Washington

The MBR manufacturers are also recognized for participating in the pilot study (at no cost to the project) and for sharing the cost information used in this feasibility study.

- Dennis Livingston, Enviroquip
- Susan Pilgram, US Filter
- Christian Roedlich, Huber Technology, Inc.
- Paul Schuler, Zenon Environmental
- Michael Sparks, Ionics

Special thanks are also extended to Dr. Westley Chun, who helped originate the project, and Elmer “Bud” Reiter, who helped operate the pilot units during the early stages of the project.

CHAPTER 2

PROJECT DRIVERS

2.1 WATER SUPPLY AND DEMAND

2.1.1 Summary of Current Water Supply Resources

More than 90% of Oahu's potable water comes from basal water bodies that underlie Oahu's coastal plain. This fresh body of water floats on seawater due to the differences in density, and an intermediate transition zone of brackish water exists between the freshwater lens and seawater. Seaward flow of the fresh water is restricted by relatively impermeable sediment, called caprock, that extends out and down from the island shorelines. The thickness of the freshwater lens, which can range from a few feet to several hundred feet, depends on the degree of impermeability of the caprock barrier. Recharge of the basal lens comes from rainfall that percolates through the island's rock and soil. Steady trade winds drive evaporated moisture from the ocean up against the Ko'olau Mountains, where it cools, condenses, and falls as rain. The rain infiltrates the porous volcanic rock until it reaches the basal aquifer, and the water is naturally purified in the process. The water from the basal lens is pristine, requiring almost no treatment. There is a significant amount of water stored in this basal lens, permitting drafting rates that exceed the sustainable yield during periods of high demand and low recharge, as long as there is recharge during other periods. Drafting indefinitely beyond the sustainable yield, however, can have detrimental effects on this precious resource.

Trapped rainfall in watertight dikes in the mountain serves as another water source for the island. The dikes consist of nearly vertical slabs of dense, massive rock that are generally a few feet thick and extend for considerable distances. They are formed from molten lava that has cooled and solidified into conduits beneath the surface. Water from the dikes is of excellent quality as it is filtered by volcanic rock and is not subject to salt water intrusion. Dike water can be tapped by water development tunnels and supplies most of the water for eastern Oahu and smaller amounts elsewhere on the island.

Other minor sources of water include perched water that sits on layers of impermeable material and can be developed by tunnels or collected around spring openings and stream flow that can be diverted for irrigation. Brackish water from caprock, basal springs, and the transition zone of the basal lens can be used, but it requires blending and/or demineralization to reduce chloride concentrations to tolerable levels.

The management of Oahu water supplies is crucial for ensuring sustainable use of Oahu's valuable and finite water resources. The BWS of the CCH is in the progress of developing watershed management plans for the eight Oahu watersheds to provide guidance for short-, mid-, and long-range planning and sustainable management of the island's water supplies. The public review draft of the Waianae Watershed Management Plan is the first of the eight documents to be released and includes an overview of Oahu's Water Management Plan. The overview provides current data on sustainable yield, permitted water use, and existing water use for each of the island's aquifer systems. These values are listed in Table 2.1. The sustainable yield reflects the withdrawal rate of groundwater that can be sustained indefinitely without affecting the quality of the pumped water or the pumping flow rate and is estimated for each aquifer based on a simple water balance equation.

Table 2.1. Sustainable yield and permitted and existing groundwater use in MGD by aquifer system[a]

Sector	Aquifer system	Sustainable yield (SY)	Permitted water use	Unallocated SY	Existing water use (July 2005)	SY minus pumpage
Honolulu	Waialae-E	2	0.790	1.210	0.193	1.807
	Waialae-W	4	2.797	1.203	0.385	3.615
	Palolo	5	5.646	−0.646	4.431	0.569
	Nuuanu	15	15.271	−0.271	13.351	1.649
	Kalihi	9	8.761	0.239	8.416	0.584
	Moanalua	18	19.96	−1.960	17.340	0.660
Pearl Harbor	Waimalu	45	46.951	−1.951	39.011	5.989
	Waipahu-Waiawa	104	83.892	20.108	53.354	50.646
	Ewa-Kunia	16	15.457	0.543	11.092	4.929
	Makaiwa	0	0.000	0.000	0.000	0.000
Central	Wahiawa	23	20.386	2.614	9.246	13.755
Waianae	Nanakuli	1	0.000	1.000	0.000	1.000
	Lualualei	3	0.000	3.000	0.112	2.736
	Waianae	3	0.000	3.000	2.515	0.485
	Makaha	4	0.000	4.000	0.943	2.233
	Keaau	4	0.000	4.000	0.000	4.000
North	Mokuleia	12	8.301	3.699	0.401	11.697
	Wailua	40	30.311	9.689	3.106	36.980
	Kawailoa	39	1.549	37.451	0.682	38.318
Windward	Koolauloa	35	21.508	13.492	9.738	26.336
	Kahana	13	1.101	11.899	0.085	12.915
	Koolaupoko	43	10.312	32.688	12.828	30.172
	Waimanalo	8	1.656	6.344	0.720	7.371
Total		**446**	**294.650**	**151.352**	**187.948**	**258.446**
Ewa Caprock[b]	Malakole	—	5.928	—	4.628	
	Kapolei	—	2.033	—	0.471	
	Puuloa	—	14.817	—	1.826	

[a]Water use is based on reported pumpage. Allocation and water use exclude saltwater and caprock sources, except the Ewa Caprock Aquifer Sector Area.
[b]Brackish water (from Ewa Caprock) is managed by a chloride limit of 1000 mg/L.

Water use does not currently exceed the sustainable yield for all aquifers. However, the reported pumpage is nearing the sustainable yield in some areas, particularly in the Honolulu and Waianae sectors.

2.1.2 Current and Projected Water Demands

Census and population forecasts from 2000 to 2030 by land use districts are included in the Oahu Water Management Plan Overview and listed in Tables 2.2 and 2.3. The data and forecast are provided by the city's Department of Planning and Permitting (DPP). DPP estimates that the population will increase from 870,000 to about 1.1 million residents from 2000 to 2030. The projected water demands for 2030 were estimated based on the population forecast.

Table 2.2. Population and water demand in 2000 by land use district

Area	Resident population	Population served	Per capita demand	Demand (MGD)
Waianae	42,259	41,371	223.79	9.34
Ewa	68,696	61,660	223.58	15.3
East Honolulu	46,735	45,702	221.3	10.11
PUC[a]	419,422	447,114	170.98	76.45
Central Oahu	148,208	124,455	155.96	19.41
Ko'olaupoko	117,910	113,256	175.14	19.84
Ko'olauloa	14,546	10,409	142.47	1.48
North Shore	18,380	14,438	194.97	2.82
Total	876,156	858,766		154.75

[a]Public Urban Center.

Table 2.3. Forecasted population and water demand in 2030 by land use district

Area	Resident population	Population served	Per capita demand	Demand (MGD)
Waianae	50,616	52,211	223.79	11.68
Ewa	184,612	190,099	223.58	42.5
East Honolulu	51,059	51,150	221.3	11.32
PUC	489,389	526,579	170.98	90.04
Central Oahu	189,599	165,651	155.96	25.83
Ko'olaupoko	115,357	112,048	175.14	19.62
Ko'olauloa	16,725	14,369	142.47	2.05
North Shore	19,945	17,174	194.97	3.35
Total	1,117,302	1,129,280		206.40

Absent residents, visitors, and those receiving private or military water service are accounted for in the difference between the resident population and population served. The assumption was made that the per capita demand remains unchanged from 2000 to 2030, and the municipal water demand was estimated by multiplying the population served by the per capita demand in 2000. The municipal water demand is expected to increase from 154.7 MGD in 2000 to over 206 MGD in 2030. The increase in demand of over 50 MGD will occur primarily in Ewa, the Primary Urban Center (PUC), Central Oahu, Waianae, and East Honolulu. Some of these districts overlap with areas where pumpage is nearing sustainable yield. Alternative water resources must be developed to avoid impairment of these aquifer systems. Recycled water production using MBRs provides an alternative nonpotable water supply that can help alleviate strain on Oahu's aquifers.

2.1.3 Current Water Recycling Efforts

There are a number of public and private water reclamation facilities (WRFs) on Oahu (see Figure 2.1). The largest of these facilities is the Honouliuli WRF in Ewa Beach, which currently has the capacity to produce 12 million gallons of recycled water per day. The significant growth of the Ewa district in the last decade, via residential, commercial, and industrial development, has severely impacted the region's available water resources. The Honouliuli WRF was constructed in response to the strain of the Ewa caprock aquifer from increased water demands and from reduced groundwater recharge accompanying a reduction in agricultural activity. The facility is located next to the CCH's Honouliuli WWTP and is operated by US Filter under contract to BWS.

In 1995, an agreement with the U.S. Environmental Protection Agency (EPA), known as the 309 Consent Decree, required the city to develop an effluent reuse system to recycle 10 MGD of water by July 2001. The Honouliuli WWTP was selected for the implementation of the 309 Consent Decree because of its proximity to potential users and the beneficial effect of reducing the strain on the Ewa caprock aquifer. Construction of the tertiary and advanced treatment facility was completed in the summer of 2000. The Honolulu BWS subsequently purchased the facility from US Filter Operating Services.

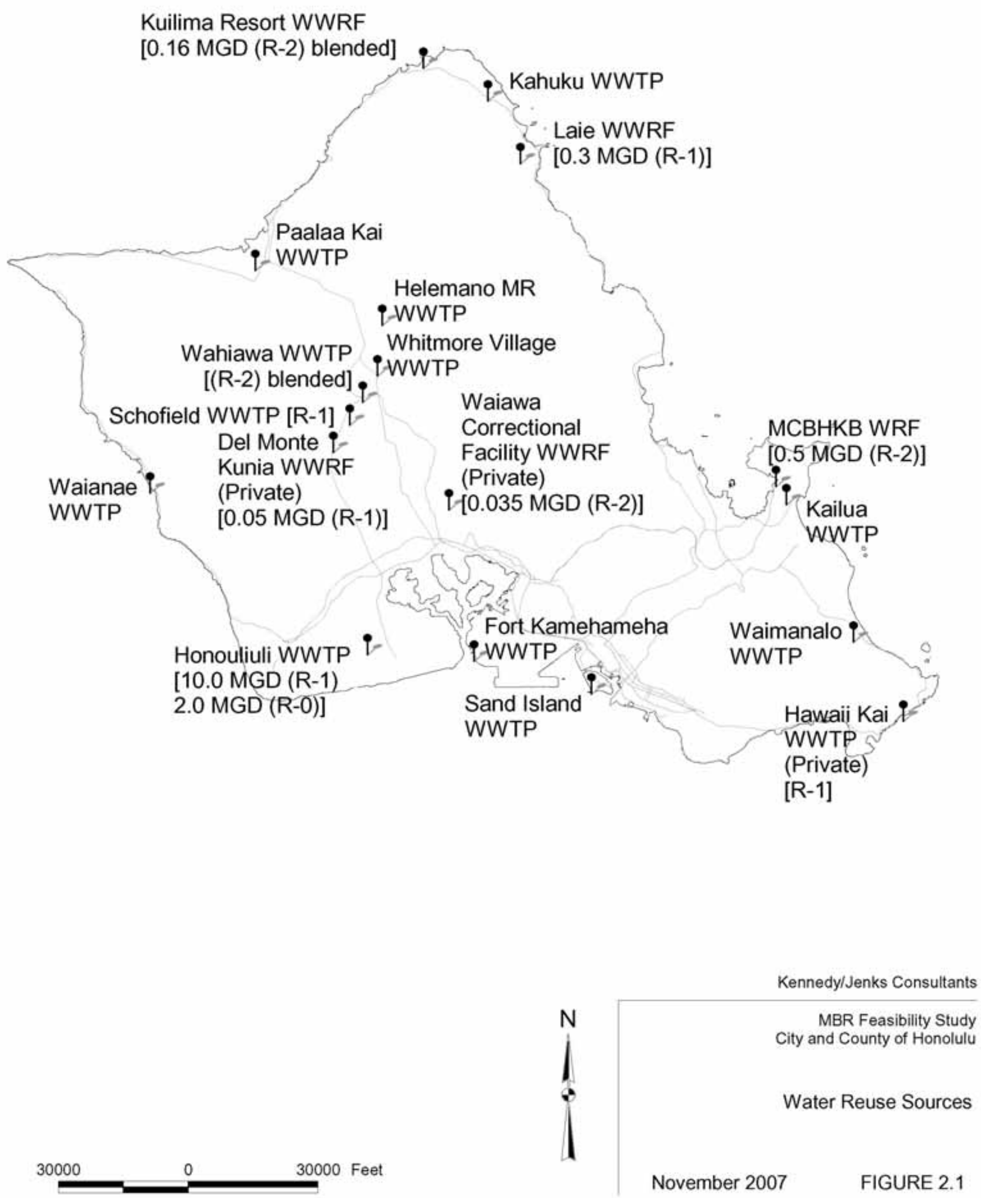
The Honouliuli WRF is currently capable of producing 10 MGD of R-1 water for irrigational uses and 2 MGD of RO water (reverse osmosis-treated recycled water) for industrial uses. Expansion of the facility is in the planning stage to increase its production capacity and to extend the distribution system to serve a larger area.

Other WRFs on the island include the Kunia, Laie, and Schofield Barracks WRFs, which produce R-1 water for agricultural and landscape irrigation. The Wahiawa, Marine Corps Base Hawaii–Kaneohe Bay, Kuilima Resort, and Waiawa Correctional WWRFs produce R-2 water, also for irrigation purposes. Table 2.4 summarizes the status of the current water recyclers on Oahu.

2.2 WASTEWATER CONSENT DECREE

2.2.1 Permit Condition

In 1972, Congress passed the Federal Water Pollution Control Act Amendments, which required all Publicly Owned Treatment Works (POTWs) to achieve secondary treatment capability by 1977. After passage, municipalities with POTWs discharging into marine waters argued that this requirement was unnecessary for their situation. They contended that their effluent was discharged into deep waters with large tides and substantial currents, which promoted and allowed for greater dilution and dispersion than their freshwater counterparts for which the requirements were set. As a result of this argument, Congress added Section 301(h) to the Clean Water Act in 1977, allowing a case-by-case review of treatment requirements for


Kuilima Resort WWRF
[0.16 MGD (R-2) blended]
Kahuku WWTP
Laie WWRF
[0.3 MGD (R-1)]
Paalaa Kai
WWTP
Helemano MR
WWTP
Whitmore Village
WWTP
Wahiawa WWTP
[(R-2) blended]
Schofield WWTP [R-1]
Del Monte
Kunia WWRF
(Private)
[0.05 MGD (R-1)]
Waiawa
Correctional
Facility WWRF
(Private)
[0.035 MGD (R-2)]
MCBHKB WRF
[0.5 MGD (R-2)]
Kailua
WWTP
Waianae
WWTP
Fort Kamehameha
WWTP
Waimanalo
WWTP
Honouliuli WWTP
[10.0 MGD (R-1)
2.0 MGD (R-0)]
Sand Island
WWTP
Hawaii Kai
WWTP
(Private)
[R-1]
N
30000
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30000 Feet
Kennedy/Jenks Consultants
MBR Feasibility Study
City and County of Honolulu
Water Reuse Sources
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FIGURE 2.1

Table 2.4. Current WRFs on Oahu

Facility	Capacity, MGD	Quality	End users
Honouliuli WRF	10 2	R-1 R-0	Ewa Villages Golf Course, Fort Weaver Road medians, Coral Creek Golf Course, Hawaii Prince Golf Course, Kapolei Golf Course, West Loch Golf Course, West Loch Shoreline Park, Ewa Mahiku District Park, Asing Park, AES Hawaii, Inc., Kalaeloa Cogeneration, Tesoro Hawaii Corporation, The Gas Company, Chevron refinery
Waiawa Correctional Facility WWRF	0.035	R-2	Waiawa Correctional Facility
Kunia WRF	0.05	R-1	Del Monte
Schofield Barracks WRF	4.2	R-1	Waialua Division Agriculture, Oahu Flowers, Pioneer Hybrid International, Kahuku Farms, University of Hawaii Research
Turtle Bay WWRF	0.16	R-2	Turtle Bay Resort–Palmer Course
Laie WWRF	0.3	R-1	Hawaii Reserves/BYUH
Kaneohe MCBH WWRF	0.5	R-2	Klipper Golf Course

marine dischargers. Eligible applicants that met the environmentally stringent criteria in section 301(h) would receive a modified National Pollutant Discharge Elimination System (NPDES) permit that waived the secondary treatment requirements for conventional pollutants such as biochemical oxygen demand (BOD), suspended solids (SS), and pH.

2.2.2 301(h) Waiver Status

The CCH has NPDES permit waivers for its two largest WWTPs—the Sand Island and Honouliuli WWTPs. The permits for these facilities have expired; however, the city has received administrative extensions. The city made timely application for renewal and is currently awaiting decisions from the EPA's Region IX. Should its 301(h) waiver applications be denied, the city will need to give the wastewater at both facilities full secondary treatment prior to discharge into the ocean. Large-scale MBRs for retrofitting the existing plant may be a viable alternative for the given situation. However, this study will focus on decentralized MBR applications that lessen the quantity of wastewater that must be treated by the Sand Island and Honouliuli WWTPs and discharged into the ocean.

CHAPTER 3

HAWAII REGULATORY FRAMEWORK FOR MBR SATELLITE RECYCLING

3.1 GUIDELINES FOR THE TREATMENT AND USE OF RECYCLED WATER

In order to understand MBR recycling opportunities in Hawaii, it is first necessary to understand the regulations that govern water recycling in Hawaii. Hawaii's Guidelines for the Treatment and Use of Recycled Water (Guidelines) are largely based on California Title 22 standards, but there are some nuances that are inherent to Hawaii.

Three classes of recycled water are described in the Guidelines. R-3 water is undisinfected secondary recycled water. R-2 water is disinfected secondary recycled water. R-1 water is disinfected, tertiary-treated (oxidized and filtered) recycled water. Since MBR effluent, when coupled with an appropriate disinfection quality, meets R-1 criteria, we will focus on those requirements.

Filtration requirements for R-1 water include the following:

- A continuous recording turbidimeter shall be installed and operated prior to and after the filtration process; and
- The filtered effluent turbidity shall not exceed 2.0 NTU. Filtered effluent with greater than 2.0 NTU shall be diverted to a backup disposal system acceptable to the state Department of Health (DOH);
- For R-1 application on edible crops, the turbidity of the influent to the filters is continuously measured, the influent turbidity does not exceed 5 NTU for more than 15 min and never exceeds 10 NTU, and there is the capability to automatically activate chemical addition or divert the wastewater should the filter influent turbidity exceed 5 NTU for more than 15 min.

Disinfection, as defined by the guidelines, is a process that, when combined with the filtration process, has been demonstrated to inactivate and/or remove 99.999% of the plaque-forming units of F-specific bacteriophage MS2 or polio virus in the wastewater. A virus that is at least as resistant to disinfection as polio virus may be used for purposes of demonstration. Additionally, the process must limit the concentration of fecal coliform bacteria according to the following criteria:

- The median density measure in the disinfected effluent does not exceed 2.2 per 100 mL in the bacteriological results of the last 7 days for which analyses have been completed; and
- The density does not exceed 23 per 100 mL in more than one sample in any 30-day period; and
- No sample shall exceed 200 per 100 mL.

In the case of this study, it is assumed that disinfection shall be by ultraviolet (UV) disinfection as free and combined chlorine disinfection systems will require contact time that is not likely available in a satellite application. Acceptable UV disinfection systems must meet the applicable provisions of the *UV Guidelines for Drinking Water and Water Reuse,* dated December 2000, or the latest version, published by the National Water Research Institute (NWRI) and the American Water Works Association Research Foundation (AwwaRF). These guidelines were the update of the original 1993 *UV Disinfection Guidelines for Wastewater Reclamation in California* and *UV Disinfection Research Needs Identification*. These new guidelines are intended to be dynamic. As more operational experience is gained and as the technology advances, they will be updated. The UV disinfection system must be able to meet the required inactivation levels for the target microorganisms established for R-1 water.

There are different uses for the different classes of recycled water with more options available to the higher classes of recycled water. MBR effluent complies with R-1 standards prior to disinfection. Therefore, this study will focus on applications capable of utilizing R-1 water. Based on the Guidelines, the following are allowable uses for R-1 water.

Irrigation

- Golf course landscapes
- Freeway and cemetery landscapes
- Food crops where recycled water contacts the edible portion of the crop, including all root crops
- Parks, elementary schools' yards, athletic fields, and landscapes around some residential property
- Roadside and median landscapes
- Inedible vegetation in areas with limited public exposure
- Sod farms
- Ornamental plants for commercial use
- Food crops above ground and not contacted by irrigation
- Pastures for milking and other animals
- Fodder, fiber, and seed crops not eaten by humans
- Orchards and vineyards bearing food crops
- Orchards and vineyards not bearing food crops during irrigation
- Timber and trees not bearing food crops
- Food crops undergoing commercial pathogen-destroying process before consumption

Supply to Impoundments

- Restricted recreational impoundments
- Basins at fish hatcheries
- Landscape impoundments without decorative fountain
- Landscape impoundments with decorative fountain

Supply to Other Uses

- Flushing of toilets and urinals
- Structural firefighting
- Nonstructural firefighting
- Commercial and public laundries
- Cooling of saws while cutting pavement
- Decorative fountains
- Washing of yards, lots, and sidewalks
- Flushing of sanitary sewers
- High-pressure water blasting to clean surfaces
- Industrial process without exposure of workers
- Industrial process with exposure of workers
- Cooling or air conditioning system without tower, evaporative condenser, spraying, or other features that emit vapor or droplets
- Cooling or air conditioning system with tower, evaporative condenser, spraying, or other features that emit vapor or droplets
- Industrial boiler feed
- Water jetting for consolidation of backfill material around potable water piping during water shortages
- Water jetting for consolidation of backfill material around piping for recycled water, wastewater, storm drainage, and gas and around electrical conduits
- Washing of aggregate and making concrete
- Dampening of roads and other surfaces for dust control
- Dampening of brushes and street surfaces in street sweeping

Additional uses may be considered by the DOH but would be subject to additional scrutiny and perhaps additional permitting requirements.

3.2 CRITICAL DISPOSAL AREAS

The State of Hawaii (Oahu, in particular) is highly reliant on groundwater for its potable water source. As such, the DOH is very protective of the potable groundwater aquifers. Hawaii Administrative Rules, Title 11, Chapter 62 defines Critical Wastewater Disposal Areas (CWDAs) for each island. CWDAs are areas where the disposal of wastewater has or may cause adverse effects on human health or the environment due to existing hydrogeological conditions. Within these areas, the DOH director may impose more stringent effluent quality requirements than those typically specified.

For Oahu, the CWDA covers basically the entirety of the island. In practice, DOH has allowed recycled water projects to occur on Oahu without more stringent effluent quality requirements but has limited them to areas that lie seaward of the Underground Injection Control (UIC) line. This line generally indicates the boundaries between exempted aquifers (aquifers not currently used as drinking water sources or likely to be used as drinking water sources in the future) from underground sources of drinking water.

CHAPTER 4

SATELLITE MBR SYSTEM AREA REQUIREMENTS

For the purpose of this study, we have chosen to focus on smaller MBR facilities. Although economies of scale can be realized in construction costs for larger facilities, it is also more difficult to gain community acceptance for these facilities. Furthermore, finding available space for larger facilities becomes more difficult or at the very least more expensive.

Since project economics will be a major driver in the viability of a satellite MBR facility, we have decided to focus on smaller facilities that could be located on city-owned property, presumably at little to no cost. This assumption would need to be verified on a case-by-case basis should an actual project be considered.

In reviewing the range of the potential users, it was determined that developing costs for each specific user would be extremely tedious. We have therefore chosen to develop costs for four discrete sizes of satellite MBR systems—0.1, 0.25, 0.5, and 1.0 MGD. We believe that these sizes will bracket most of the applications that we have identified and allow for reasonable interpolation, should it be required.

In developing footprints for these facilities of different sizes, we have sought assistance from the various manufacturers and developed some information based on our experience. We have made the following assumptions regarding the facilities:

- The MBR facilities would be housed in a building to mitigate odor and visual impacts to the surrounding neighborhood.

- Facilities housed in the building would include
    - Coarse screens
    - Grit removal
    - Fine screens
    - Process (aeration) tank
    - MBR tank
    - UV disinfection
    - Recycled water pumps
    - Electrical room
    - Storage space

- Additional area is required outside of the building for
    - Soil filter for odor control
    - Parking and vehicular access
    - Buffer from neighboring facilities

Based on some preliminary layouts, we have developed the following area requirements for the satellite MBR facilities of various sizes:

Table 4.1. Space requirements for satellite MBR facilities

Facility capacity, MGD	Building footprint, sq. ft.	Facility footprint, in acres
0.1	3400	0.6
0.25	7000	0.8
0.5	9000	0.9
1.0	13,500	1.1

The space requirements listed in Table 4.1 do not include space required for storage of recycled water or diversion facilities to shunt raw wastewater to the satellite facility. The latter would presumably be located at the pump station or next to the sewer in a street.

CHAPTER 5

IDENTIFICATION OF POTENTIAL USERS

5.1 SURVEY OF LARGE USERS

Using the BWS's list of its top water users from 2005 as a basis (see Appendix A), we conducted a survey to identify potential users of MBR recycled water and their general water requirements. The survey requested service holders to

- indicate whether they have an interest in using MBR recycled water,
- provide quantities of current water demand, description of present uses, and information on their facility's water system, and
- identify potential recycled water applications, specific water quality requirements, a ranking of desired water quality attributes, percentage of price break necessary (% below the cost of potable water) to entice use, and concerns with using recycled water.

The survey was intended to gauge the potential annual demand, seasonality of demand, storage requirements, ease of conversion to recycled water use, and willingness to convert to recycled water of potential users.

Seventy-three service holders were contacted, and 30 responses were obtained, generally from the operation and maintenance managers of these facilities. Three of these users indicated that they would not be interested in using recycled water. One is an agricultural company that stated recycled water cannot be used in its business, which deals with the production of food for human consumption. Another is a private school that was concerned about the impact of the use of recycled water on the health and safety of its students, faculty, and administration.

Of the users expressing interest in using recycled water, only 14 completed the survey. These users included two hotels, four multi-unit complexes, two commercial facilities, a golf course, a common area (irrigation), a hospital, two state facilities, and a high school. While many of the companies and institutions indicated an interest in the recycled water program, they also added that their boards of directors made the ultimate decision. Current water demands at these facilities are mainly for irrigation and daily continuous use. It should be noted that a significant portion of hotels' and multi-unit complexes' water demand is for potable applications. However, they do require water for irrigation of landscaping and of open areas as well. Use at hotels is seasonal, as occupancy varies. The irrigation schedule of recreational fields at the high school is also seasonally dependent. Certain fields receive more frequent irrigation when they are needed for athletic activities that are in season. Additionally, one of the state facilities (a community college) uses less water during the summer months when fewer students are on campus. Water consumption at the remaining facilities does not vary throughout the year. The average monthly irrigational demands at these facilities are shown in Figure 5.1. Less than half of these users have segregated systems, and only two have water storage facilities on site (a multi-unit complex and the golf course).

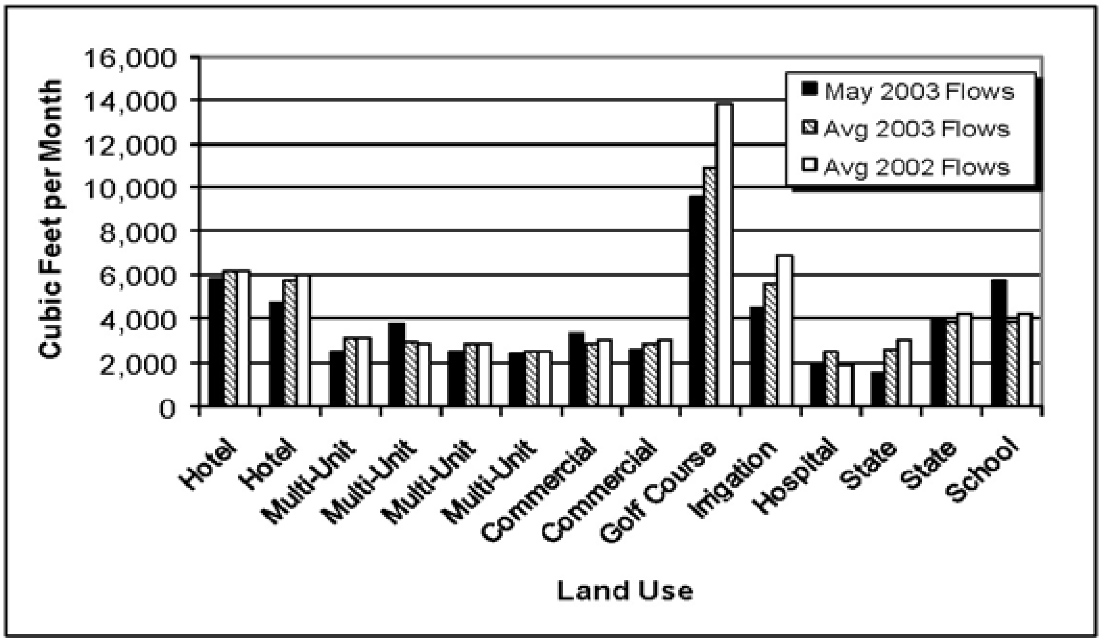


Figure 5.1. Average monthly water consumption of large users.

Based on the completed surveys, the companies and institutions would use the recycled water for landscape irrigation and water features. Other potential applications include toilet flushing, though replumbing may be an obstacle. Specific water quality requirements at these facilities were generally unknown. Water quality is not carefully monitored at these facilities since potable water is used. It should be noted that recycled water was previously used by a golf course for irrigation but that it has reverted to using potable water as the recycled water was found to be too saline. Most of these companies and institutions indicated that they would likely be willing to use the recycled water immediately and that they would require assistance in retrofitting their facility to use the recycled water.

Though many of the companies and institutions were unaware of specific water quality requirements at their facility, more than half ranked water quality as the most important attribute of the recycled water. Some of the institutions indicated an association between water quality and health and safety. Reliability and price were the next most important attributes. Concerns shared by all users included health and safety issues. Price breaks necessary to persuade use of the recycled water were distributed across all ranges (as a percentage below the price of potable water), though both hotels indicated that it would depend on retrofitting costs.

5.2 IDENTIFICATION OF MAIN POTENTIAL USERS

In order to clearly delineate potential users, a screening methodology was developed. Figure 5.2 diagrams the method used to identify the main potential users of recycled water on Oahu.

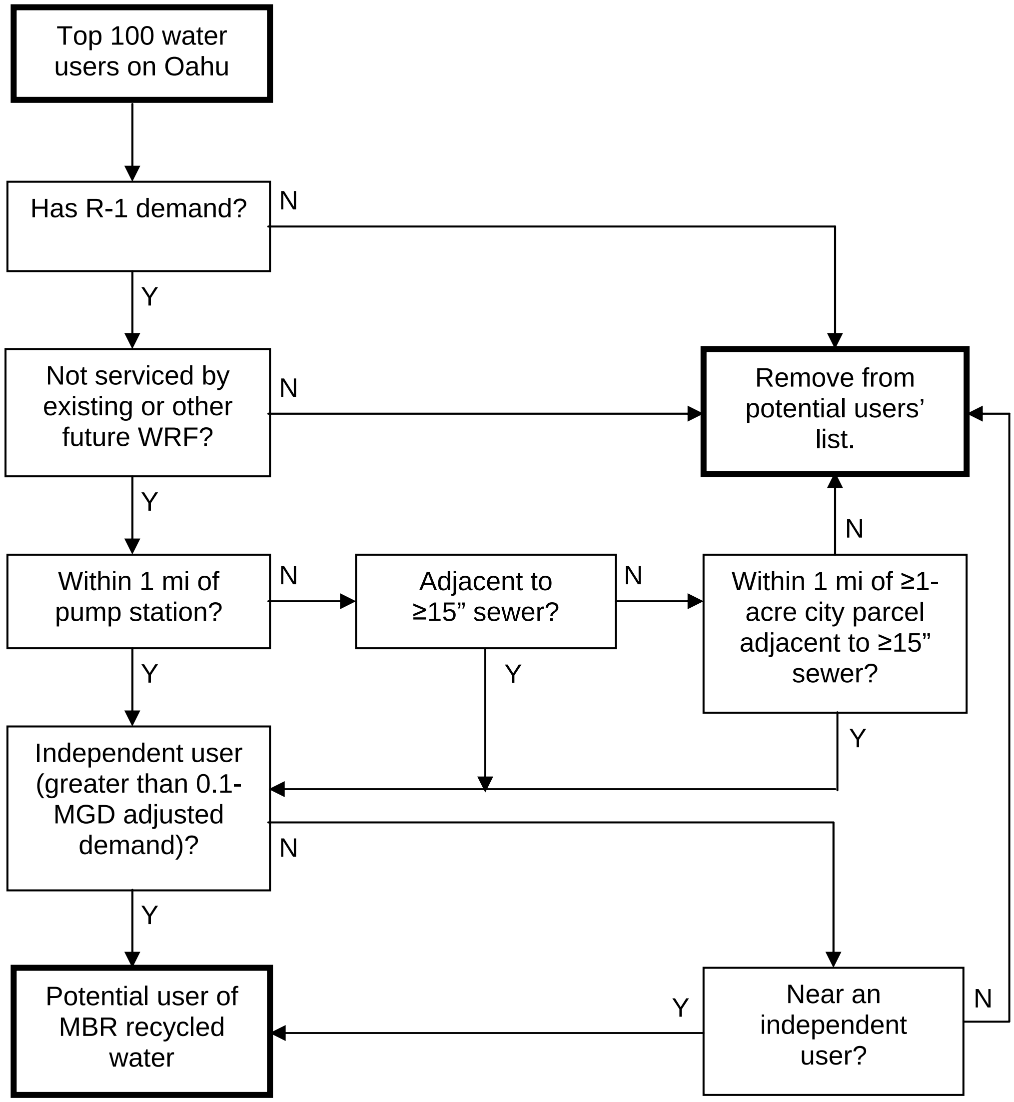


Figure 5.2. Recycled water user screening methodology.

5.2.1 R-1 Water Demand

Users with no R-1 water demand were eliminated from the list. Such users include bottling companies that require potable water for their production. Several commercial and industrial users such as Tesoro, Chevron, and the Hawaii Resource Recovery Venture are known to require RO water for their operation and were eliminated as well. While R-1 water may be suitable for some industrial processes, industrial users were generally removed from the list. The quantity and water quality requirements for industrial reuse vary by industry, and further in-depth research would be needed to evaluate the recycled water demands for each industrial user. Since the total water usage of industrial users does not comprise a significant portion of the total water usage by the largest water users on the island and since some of these industrial users are known to require RO water, industrial users were eliminated from consideration.

5.2.2 Absence of Recycled Water Service from Other Sources

Users that are already or may potentially be receiving R-1 water from existing or other future WRFs were removed from consideration. The Honouliuli WRF, owned and operated by the CCH, currently provides R-1 and RO water to a number of users on the Ewa plain. The environmental assessment for the expansion of the facility suggests that the facility will be servicing users within a 3- to 5-mi radius of the facility (Final Environmental Assessment: Expansion of the Ewa Nonpotable Water System, September 2004). Thus, users within this distance of the Honouliuli WRF were eliminated from consideration. The Marine Corps Base Hawaii–Kaneohe Bay was also eliminated, as its WWRF has the capacity to produce and distribute R-2 water.

5.2.3 Proximity to Supply

A benefit of decentralized WRFs is reduced cost for conveyance and distribution systems to and from the facility. It is intended that raw wastewater will be used as influent into the satellite MBR stations and that the waste from the MBR units will be returned directly to the sewer lines. Thus, the potential user should be located near wastewater sources. The established criteria for further scrutinizing the list of potential uses is as follows: (i) the user's property must be adjacent to a 15-in.-diameter or larger sewer line, (ii) the user's property must be within 1 mi of a pump station, or (iii) the user's property must be within 1 mi of a city-owned parcel larger than 1 acre that is adjacent to a sewer line of 15 in. or larger in diameter. An explanation of the established criteria is given in the following sections.

5.2.3.1 Adjacent to a 15-In.-Diameter or Larger Wastewater Line

The largest MBR installation considered in this study is 1 MGD. Therefore, the MBR facilities should be located near sewer lines conveying greater than 1 MGD of wastewater. Sewer lines with a 15-in. diameter were identified as having the narrowest diameter able to convey greater than 1 MGD of wastewater at a minimum slope specified by the city's design standards. The city requires that sewer lines be constructed at a slope such that the full flow velocity in the pipe is no less than 2 fps. To meet this criterion, the minimum slope for 15-in.-diameter pipes is 0.2%. The capacity of 15-in. sewer lines at this slope is 1.6 MGD. For a flow of 1 MGD, the capacity in the 15-in. pipe is 62% with a normal depth of 8.5 in. Properties within 50 ft of the sewer line are considered to be adjacent to the sewer line, since a right of way is approximately 50 ft in width.

5.2.3.2 Within 1 Mi of a Pump Station

Pump stations are constructed for the purpose of conveying wastewater from low-lying areas to the nearest wastewater treatment facility. Insofar as they are city-owned facilities that provide controlled access to wastewater, they are an ideal source of supply for a satellite reclamation facility

The 1-mi distance from the pump station was selected on the basis minimizing the cost of the distribution system. The cost of the distribution system should be no more than $1 million, which is less than 20% of the smallest MBR unit. Assuming $200 per linear foot of distribution piping, the distribution system should be no longer than 5900 ft or approximately 1 mi.

5.2.3.3 Within 1 Mi of a City Parcel Larger than 1 Acre and Adjacent to a 15-In.-Diameter or Larger Wastewater Line

MBR satellite facilities can be located on parcels of land owned by the CCH. However, the impact of these facilities on the functionality of the parcels must be minimized. The MBR facilities all have a building requirement of less than 0.5 acre of area. It is assumed that parking and other building exterior access and amenities could be coordinated to minimize use impacts to the parcel. Therefore, only CCH-owned parcels larger than 1 acre were considered for potential locations of MBR stations to maintain the functionality of the parcel. The 1-mi radius criterion is as described in the previous section.

5.2.4 Sufficient Demand as Independent User

Independent users are large users with nonpotable water demands that exceed 0.1 MGD (3,000 thousand gallons per month), i.e., the smallest capacity MBR unit under consideration in the study. The water demands of service holders were adjusted to reflect only nonpotable demands, which, for the purposes of this study, include only irrigational uses and washing down for quarries and WWTPs. The adjusted nonpotable demands were obtained by multiplying the average monthly usage (from 2005 BWS records) by the fraction of total water usage expended for irrigation only. The percentages applied for the different types of institutions are given below:

- 95% - irrigation (labeled IRP, IRC, or IRS on BWS records)
- 90% - parks, cemeteries, golf courses, quarries
- 80% - WWTPs
- 25% - schools
- 22% - shopping centers, business offices
- 10% - hotels, apartment complexes, correctional facilities
- 5% - hospitals

A 95% water usage for irrigation was assumed for those service holders marked as irrigational users (according to BWS records). Ninety percent was assumed for parks, cemeteries, golf courses, and quarries, which often include comfort stations that contribute to water usage. Eighty percent of the water usage at WWTPs was assumed to be nonpotable, based on water usage records for the Honouliuli WWTP. General percentages for school, business offices, hotels, and hospitals were obtained from a New Mexico water conservation guide (Schultz Communications, 1999).

The independent users' properties or city parcels (as denoted by parcel number, Tax Map Key (TMK)) in proximity of these users were identified as potential sites for the satellite MBR stations. The MBR stations can supply R-1 water to other nearby large users, but the independent users ensure sufficient recycled water demand for a single MBR unit if there are no other users nearby. Presented in Table 5.1 are the independent users with R-1 water demand that are not currently served or expected to receive service by other WRFs and are near wastewater sources.

Table 5.1. Independent potential recycled water users and their adjusted water demand

Service holder	TMK	Adjusted (nonpotable) demand (1000 gal/month)
Central Oahu Regional Park	94005074	10,758
Kapiolani Park and Zoo	31043001	10,149/7114
Sand Island WWTP	15041005	8119
Halawa Quarry	99010010	7978
Ala Moana State Recreation Area	23037025	7300
Ala Wai Golf Course	27036002	5787
Mid-Pacific Country Club	42002002	5551
Honolulu International Airport	11003001	4894
Fort DeRussy Armed Forces Recreation Center	26005001	4610/1274
Waikele Community Association	94007010	4389/1784
National Memorial Cemetery of the Pacific	22005002	4081
Keehi Lagoon	11003006	3347
University of Hawaii at Manoa	28029001	3236/889

CHAPTER 6

IDENTIFICATION OF POTENTIAL SITES

The list of potential large users of recycled water served as a basis for identifying possible locations for the MBR stations. Initial sites were identified on city-owned properties, either adjacent to a wastewater pump station or large-diameter sewer main (greater than 15 in. in diameter), in proximity to the potential users. After we used the preceding selection criteria, the following top 10 sites emerged for further consideration. These site locations are shown on the island map in Figure 6.1. Photos of selected MBR facility sites are provided in Appendix B.

6.1 SITE 1—CENTRAL OAHU REGIONAL PARK

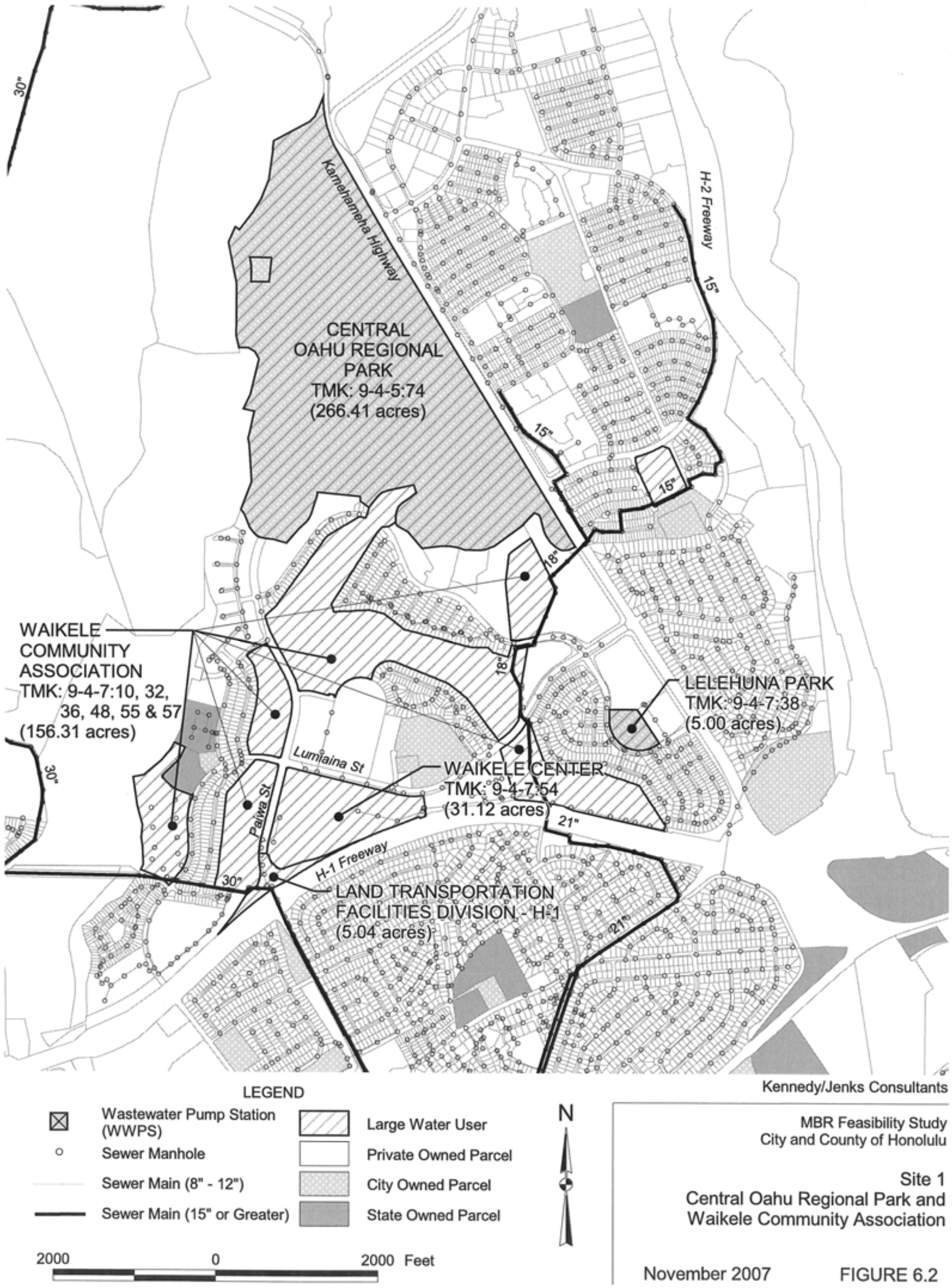
The largest potential water user identified for recycled water is Central Oahu Regional Park, located in Waikele, off Kamehameha Highway. The 269-acre city park includes 20 tennis courts, a 20-lane archery range, a stadium court, and acres of open, grassy area. In 2005, Central Oahu Regional Park consumed an average of 11,952.8 thousand gallons per month. It is anticipated that approximately 10,758 thousand gallons/month can be converted to recycled water or 0.359 MGD. Other large water users located near the park are the Waikele Community Association, including Waikele Golf Course with a possible nonpotable water demand of 0.206 MGD; Waikele Center; Lelehuna Park; Fairway Village; and the State Land Transportation Facilities Division. The water use of these BWS service holders is primarily for irrigation, according to BWS records.

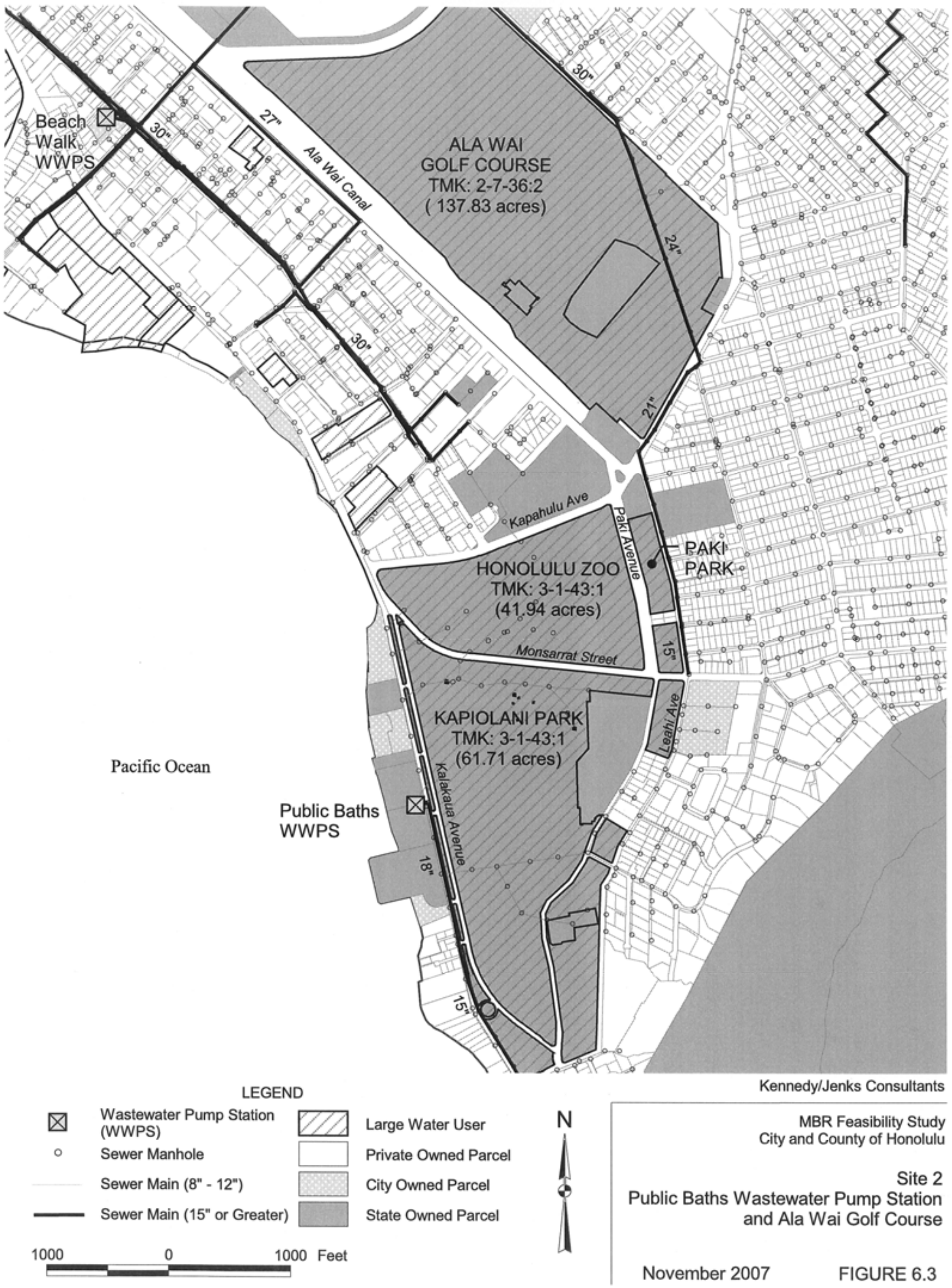
As shown in Figure 6.2, possible locations for a minimum 0.50 MGD MBR facility are on the south end of the park near the park entrance. A 15-in. sewer runs along Kamehameha Highway, opposite the park. The 15-in. sewer combines with another 15-in. sewer into an 18-in. sewer at the southeast tip of the park. Near the entrance of the park is a pesticide treatment facility. Between the pesticide treatment facility and the park entrance road is a large open area on which the MBR facility can be located. The pesticide treatment facility is hidden behind large bushes and trees. A similar tactic can be used to hide the MBR facility. Another possible location is at the southeast tip of the park, along Kamehameha Highway. At this tip is a large open area. However, houses border the west edge of this tip and residents may oppose looking out into a water treatment facility from their homes.

6.2 SITE 2—PUBLIC BATHS WASTEWATER PUMP STATION AND ALA WAI GOLF COURSE

On the east end of Waikiki are three large water users: Kapiolani Park (0.338 MGD), the Honolulu Zoo (0.237 MGD), and the Ala Wai Golf Course (0.193 MGD) as shown in Figure 6.3. Kapiolani Park is a large recreational area that comprises 96 acres of open grassy fields, open pavilion theatre (Waikiki Shell), a comfort station, bandstand, and large water feature.


Kahuku
Laie
Waimea
Haleiwa
Kaena Point
Waialua
Kaaawa
Kualoa
Wahiawa
Makaha
Mililani
Kahaluu
Waianae
Kunia
Maili
SITE 1
Pearl City
SITE 5
Kaneohe
Kailua
Waipahu
Aiea
Nanakuli
Waimanalo
Makakilo
SITE 6
Ewa Beach
SITE 8
Barbers Point
SITE 3
Waikiki
Makapuu Point
Hawaii Kai
SITE 4
Koko Head
SITE 7
SITE 2
Kennedy/Jenks Consultants
N
MBR Feasibility Study
City and County of Honolulu
Potential Site Location Key Map
30000
0
30000 Feet
November 2007
FIGURE 6.1


30"
Kamehameha Highway
H-2 Freeway
15"
CENTRAL
OAHU REGIONAL
PARK
TMK: 9-4-5:74
(266.41 acres)
15"
15"
18"
18"
WAIKELE
COMMUNITY
ASSOCIATION
TMK: 9-4-7:10, 32,
36, 48, 55 & 57
(156.31 acres)
LELEHUNA PARK
TMK: 9-4-7:38
(5.00 acres)
30"
Lumiaina St
Paiwa St
WAIKELE CENTER
TMK: 9-4-7:54
(31.12 acres)
21"
H-1 Freeway
30"
LAND TRANSPORTATION
FACILITIES DIVISION - H-1
(5.04 acres)
21"
LEGEND
Wastewater Pump Station (WWPS)
Sewer Manhole
Sewer Main (8" - 12")
Sewer Main (15" or Greater)
Large Water User
Private Owned Parcel
City Owned Parcel
State Owned Parcel
2000
0
2000 Feet
N
Kennedy/Jenks Consultants
MBR Feasibility Study
City and County of Honolulu
Site 1
Central Oahu Regional Park and
Waikele Community Association
November 2007
FIGURE 6.2


Beach Walk WWPS
30"
27"
Ala Wai Canal
ALA WAI GOLF COURSE
TMK: 2-7-36:2
(137.83 acres)
30"
24"
21"
30"
Kapahulu Ave
Paki Avenue
PAKI PARK
HONOLULU ZOO
TMK: 3-1-43:1
(41.94 acres)
Monsarrat Street
15"
KAPIOLANI PARK
TMK: 3-1-43:1
(61.71 acres)
Leahi Ave
Pacific Ocean
Public Baths WWPS
Kalakaua Avenue
18"
15"
Kennedy/Jenks Consultants
LEGEND
Wastewater Pump Station (WWPS)
Sewer Manhole
Sewer Main (8" - 12")
Sewer Main (15" or Greater)
Large Water User
Private Owned Parcel
City Owned Parcel
State Owned Parcel
N
1000
0
1000 Feet
MBR Feasibility Study
City and County of Honolulu
Site 2
Public Baths Wastewater Pump Station and Ala Wai Golf Course
November 2007
FIGURE 6.3

The Honolulu Zoo is west of Kapiolani Park on the other side of Monsarrat Avenue and is bounded by Kapahulu and Paki Avenue to the north and east, respectively. It encompasses approximately 50 acres. The Ala Wai Golf Course is on the west side of Kapahulu Avenue, along Date Street with the Manoa Palolo Drainage Canal and Ala Wai Canal along its north and west boundaries. It covers approximately 138 acres.

A possible location for a central 1.0 MGD MBR facility that can handle the water demands of all three large water users is in Paki Park, a community park on Leahi Avenue. The park is located next to a residential area, just east of the Honolulu Zoo. An 18-in. sewer main runs along the east side of the park on Leahi Avenue. There is a comfort station and playground at the north end of the park. The south end is an open grassy field that is available for placement of an MBR unit. However, situating an MBR unit at this location would significantly reduce the park area. Additionally, the residents of the homes adjacent to the south end of the park may oppose the placement of WRF in the area.

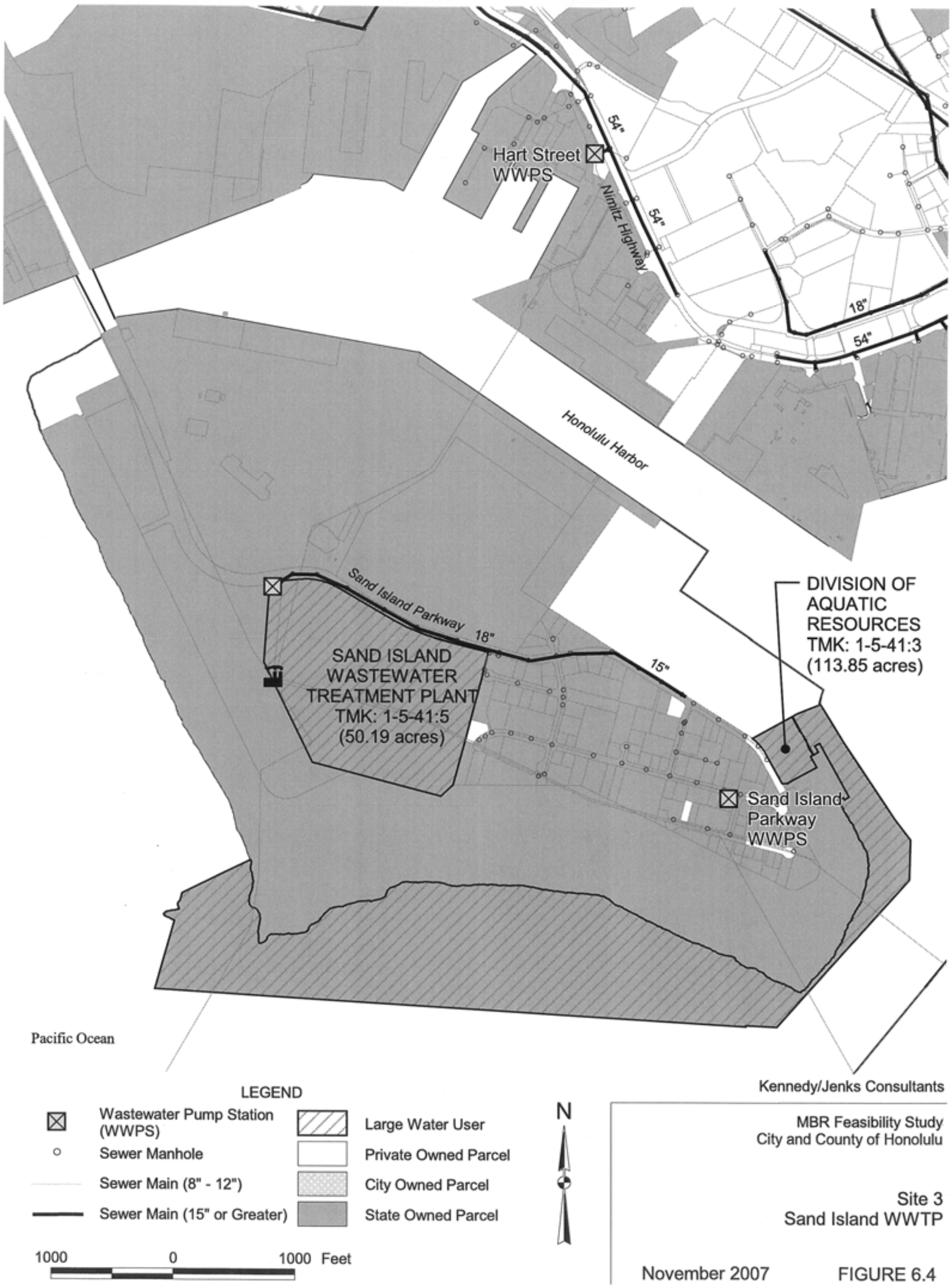
Another option is the location next to the Public Baths Wastewater Pump Station, immediately west of Kapiolani Park. The Public Baths Wastewater Pump Station received and handled 64.969 million gallons in the 2005–2006 fiscal year. This sum averages to 0.178 MGD. South of the pump station is the Waikiki Aquarium, and north of the pump station is an open parcel. A 1.0 MGD MBR facility can be located on this parcel to serve Kapiolani Park and the Honolulu Zoo. Although it is not identified as a city parcel on the Geographic Information System (GIS) map in Figure 6.3, the TMK map indicates that the parcel belongs to the CCH. Construction of an MBR facility on this parcel would require the relocation of many trees, as there are numerous coconut trees on the plot. High salinity may also be a problem, as the wastewater sources are near the island coastline.

Authorities could place, in conjunction with the Public Baths Wastewater Pump Station, which does not have the potential to service the entire nonpotable water needs of the Ala Wai Golf Course, a second 0.25 MGD MBR facility on the its site to specifically serve its water needs. An existing 24-in. sewer cuts through the Ala Wai Golf Course's northeast boundary, adjacent to its water feature pond. This is an ideal site for the MBR facilities as the water feature serves as storage for the irrigation water. This alternative had been proposed and investigated in 2004 by the city for a 0.30 MGD facility.

6.3 SITE 3—SAND ISLAND WWTP

The Sand Island WWTP is identified as a large water user of potentially 0.271 MGD of nonpotable water and is located on Sand Island Parkway, as shown in Figure 6.4. Recycled water can be used for washing down the facility. The WWTP is the primary treatment facility serving metropolitan Honolulu and last year treated 24,290,590 million gallons or an average of 66.55 MGD. Currently, the Sand Island WWTP provides primary treatment before discharging into the ocean. Wastewater for an MBR unit can pulled from the treatment facility itself. An MBR station can be located on the WWTP property. The Division of Aquatic Resources' Anuenue Fisheries Research Center is another large water user on the island that can benefit from the production of recycled water.

One of the MBR pilot units at Honouliuli WWTP is being considered for relocation to the Sand Island WWTP site.


Hart Street WWPS
54"
Nimitz Highway
54"
18"
54"
Honolulu Harbor
Sand Island Parkway
18"
15"
SAND ISLAND WASTEWATER TREATMENT PLANT TMK: 1-5-41:5 (50.19 acres)
DIVISION OF AQUATIC RESOURCES TMK: 1-5-41:3 (113.85 acres)
Sand Island Parkway WWPS
Pacific Ocean
LEGEND
Wastewater Pump Station (WWPS)
Sewer Manhole
Sewer Main (8" - 12")
Sewer Main (15" or Greater)
Large Water User
Private Owned Parcel
City Owned Parcel
State Owned Parcel
N
1000 0 1000 Feet
Kennedy/Jenks Consultants
MBR Feasibility Study
City and County of Honolulu
Site 3
Sand Island WWTP
November 2007
FIGURE 6.4

6.4 SITE 4—MOANA PARK WASTEWATER PUMP STATION

The Ala Moana State Recreation Area, which encompasses the Ala Moana Regional Park, Ala Moana Beach Park, and Magic Island, is located across from Ala Moana Shopping Center (see Figure 6.5). Its anticipated recycled water demand of 0.243 MGD is mainly attributed to irrigation of the Ala Moana Regional Park.

On the corner of the Ala Moana Regional Park, near the intersection of Atkinson Drive and Ala Moana Boulevard, is the Moana Park Wastewater Pump Station. It pumped 263.312 million gallons of raw wastewater last year for an average of 0.72 MGD. A 0.25 MGD MBR facility can be constructed on the park grounds, immediately west of the pump station. There are large banyan trees and a walkway in the area that may require removal and rerouting, respectively.

It should be noted that the wastewater source is located along the coastline, which may pose water quality problems. There may be possible high salt content in the influent wastewater from salt intrusion through sewer infiltration. Since the MBR does not remove salt, the recycled water may be too saline for irrigation. Water quality tests on wastewater samples should be performed to ensure that the salinity of the wastewater will not pose a problem.

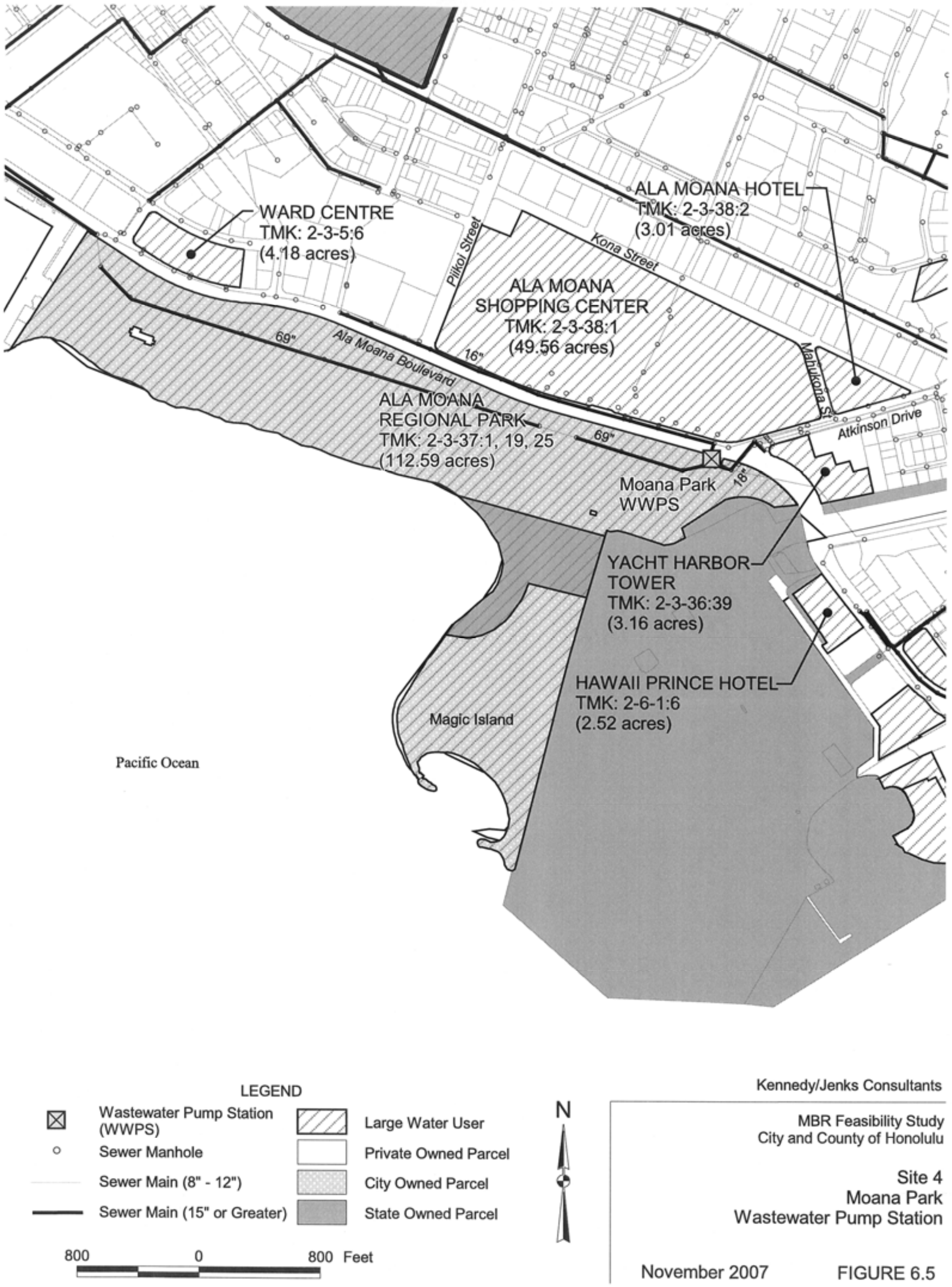
6.5 SITE 5—KAILUA BEACH PARK

Figure 6.6 shows the potential large user, Mid-Pacific Country Club (MPCC), and its surrounding area. MPCC is located on the east side of Oahu in Kailua town. It is an exclusive, privately owned golf course and recreation club. The 162-acre property includes a golf course, clubhouse, golf shop, driving range, swimming pool, and tennis courts. Recycled water can be used at MPCC primarily for golf course and ornamental landscape irrigation. This potential large user’s anticipated nonpotable water demand is 0.185 MGD.

The Kailua Heights Wastewater Pump Station, located to the west of MPCC, can potentially serve as the source of wastewater for an MBR WRF. However, the existing wastewater pump station site is too small to accommodate a 0.25 MGD MBR facility and there are no other city parcels near the wastewater pump station for an MBR facility.

An alternative wastewater supply is the 18-in. sewer main on Kawailoa Road, adjacent to the Kailua Beach Park. An MBR facility can be built in the park at the corner of Kawailoa Road and Alala Road. The distribution system can be placed on Alala Road, which would extend to the edge of MPCC property. This system could also feed Lanikai Elementary School.

Kailua Beach Park and the 18-in. sewer main are located along the island coastline, and the wastewater source’s water should be tested for salt content.

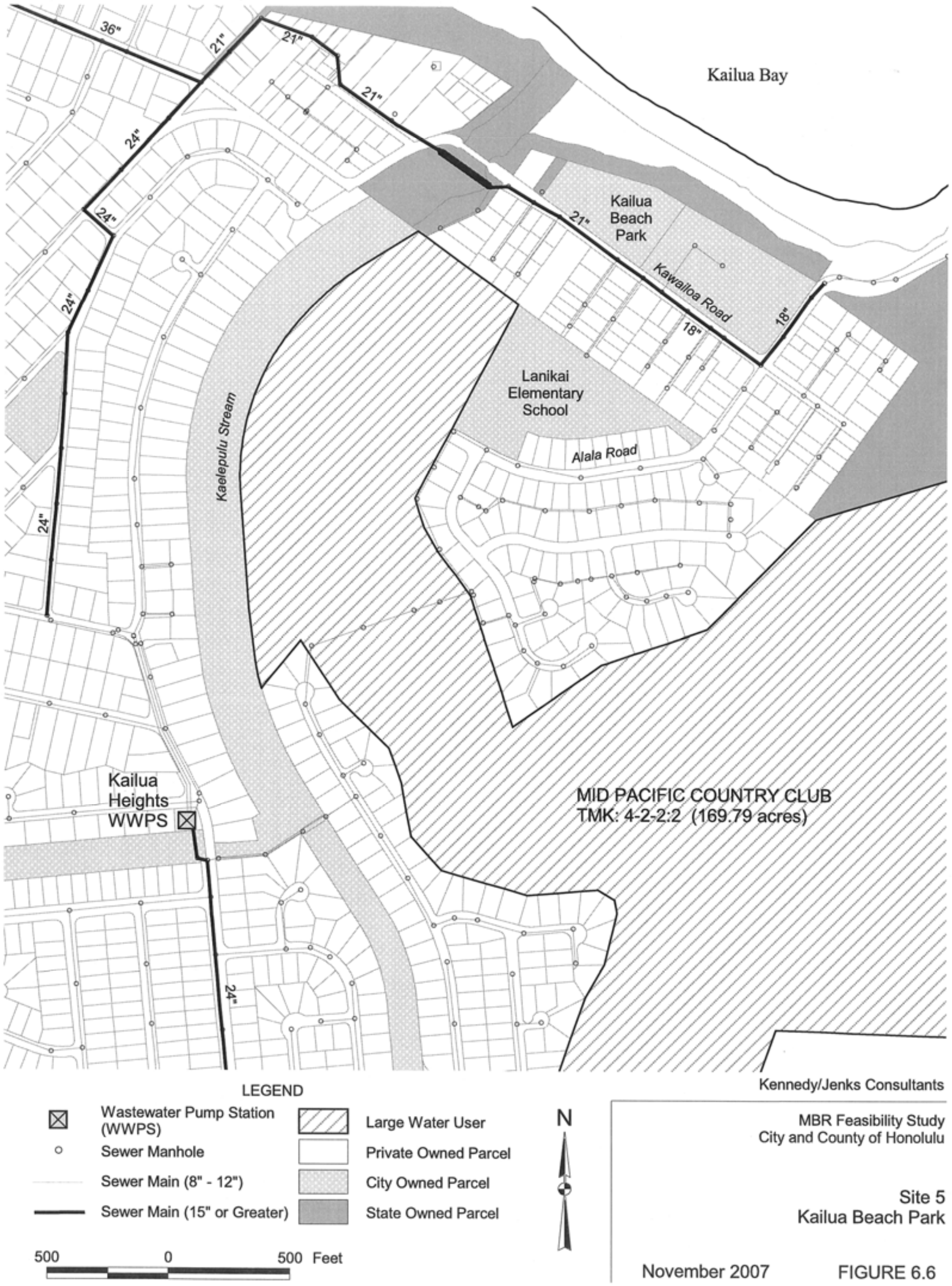


Kennedy/Jenks Consultants

MBR Feasibility Study
City and County of Honolulu

Site 4
Moana Park
Wastewater Pump Station

November 2007 FIGURE 6.5



Kennedy/Jenks Consultants

MBR Feasibility Study
City and County of Honolulu

Site 5
Kailua Beach Park

November 2007

FIGURE 6.6

6.6 SITE 6—KAMEHAMEHA HIGHWAY WASTEWATER PUMP STATION

The Honolulu International Airport (HIA) uses over 22,246 thousand gallons per month, of which it is anticipated 4,894 thousand gallons can be for nonpotable use. This amount equates to 0.163 MGD. The HIA does have its own nonpotable well that is used for irrigation.

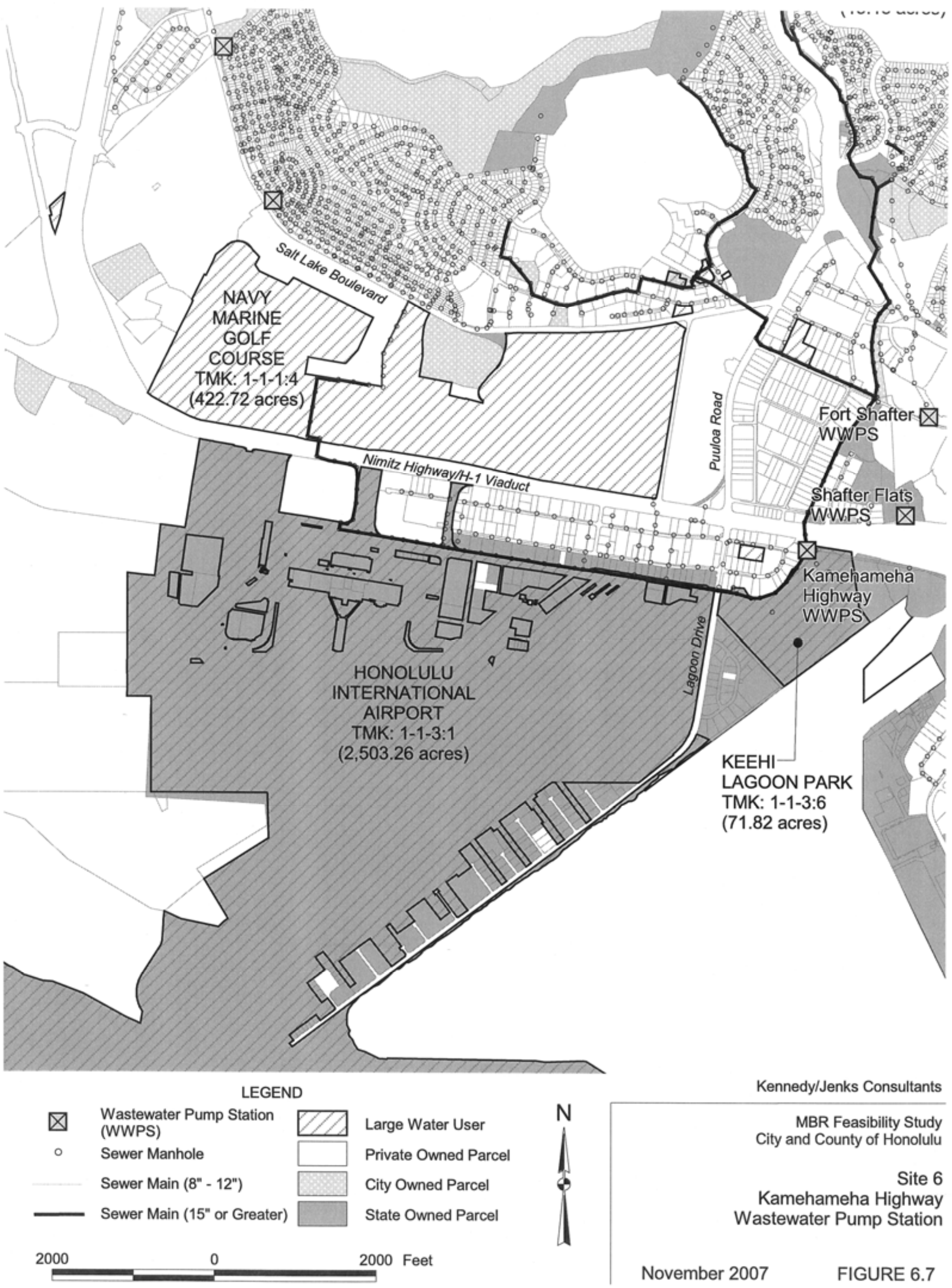
Keehi Lagoon Beach Park is a 72-acre park on Keehi Lagoon Drive, at the east end of the HIA. The park facilities include tennis courts; baseball, softball, soccer, and cricket fields; a canoe storage building; and comfort stations and showers. The park has also been identified as a large water user, and it is anticipated approximately 0.122 MGD of its water demand is nonpotable and can be used to irrigate its large grassy areas.

As seen in Figure 6.7, the Kamehameha Highway Wastewater Pump Station is located near the north end of the park, next to the tennis courts. Last year it pumped 2,109.232 million gallons for an average of 5.78 MGD. It is bordered on the south by a Department of Parks and Recreation (DPR) base yard. There is no room for an MBR facility immediately adjacent to the pump station. A 0.25 MGD MBR facility can be constructed in the park, possibly at the northeastern corner, near the tennis courts and draw wastewater from the pump station. There is also a 42-in. gravity sewer line that runs along the northwest edge of the park and connects to the pump station. An MBR facility can alternately be constructed on the park near this sewer main. Other potential users in the vicinity include the Navy-Marine Golf Course, Nimitz Highway landscaped medians, and other smaller users.

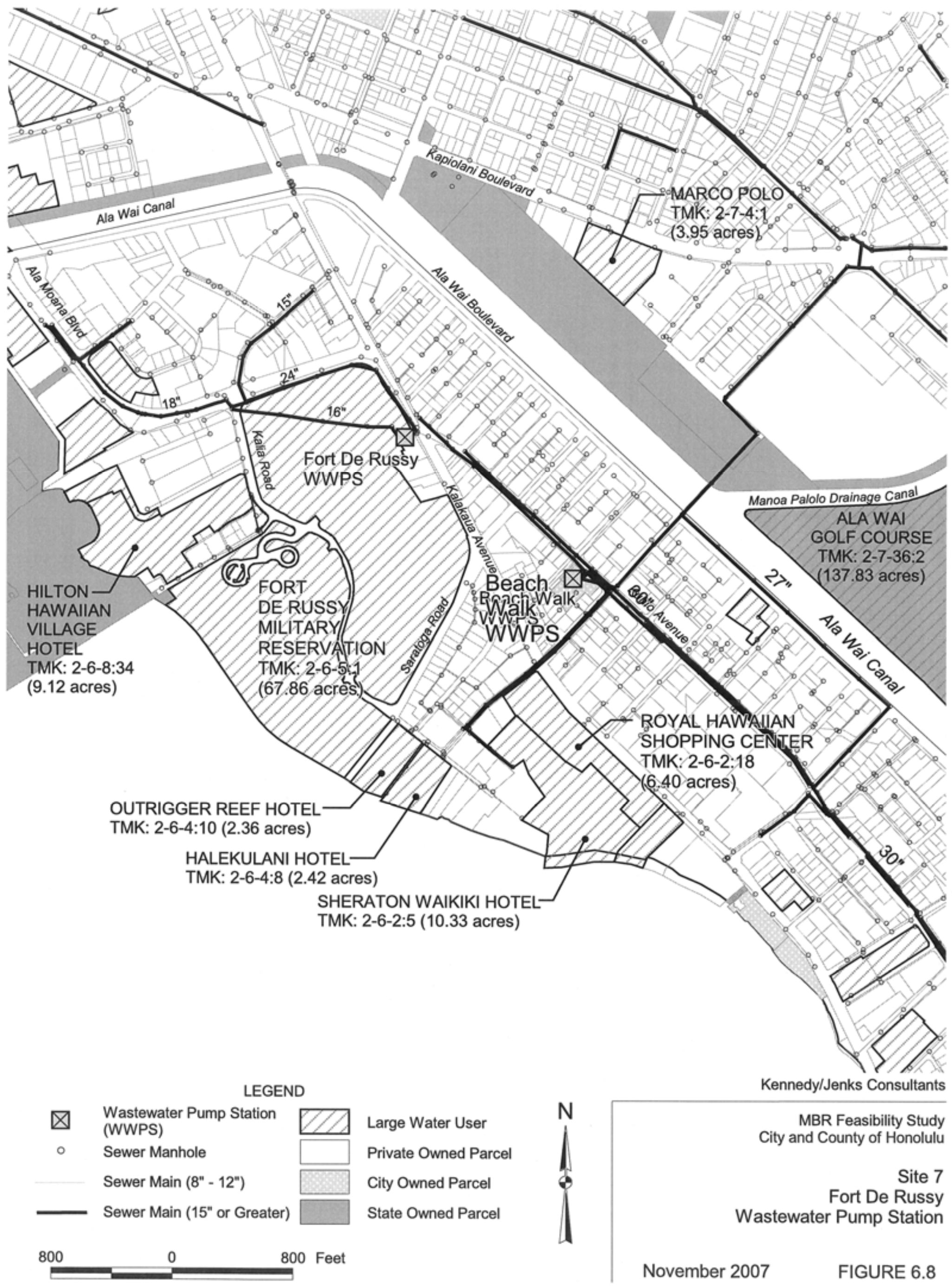
6.7 SITE 7—FORT DeRUSSY WASTEWATER PUMP STATION

The Fort DeRussy Armed Forces Recreation Center is located on the west end of Waikiki Beach. The Fort DeRussy complex consists of a large grassy park, the U.S. Army Museum of Hawaii, and the U.S. military's Hale Koa Hotel. A recycled water demand of 0.196 MGD primarily for park and ornamental landscape irrigation is anticipated. A number of other large water users in the vicinity of Fort DeRussy can also utilize nonpotable water for landscape irrigation. They include the Hilton Hotel Corporation, Sheraton Waikiki Hotel, Halekulani Hotel, Outrigger Reef Hotel, Island Colony Hotel, and a condominium run by Marco Polo Management.

Two pump stations near the Fort DeRussy property are identified in Figure 6.8, the Fort DeRussy Pump Station on Kalakaua Avenue and the Beach Walk Pump Station on Kuhio Avenue. The Fort DeRussy Pump Station, near the Fort DeRussy property, last year pumped 809.243 million gallons of wastewater for an average of 2.22 MGD. It is bordered by a gas station and 7-Eleven to the south, Kalakaua Avenue on the east, and Fort DeRussy property to the north and west. There is an open area north of the pump station that can house a 0.25 MGD MBR facility. Relocation of a few coconut trees may be necessary as well as the rerouting of a walkway. High salt content in the wastewater is again a concern, as the wastewater source is located along the island coastline. The Beach Walk Pump Station handled 4,268,095 million gallons last year for an average of 11.69 MGD.



Salt Lake Boulevard
NAVY
MARINE
GOLF
COURSE
TMK: 1-1-1:4
(422.72 acres)
Nimitz Highway/H-1 Viaduct
Puuloa Road
Fort Shafter
WWPS
Shafter Flats
WWPS
Kamehameha
Highway
WWPS
Lagoon Drive
HONOLULU
INTERNATIONAL
AIRPORT
TMK: 1-1-3:1
(2,503.26 acres)
KEEHI
LAGOON PARK
TMK: 1-1-3:6
(71.82 acres)
LEGEND
Wastewater Pump Station
(WWPS)
Sewer Manhole
Sewer Main (8" - 12")
Sewer Main (15" or Greater)
Large Water User
Private Owned Parcel
City Owned Parcel
State Owned Parcel
N
2000
0
2000 Feet
Kennedy/Jenks Consultants
MBR Feasibility Study
City and County of Honolulu
Site 6
Kamehameha Highway
Wastewater Pump Station
November 2007
FIGURE 6.7

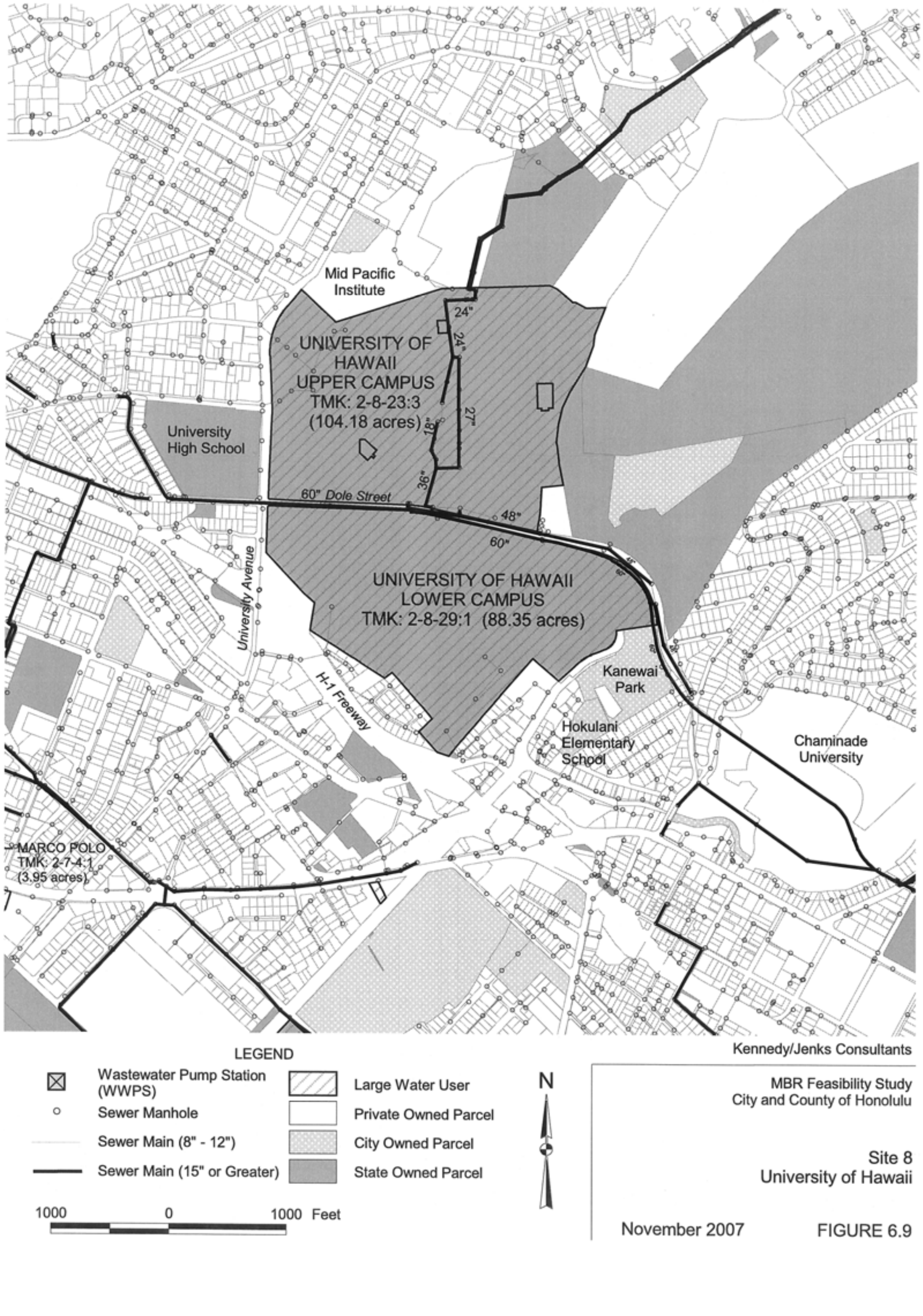

Ala Wai Canal
Kapiolani Boulevard
Ala Wai Boulevard
Ala Moana Blvd
MARCO POLO
TMK: 2-7-4:1
(3.95 acres)
15"
24"
18"
16"
Kalia Road
Fort De Russy
WWPS
Kalakaua Avenue
Manoa Palolo Drainage Canal
ALA WAI
GOLF COURSE
TMK: 2-7-36:2
(137.83 acres)
27"
Ala Wai Canal
Beach
Walk
WWPS
Beach Walk
WWPS
Kuhio Avenue
30"
HILTON
HAWAIIAN
VILLAGE
HOTEL
TMK: 2-6-8:34
(9.12 acres)
FORT
DE RUSSY
MILITARY
RESERVATION
TMK: 2-6-5:1
(67.86 acres)
Saratoga Road
ROYAL HAWAIIAN
SHOPPING CENTER
TMK: 2-6-2:18
(6.40 acres)
OUTRIGGER REEF HOTEL
TMK: 2-6-4:10 (2.36 acres)
HALEKULANI HOTEL
TMK: 2-6-4:8 (2.42 acres)
SHERATON WAIKIKI HOTEL
TMK: 2-6-2:5 (10.33 acres)
30"
LEGEND
Wastewater Pump Station (WWPS)
Sewer Manhole
Sewer Main (8" - 12")
Sewer Main (15" or Greater)
Large Water User
Private Owned Parcel
City Owned Parcel
State Owned Parcel
N
800
0
800 Feet
Kennedy/Jenks Consultants
MBR Feasibility Study
City and County of Honolulu
Site 7
Fort De Russy
Wastewater Pump Station
November 2007
FIGURE 6.8

6.8 SITE 8—UNIVERSITY OF HAWAII AT MANOA

The University of Hawaii at Manoa is located east of downtown Honolulu on the urban fringes. The 192-acre university campus includes the upper campus consisting of classroom buildings separated by large grassy areas and a lower campus with athletic fields and the parking structure. Dole Street separates the two parts of the campus. Recycled water can be used to irrigate the grassy areas and athletic fields on the campus. It is anticipated their total irrigation demands would require 0.138 MGD. A 0.25 MGD MBR facility would sustain this demand as well as provide nonpotable water to other users in the surrounding area, including the Mid-Pacific Institute, University Elementary and High School, Kanewai Park, and Hokulani Elementary School.

As shown in Figure 6.9, the nearest city-owned location for an MBR station is in Kanewai Park, next to the east side of the university campus. A stream separates the park from the university. A site investigation of the park revealed that the park site is unsuitable for an MBR facility. No space is available in the upper grounds of the park, on which exists a small recreation building, a comfort station, basketball courts, a playground, a pool, and tennis courts. Two softball fields occupy the lower grounds of the park. Additionally, there is an elementary school next to the park, and there is no clear separation between the park and elementary school grounds. A small fenced plot next to the tennis courts is the only possible location for the MBR facility on the park grounds, but there may be insufficient space on this plot.

A more probable location for the MBR facility is on the campus grounds. Wastewater can be withdrawn directly from the large 27-in. gravity sewer main that runs through the center of the upper campus. There is also a 60-in. and a 48-in. sewer main on Dole Street. However, it should be noted that these two sewer mains are very deep. Identification of a site on the campus would require coordination with the university.


Mid Pacific Institute
UNIVERSITY OF HAWAII UPPER CAMPUS TMK: 2-8-23:3 (104.18 acres)
University High School
24"
24"
27"
18"
36"
60" Dole Street
48"
60"
UNIVERSITY OF HAWAII LOWER CAMPUS TMK: 2-8-29:1 (88.35 acres)
University Avenue
H-1 Freeway
Kanewai Park
Hokulani Elementary School
Chaminade University
MARCO POLO TMK: 2-7-4:1 (3.95 acres)
LEGEND
Wastewater Pump Station (WWPS)
Sewer Manhole
Sewer Main (8" - 12")
Sewer Main (15" or Greater)
Large Water User
Private Owned Parcel
City Owned Parcel
State Owned Parcel
N
1000 0 1000 Feet
Kennedy/Jenks Consultants
MBR Feasibility Study
City and County of Honolulu
Site 8
University of Hawaii
November 2007
FIGURE 6.9

The potential sites and users are summarized in Table 6.1.

Table 6.1. Potential MBR sites and nonpotable water users

Site	Potential user
Central Oahu Regional Park	Central Oahu Regional Park Waikele Community Association Kamehameha Highway irrigation
Public Baths Wastewater Pump Station	Kapiolani Park and Honolulu Zoo
Ala Wai Golf Course	Ala Wai Golf Course
Sand Island WWTP	Sand Island WWTP Division of Aquatic Resources
Moana Park Wastewater Pump Station	Ala Moana Recreation Center (Ala Moana Regional Park, Ala Moana Beach Park, and Magic Island)
Kailua Beach Park	MPCC Lanikai Elementary School
Kamehameha Hwy Pump Station	HIA Keehi Lagoon Park Navy-Marine Golf Course Nimitz Highway median irrigation
Fort DeRussy Pump Station	Fort DeRussy Recreation Center Hilton Hotel Corporation Sheraton Waikiki Hotel Halekulani Hotel Outrigger Reef Hotel Island Colony Hotel Marco Polo Management
University of Hawaii, Manoa	University of Hawaii, Manoa University of Hawaii Elementary and High School Mid-Pacific Institute Kanewai Park Hokulani Elementary School

CHAPTER 7

ANCILLARY BENEFITS

In addition to strict monetary benefits, there are ancillary benefits that result from the implementation of satellite MBR reclamation facilities. These ancillary benefits include conservation of existing potable water resources, deferment of the development of new water resources, and potential avoidance of existing infrastructure expansion (such as water and wastewater facilities). The valuation of these benefits needs to be carefully considered by impacted agencies to determine the true costs and benefits of a given project. Each of these benefits is discussed below.

7.1 PRESERVATION OF OAHU'S POTABLE WATER SUPPLY

A major environmental benefit of water reuse on the island of Oahu is the sustenance of the island's natural water supply. Virtually all of Oahu's domestic water supply comes from an underground water reservoir that is recharged from rainfall percolating through the island soil and rock. Underwater caprock, spanning from inland to shoreline, holds a lens-shaped body of fresh water in place. The fresh water floats on the denser layer of brackish water that exists as a transition zone between the fresh water and seawater. The thickness of this zone changes with seasonal influences and the drafting of the fresh water from wells. The transition zone expands and the lens of fresh water shrinks when water from the aquifer is pumped faster than it is recharged. The water level in the wells drops and the water supply can be contaminated with high levels of salt when the aquifer is overpumped. The production of recycled water creates an alternative water supply for nonpotable applications and alleviates the need for fresh water from this reservoir. Water reuse reduces strain on the aquifer, allowing it to recharge and promoting the preservation of this natural supply of fresh water.

7.2 AVOIDANCE OF DEVELOPMENT OF NEW WATER RESOURCES

While water demands continue to grow with the island's population, the island's potable water supply remains virtually constant and even diminishes with development. Development creates more impervious area, which reduces the amount of rainfall that recharges the aquifer. Wastewater reclamation can supply water for nonpotable applications and will help conserve potable water for potable uses. The reduced strain on the island's natural water supply will allow it to serve the island for many more years and postpones the need to develop other water sources to meet water demands.

7.3 AVOIDANCE OF UPSIZING OF WATER TRANSMISSION MAINS

As new water demands emerge in response to the growing population, water transmission main capacity must also be increased. Satellite MBR facilities can supply R-1 water for nonpotable uses, thereby relieving some of the demand and subsequently the need for capital investment in the upsizing. This recycled water supply can alleviate demands on the potable supply that is conveyed through the existing distribution system, thereby eliminating the need to upsize existing water transmission mains.

7.4 WASTEWATER FACILITY IMPACTS

As water demands increase, so too will the generation of wastewater. Impacts to the wastewater conveyance and treatment facilities could be mitigated by the implementation of a satellite MBR facility if an alternate disposal method were available, such as a reject water storage pond.

Our vision for the satellite MBR facilities does not include such storage facilities, and it is assumed that noncompliant water and residual biosolids would be returned to the source of the wastewater for treatment downstream. As such, no direct benefit for deferment of conveyance or treatment capacity results from the implementation of satellite MBR reclamation. However, in the case of Oahu, there are some potential benefits in regard to reaching EPA-mandated recycling requirements that should be considered. In this case, the cost of compliance and not the avoided cost of wastewater facility capacity upgrades is the appropriate metric for comparison.

CHAPTER 8

DEVELOPMENT OF COSTS

Costs for each of the discrete sizes of systems (0.1, 0.25, 0.5 and 1.0 MGD) were developed by using information from the various vendors. An attempt has been made to put each of the vendors on the same basis in terms of replacement costs, energy costs, etc.

8.1 ASSUMPTIONS

The following assumptions were made relative to the cost development.

8.1.1 No Provision of Storage

It has been assumed for the purpose of this analysis that storage will be provided by the end user or otherwise made available to the project. Recycled water will be produced on a steady flow basis to help reduce the costs of the MBR equipment. Storage costs are excluded from this estimate.

8.1.2 No Inclusion of Distribution Costs

It is difficult to provide a cost for distribution piping given the variability in the routing of the pipeline and the potential for interference with other utilities. This cost is excluded from this estimate.

8.1.3 No Sludge Treatment

For the satellite MBR facility, waste biosolids are returned to the wastewater source for treatment downstream at the centralized facility. This practice reduces the potential for objectionable odors being released from the satellite facility and also reduces the size of the satellite facility.

8.1.4 Land and Easements

It has generally been assumed that land to site the satellite MBR facility will be on city-owned property and that there are no costs associated with this approach.

8.2 TREATMENT OBJECTIVES

The following influent wastewater characteristics (Table 8.1) and effluent goals (Table 8.2) were assumed to size the various MBR systems.

Table 8.1. Influent wastewater characteristics

Parameter	Value
Temp	20 °C
BOD	270 mg/L
TSS	230 mg/L
Total nitrogen	40 mg/L
Total phosphorus	7 mg/L
Alkalinity	230 mg of $CaCO_3$/L
Fecal coliform	3.9×10^7 CFU/100 mL

Table 8.2. Effluent goals[a]

Parameter	Value
BOD	10 mg/L
TSS	10 mg/L
Fecal coliform	<2.2 CFU/100 mL
UVT_{254}	65% (Assume UV disinfection)
Turbidity	0.2 NTU (Assume UV disinfection)

[a]R-1 as defined by the State of Hawaii's DOH.

8.3 COST ITEMS

8.3.1 Preliminary Treatment

Preliminary treatment for a satellite MBR facility would include coarse screens, grit removal, and fine screens. Coarse screens are based on 6-mm units with integral dewatering apparatus. Grit removal is based on the Eutek Teacup and grit washer rather than on a conventional aerated grit chamber to reduce space requirements. Fine screens are based on a 2-mm rotating drum screen.

8.3.2 MBR Systems

Cost quotations were received from Huber, US Filter, and Zenon for their MBR systems at each of the designated flow capacities. Their quotes varied in the level of detail provided, and an attempt was made to make the quotes comparable. The quotes generally included the following items:

- Membranes
- Permeate pumps
- Blowers and aeration equipment

- Integral piping and valves
- Packaged control system
- Clean-in-place systems
- Training and startup

8.3.3 Process Tanks and Structures

Process tanks for the MBR process are not included in the costs provided by the manufacturers. Two sets of tanks—aeration and membrane—are provided. The aeration tank utilizes fine bubble diffusers to provide oxygen to the activated sludge process where most of the treatment occurs. Coarse bubble diffusers are used in the membrane tank to scour the outside of the membranes and keep them clean. It has been assumed that the tanks will be constructed of concrete for long-term durability and will utilize common wall construction to reduce the overall cost.

Since this facility will be located within public locations, it was decided that it should be enclosed in a building to help mask odors and prevent vandalism. A simple concrete masonry unit building has been estimated based on the approximate footprint required.

8.3.4 Disinfection System

Disinfection is necessary to destroy or inactivate pathogenic organisms and is a requirement for recycled water production. Two common methods of disinfection are chlorination and UV light radiation. Because space at the site is a concern and because chlorination requires contact time with the water to properly disinfect, it was decided that UV disinfection would be provided.

8.3.5 Pumping System

A pumping system is needed to deliver the treated water to the end user. An assumption regarding the discharge pressure required (60 psi) was made to size the pump and develop operational (energy) costs.

8.3.6 Operational Costs

8.3.6.1 Energy

Energy costs were estimated by using the various motor horsepower ratings and the estimated duration of operation. Energy costs were assumed to average $0.17/kWh.

8.3.6.2 Chemicals

Maintenance of the membranes in an MBR system involves periodic chemical cleaning with sodium hypochlorite and/or citric acid solutions. Chemical cleaning is necessary to maintain and restore membrane performance, prevent rapid fouling, and extend the life of the membranes. The annual chemical cost was extrapolated from the manufacturer’s cost quotation.

8.3.6.3 Manpower

It is assumed that 1 man-year (two men, half-time) would be sufficient for operating the MBR facility.

8.3.6.4 Membrane Replacement

Membrane flux inevitably declines over time due to irreversible fouling in spite of regular cleanings. The expected lifetime of the membranes has increased in recent years, and manufacturers are now offering 8- to 10-year warranties. An 8-year life is assumed for this study, and annual replacement costs reflect one-eighth of the total replacement cost.

8.3.6.5 UV Equipment Replacement

According to the EPA fact sheet on UV disinfection (EPA, 1999b), the average lamp life ranges between 8760 and 14,000 working hours, and the lamps are typically replaced after 12,000 hours of use. The ballast and sleeves must also be replaced periodically. Ballasts last about 10 to 15 years and are usually replaced every 10 years. Quartz sleeves last approximately 5 to 8 years and are generally replaced every 5 years.

8.4 SUMMARY OF COSTS

The capital and annual operation and maintenance (O&M) costs for an MBR facility are summarized in Table 8.3.

Table 8.3. Summary of costs

Item	Installation capacity (in MGD)			
	0.1	**0.25**	**0.5**	**1.0**
Capital costs[a]				
Preliminary treatment	$194	$389	$518	$751
MBR system	$406–$688	$713–$1000	$1251–$1281	$1625–$2288
Process tanks/structures	$655	$1064	$1389	$2181
UV system	$156	$214	$214	$281
Pumping system	$20	$35	$50	$75
Subtotal	$1431–$1713	$2415–$2702	$3422–$3452	$4913–$5576
Electrical/instrumental (15%)	$215–$257	$362–$405	$513–$518	$737– $836
Mechanical (10%)	$143–$171	$242–$270	$342–$345	$491–$558
Site work (15%)	$215–$257	362–$405	$513–$518	$737–$836
Subtotal	$2004–$2398	$3381–$3783	$4790–$4833	$6878–$7806
Contractor OH&P (15%)[b]	$301–$360	$507–$567	$719–$725	$1032–$1171
Contingency (25%)	$501–$600	$845–$946	$1198–$1208	$1720–$1952
Total capital cost	$2804–$3357	$4733–$5296	$6707–$6766	$9630–$10,029
Annualized capital cost[c]	$204–$244	$344–$385	$487–$492	$700–$794
O&M costs[a]				
Energy	$17–$31	$37–$43	$74–$84	$141–$168
Chemicals	$0.2	$0.30	$0.70	$1.4
Manpower	$23	$23	$45	$45
Membrane replacement[d]	$8–$12	$14–$21	$28–$42	$111–$166
UV equipment replacement	$10	$25	$50	$100
Total O&M cost	$58–$76	$99–$112	$198–$222	$398–$480
Annualized cost	$262–$320	$443–$497	$685–$714	$1098–$1274

[a]All capital and O&M costs in thousands of dollars, based on ENR Construction Cost Index value of 8092.
[b]OH&P is overhead and profit.
[c]Capital costs are amortized on a 6%, 30-year basis.
[d]Membrane replacement based on an 8-year life.

CHAPTER 9

RECOMMENDATIONS

9.1 FURTHER WORK

The following issues should be considered in the evaluation of the identified sites as potential locations for decentralized MBR reclamation facilities:

- Water quality of the source
- Total nonpotable demand of potential users in proximity of facility
- Sufficient wastewater flow from source
- Total distance of users from the source
- Cost and constructability of the MBR facility and distribution system
- Flood zones
- Beneficial impact of the facility
- Community issues

Each issue is discussed with respect to the various sites in the sections below.

9.1.1 Source Water Quality

The quality of the wastewater must be checked at each site to ensure that the treated water will be suitable for nonpotable use. Of primary concern is the salinity of the wastewater, as MBR treatment does not treat salinity and maintaining salt levels at tolerable levels is of utmost importance in irrigation applications. Wastewater from sources near the island coastline is prone to elevated levels of total dissolved solids (TDS) due to seawater infiltration of the sewer collection system. Potential sites near the coast include Kailua Beach Park, the Public Baths Pump Station and the park on Leahi Avenue, the Fort DeRussy Pump Station, the Moana Pump Station, and the Kamehameha Highway Pump Station. Although Sand Island WWTP is just off the coast of Oahu, some of the wastewater pumped to the plant is from further inland and is less likely to have high salt concentrations. If this source wastewater can be intercepted prior to comingling with other coastal wastewater sources, it may be of acceptable quality. In addition, the wastewater from the sewer lines near Halawa Quarry should be tested for industrial pollutants, as the nearby sewer lines convey wastewater from industrial facilities. Water quality tests must still be performed on the wastewater from all sites.

9.1.2 Total Nonpotable Water Demand

While the total nonpotable water demands at all sites are greater than that supplied by the smallest discrete MBR unit under consideration in this study (0.1 MGD), sites with larger combined water demands provide greater benefit in terms of conserving potable water supplies. Additionally, the larger MBR facilities are more cost effective due to economies of scale. Therefore, it would be more favorable to construct an MBR facility in areas with larger demand. The Ala Wai Golf Course, Kapiolani Park, and Honolulu Zoo have the largest combined nonpotable water demand of 23,050 thousand gallons per month or 0.77

MGD. The sites with the next largest demand are Central Oahu Regional Park, Fort DeRussy Park, Keehi Lagoon Park, and Sand Island WWTP, with demands of 16,322, 12,070, 11,170, and 9205 thousand gallons per month, respectively, which are between 0.25 and 0.5 MGD. It should be noted that the quantities for Central Oahu Regional Park, Fort DeRussy Park, and Keehi Lagoon Park include demand by nearby irrigational areas, hotels, and airport facilities, which may not receive nonpotable water from the MBRs if supplying them is determined to be uneconomical based on their distance from the MBRs. Thus, the demands at the three sites may be less. Halawa Quarry has a demand of 7978 thousand gallons per month, just exceeding 0.25 MGD. The remaining sites, Ala Moana Regional Park, Kailua Beach Park, and the University of Hawaii at Manoa, have demands of 7300, 5551, and 4125 thousand gallons per month, respectively, which are between 0.1 to 0.25 MGD. Table 9.1 summarizes the nonpotable demands at each potential site.

Table 9.1. Nonpotable water demand and MBR capacity for each potential site

Site	Demand in 1000 gal/month (MGD)	MBR capacity (MGD)
Parcel next to public baths or park on Leahi Avenue	23,050 (0.7683)	1.0
Central Oahu Regional Park	16,322 (0.5440)	0.5
Fort DeRussy Park	12,070 (0.4023)	0.5
Keehi Lagoon Park	11,170 (0.3723)	0.5
Sand Island WWTP	9205 (0.3068)	0.5
Ala Moana Regional Park	7300 (0.2433)	0.25
Kailua Beach Park	5551 (0.1850)	0.25
University of Hawaii, Manoa	4125 (0.1375)	0.25

In addition to the total demand, the diurnal and seasonal demands will have to be analyzed. The MBR systems were developed to run on a steady flow basis. While there is some innate peaking capacity, attempting to match treatment capacity with demand will result in higher equipment costs. Using the potable water system to deal with peak demands, providing sufficient storage to avoid on-demand treatment or pumping, and altering demand patterns are all possibilities for addressing varying demands.

9.1.3 Sufficient Wastewater Flows from Source

It was estimated that a 15-in.-diameter sewer main at minimum slope (specified in the City Design Standards) conveys approximately 1 MGD of wastewater at 62% capacity. Based on this estimate, it was assumed that all sewer lines with diameters of 15 in. and greater would probably have sufficient flows to supply the size ranges of MBRs considered in the study. This assumption was made to aid in the identification of a potential site. Now that several possible sites adjacent to wastewater sources for MBR facilities have been identified, wastewater flows at these sites must be verified to ensure sufficient flows.

Totalizer flow data dating back to 1993 for the Moana Park, Kamehameha Highway, Fort DeRussy, and Public Baths wastewater pump stations were obtained from the city's

Department of Design and Construction (DDC). The totalizer flows represent the amount of wastewater discharged through the force main from the pump station within a 24-hour period. Recorded data include the peak, average, and minimum totalizer flow for each month. The lowest flow since January 2000 and average flow since January 2006 are summarized in Table 9.2 for each pump station.

Table 9.2. Wastewater source flows at potential MBR sites

Site	Pump station totalizer flow (MGD)		Measured flow in sewer manhole (MGD)		Avg. flows from INFIX (MGD)
	Low	Avg.	Low	Avg.	
Fort DeRussy Park	1.032	2.303	—	—	—
Parcel next to Public Baths Pump Station	0.127	0.458	—	—	—
Keehi Lagoon Park	1.214	5.925	—	—	—
Ala Moana Regional Park	0.257	0.765	—	—	—
University of Hawaii, Manoa	—	—	0.5468	1.5139	—
Kapiolani Park on Leahi Avenue	—	—	—	—	0.5660
Halawa Quarry	—	—	—	—	0.1469
Kailua Beach Park	—	—	—	—	0.1907
Central Oahu Regional Park	—	—	—	—	0.7240

The Moana Park, Kamehameha Highway, and Fort DeRussy pump stations all have sufficient flows to meet estimated nonpotable demands of the large users in the area. The Public Baths Pump Station does not have sufficient flows to meet the total nonpotable demand in the area. There is enough wastewater from the pump station for a 0.25 MGD facility, as flows from the pump station typically average between 0.4 and 0.6 MGD. However, the combined demand of Kapiolani Park, Honolulu Zoo, and Ala Wai Golf Course is estimated to be 0.77 MGD. A 0.25 MGD MBR facility at the Public Baths Pump Station site would be able to meet approximately only a third of the nonpotable water demand and only half of the water demand of Kapiolani Park and Honolulu Zoo alone, which is approximately 0.58 MGD.

Wastewater must be drawn directly from sewer lines for MBR facilities at Kailua Beach Park, the University of Hawaii at Manoa, the Kapiolani Park on Leahi Avenue, Halawa Quarry, and Central Oahu Regional Park. There must be sufficient flow in the sewer lines, not only to supply wastewater to the MBR facility but also to flush sludge returned to the system. DDC has monitoring stations to collect flow data at certain sewer manholes located throughout the island. There is a monitoring station at only one of the sites, in a sewer manhole along the sewer line that runs through the University of Hawaii. Flow data provided by DDC from this monitoring station are from January 2003. The minimum measured flow in the sewer manhole is 0.55 MGD, and the average flow is 1.51 MGD. A diurnal flow pattern, peaking twice a day and then dipping, is observed in the data. For the remaining four sites where flow monitors were not available, INFIX data were obtained. INFIX is a database maintained by the city that provides estimates of average flows and other flows in sewer lines based on estimated population and generated wastewater flow per capita. The average wastewater flows for the four sites are also listed in Table 9.2.

9.1.4 Total Distance of User from Source

Although the potential users of nonpotable water are within a mile of the source, the actual length of the distribution lines must be considered. Additionally, some sites have multiple potential users and the total distance of the distribution lines must be taken into account. The suggested location for an MBR facility serving the MPCC is off site in Kailua Beach Park. The necessary length of distribution piping from the park to the edge of the club's property, along Alala Street, is less than half a mile. Suggested locations for MBR facilities for the University of Hawaii, Ala Moana Recreation Center, Sand Island WWTP, and Halawa Quarry are on site. Therefore, distribution piping at these sites should be minimal. Facilities serving Keehi Lagoon Park, Central Oahu Regional Park, and Fort DeRussy Park are also on site. However, there are other nearby large water users and the economics of servicing the other sites must be evaluated. Two sites were identified as potential locations for an MBR facility to serve Kapiolani Park, Honolulu Zoo, and Ala Wai Golf Course: the park on Leahi Avenue and the parcel next to the Public Baths Pump Station. The Public Baths Pump Station is the more favorable of the two sites for minimizing impact to the functionality of the parcel. However, the Public Baths Pump Station is farther from the Ala Wai Golf Course and may require more than a mile of distribution piping. The park on Leahi Avenue is a more central location with respect to the three large users.

In addition, a utility investigation must be performed to determine if there is a reasonable corridor for the routing of the transmission and distribution lines or if there are numerous forms of interference that will significantly increase the cost of construction.

9.1.5 Cost and Constructability

The costs developed in Chapter 8 were based on discrete sizes and for a generic site. Actual site conditions and design flow rates may impact the construction cost for a given site. Local conditions such as proximity to neighboring houses or businesses could dictate that additional architectural or landscape architectural treatments are required to further reduce the visibility of the facility.

In addition, several of the sites are located in high-visibility areas that could severely impact either vehicle or pedestrian traffic. Disruption of public access can be a logistical and public relations nightmare. While all of the projects will cause some level of impact, the ones that could be most disruptive include Public Bath Pump Station, Fort DeRussy Pump Station, and Moana Pump Station.

9.1.6 Beneficial Impact of Facility

In determining the sites to pursue, the beneficial impact of a facility at that site should be considered. Pumpage from some aquifer systems is nearing sustainable yield, and removal of users from the system with large nonpotable water demands would help to alleviate strain on those systems. Fort DeRussy Park, Kapiolani Park, the Honolulu Zoo, Ala Wai Golf Course, and the University of Hawaii at Manoa are all large users of the Palolo Aquifer System, which is in danger of exceeding sustainable yield. Removing these three groups of large users from the system could add about 1 MGD to the area's potable water supply. The Nuuanu and Waimalu aquifers would also greatly benefit from having the nonpotable portions of the water demands of the HIA, Keehi Lagoon Park, and Ala Moana Recreation Center removed from their systems. Listed in Table 9.3 (and shown in Figure 9.1) are the aquifer systems that each site draws water from and the unused sustainable yield of those systems.

Table 9.3. Remaining sustainable yield of aquifer systems supplying each group of large water users

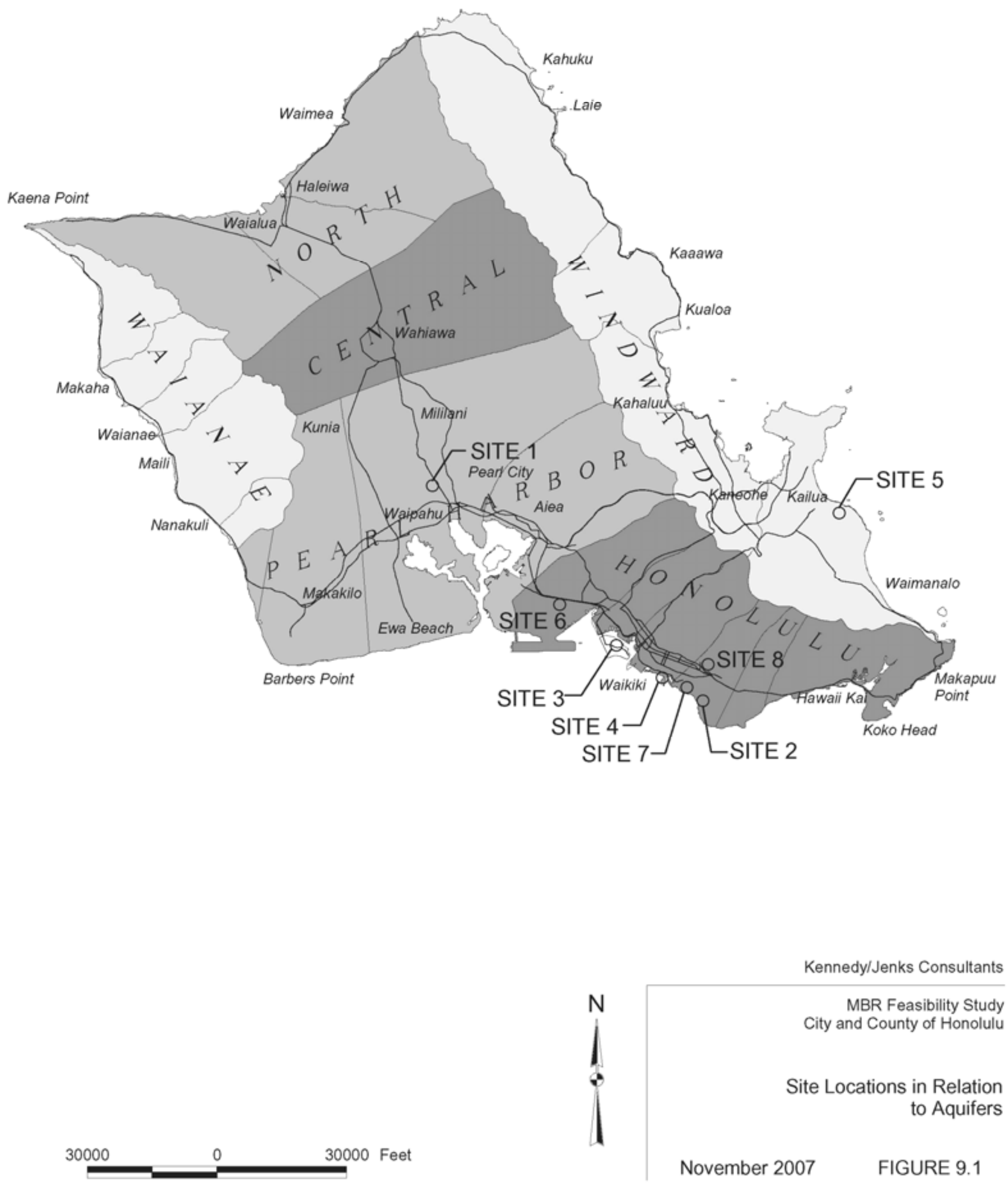
Large water user	Aquifer system	Sustainable yield minus pumpage (MGD)
Fort DeRussy Park	Palolo	0.569
Kapiolani Park, Honolulu Zoo, Ala Wai Golf Course	Palolo	0.569
University of Hawaii, Manoa	Palolo	0.569
HIA and Keehi Lagoon Park	Moanalua	0.660
Ala Moana Recreation Center	Nuuanu	1.649
MPCC	Waimanalo	7.371
Central Oahu Regional Park	Waipahu and Waiawa	50.646
Sand Island WWTP	—	—

An additional benefit of an MBR WRF at the University of Hawaii at Manoa is its potential to serve as an educational and research facility for the university.

9.2 SUMMARY OF RECOMMENDATIONS

Table 9.4 presents a summary of the various sites identified as part of this screening process.

In addition to the acceptance of the satellite MBR facility itself, as mentioned in the Cost and Constructability section, public education will be required. As indicated in the survey responses, there are still some misconceptions about the suitability of recycled water for the irrigation of food crops and athletic fields and playgrounds. While states such as California have performed outreach to the point that water recycling is generally accepted, the same cannot be said of Hawaii. Both BWS and CCH will need to increase their efforts in educating the public about the benefits of water recycling in order to facilitate its acceptance in the general community.


Kahuku
Laie
Waimea
Haleiwa
Kaena Point
Waialua
NORTH
CENTRAL
Wahiawa
WAIANAE
WINDWARD
Kaaawa
Kualoa
Makaha
Waianae
Maili
Kunia
Mililani
Kahaluu
SITE 1
Pearl City
PEARL HARBOR
Aiea
Kaneohe
Kailua
SITE 5
Nanakuli
Waipahu
HONOLULU
Waimanalo
Makakilo
Ewa Beach
SITE 6
SITE 8
Barbers Point
SITE 3
Waikiki
Hawaii Kai
Makapuu Point
SITE 4
Koko Head
SITE 7
SITE 2
30000 0 30000 Feet
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Kennedy/Jenks Consultants
MBR Feasibility Study
City and County of Honolulu
Site Locations in Relation to Aquifers
November 2007
FIGURE 9.1

Table 9.4. Summary of recommended sites

Site	Water quality issue	Demand (MGD)[a]	Adequate wastewater flows?	Constructability issues?	Distance from source	Beneficial impact
Kailua Beach Park	Salinity	0.19	Yes	No	<0.5 mi	—
University of Hawaii	—	0.14	Yes	No	On site	Aquifer near SY;[b] potential research facility
Public Baths Pump Station	Salinity	0.77	No	Yes	1 mi	Aquifer near SY
Fort DeRussy Pump Station	Salinity	0.40	Yes	Yes	On site; <1 mi for other users	Aquifer near SY
Moana Pump Station	Salinity	0.24	Yes	Yes	On site	Aquifer near SY
Sand Island WWTP	—	0.31	Yes	No	On site	—
Kamehameha Hwy Pump Station	Salinity	0.11	Yes	No	On site	Aquifer near SY
Central Oahu Regional Park	—	0.54	Yes	No	On site	—

[a]Sum of estimated nonpotable demand of potential users, including nonindependent users near site.
[b]SY, sustainable yield.

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APPENDIX I-A

LARGEST USERS FROM BWS RECORDS

User no.	Bill payer	Land use	Existing flows in May 2003	Avg. flows in 2003	Avg. flows in 2002
1	Department of Environmental Services	State	60,000	75,500	—
2	C.O.–Kaneohe MCAS	Military	55,055	56,945	66,459
3	Chevron USA Inc.	Industrial	—	49,116	49,561
4	Department of Environmental Services	Golf course	30,000	48,000	—
5	Department of Environmental Services	Golf course	30,000	48,000	—
6	Hawaii Prince Golf Club (R1)	Golf course	25,202	38,039	—
7	Coral Creek Golf (R1)	Golf course	19,531	31,475	—
8	Dept. of Transportation	State	23,331	23,824	24,112
9	Kapolei Golf Course (R1)	Golf course	25,009	20,774	--
10	Dept. of Transportation	State	14,603	16,851	15,568
11	University of Hawaii	State	20,593	16,716	16,891
12	Sheraton Makaha	Golf course	19,583	14,261	15,279
13	US Filter (RO Water)	Commercial	—	14,020	—
14	Dept. of Transportation	State	10,809	13,324	14,549
15	Hilton	Hotel	11,059	12,837	12,877
16	Sheraton Hawaii Corp.	Hotel	9483	11,593	10,389
17	Dept. of Parks & Rec.–Central Regional Park	City	10,200	11,462	—
18	US Filter (RO Water)	Commercial	—	11,079	—
19	Hale Koa Hotel	Hotel	13,695	10,940	11,026
20	Hawaii Kai Golf Course	Golf course	9554	10,935	13,895
21	Department of Environmental Services–Honolulu Zoo	State	12,552	10,419	10,230
22	Halawa Prison	State	9855	10,026	8988
23	Dept. of Parks and Rec.–Hon. Zoo	City	3987	8577	8788
24	Hyatt Regency Waikiki	Hotel	6340	7873	7135
25	Dept. of Parks and Recreation–Magic Island	City	9740	7620	8260
26	Department of Environmental Services	WWTP	5450	7416	9473
27	Hilton	Hotel	6532	6870	4555
28	United Laundry Service	Commercial	5908	6776	6825
29	Ihilani Resort	Hotel	4332	6676	5747
30	Department of Environmental Services–Ala Wai	Golf course	5696	6420	7433

User no.	Bill payer	Land use	Existing flows in May 2003	Avg. flows in 2003	Avg. flows in 2002
31	Azabu USA	Hotel	5834	6242	6170
32	American Linen	Commercial	5183	5839	6221
33	Hale Koa Hotel	Hotel	5889	5775	5845
34	MPCC	Golf course	5737	5660	5907
35	Halekulani Hotel	Hotel	4942	5585	5115
36	Hawaiian Cement	Commercial	5740	5431	4626
37	Dept. of Parks and Rec.–Keehi	City	5607	5200	5193
38	Country Club Village	Multi-Unit	5031	5158	4844
39	Div. of Pks., Mtn., & Rec.	Commercial	5426	5053	5101
40	Ilikai Apartment Bldg.	Mixed Comm/Multi	5024	5035	4806
41	Tesoro	Commercial	2728	5021	15,431
42	Crosspointe Comm.	Multi-Unit	5265	4948	5071
43	Beretania North AOAO	Multi-Unit	5055	4918	4416
44	HECO	Commercial	5994	4692	5652
45	Dept. of Parks and Rec.–Sandy Bch	City	5068	4625	3833
46	Ameron H C & D	Industrial	3618	4621	5006
47	H R R V	Commercial	3607	4620	5182
48	Department of Environmental Services	WWTP	4298	4566	4756
49	St. Francis Hospital	Hospital	4275	4458	4272
50	HHA	Multi-Unit	3941	4372	4418
51	Hawaiian Adventure Park	Commercial	3224	4362	4742
52	Pacific Beach Hotel	Hotel	3115	4330	4657
53	Hawaii Prince Hotel	Hotel	3923	4286	4043
54	Outrigger Hotels	Hotel	4123	4269	3869
55	Pacific Dairy	Agriculture	—	4148	4037
56	Marco Polo Management	Mix Comm/Multi	3529	4004	3893
57	OCCC	State	4083	3950	4156
58	HHA	Multi-Unit	3686	3929	3669
59	KCC	State	4003	3881	4197
60	McKinley High School	School	5721	3862	4215
61	HHA	Multi-Unit	4345	3850	4032
62	Kahuku High School	School	3858	3840	3478
63	Div. of Pks., Mtn, & Rec.–Wahiawa Comm. Garden	City	3300	3815	2290
64	Div. of State Parks	State	4179	3807	3157
65	AOAO Discovery Bay	Mix Comm/Multi	3735	3803	3777
66	Pauahi Management	Commercial	3155	3795	3673
67	Island Colony Hotel	Hotel	3469	3702	3279
68	DLNR	State	3066	3648	4346
69	Hale Koa Hotel	Hotel	3506	3644	3920

User no.	Bill payer	Land use	Existing flows in May 2003	Avg. flows in 2003	Avg. flows in 2002
70	Queen Emma Condo	Multi-Unit	—	3642	4098
71	HHA	Multi-Unit	3928	3618	2635
72	Rainbow Hawaii	Agriculture	—	3505	3107
73	HECO	Commercial	1285	3496	5507
74	Yacht Harbor Towers	Multi-Unit	3255	3404	3280
75	St. Francis Medical West	Hospital	3036	3320	3021
76	Makakilo Cliffs	Multi-Unit	3044	3281	3321
77	Turtle Bay Hilton	Hotel	2627	3271	3883
78	Kahala Mandarin Hotel	Hotel	3315	3241	3043
79	Ppi Del Monte	Commercial	2332	3209	3099
80	Makaha Valley Towers	Multi-Unit	2485	3205	3112
81	Waianae High School	School	1973	3195	3608
82	Honolulu Park Pl.	Multi-Unit	3140	3189	2712
83	Palm Court	Multi-Unit	3035	3178	3578
84	Waikiki Beach Marriott Resort	Hotel	2523	3150	3078
85	Kaiser Foundation Hospital	Hospital	3005	3137	2885
86	Fairway Village	Multi-Unit	2323	3136	3246
87	Meadow Gold Dairies	Industrial	2927	3115	3168
88	US Filter (RO Water)	Commercial	—	3094	—
89	Dole Corp.	Commercial	2789	3074	2907
90	Century West 14200	Multi-Unit	3752	3048	2825
91	Parkglen Waikele	Multi-Unit	2512	3017	3026
92	Sunset Lakeview Apt.	Multi-Unit	3478	2993	3144
93	Div. of Pk. Mtn. & Rec.	City	4569	2946	2120
94	Kapolei Shop Center	Commercial	3291	2931	3031
95	Dept. of Air Force	Federal	2793	2927	1606
96	Kahuku Village Assoc.	Mixed Comm/Multi	2520	2923	2831
97	Kapiolani Manor	Multi-Unit	1910	2908	3386
98	Kukui Plaza	Multi-Unit	2716	2906	2469
99	Waikele Comm. Assoc.	Irrigation	1905	2,903	3307
100	Ilima Intermediate School	School	3055	2901	3240
101	Bishop Square Management	Commercial	2554	2889	2996
102	Pepsi Cola 7UP	Commercial	2415	2824	2965
103	Iolani School	Multi-Unit	3084	2806	2549
104	1151 Mapunapuna St	Commercial	4886	2804	2136
105	1 Waterfront Towers	Multi-Unit	2504	2798	2474
106	Honolulu Tower	Multi-Unit	3132	2766	2470
107	Olomana Golf Links	Golf Course	1382	2758	2430
108	University of Hawaii	State	2573	2712	1101
109	Palm Villas	Multi-Unit	2380	2710	2655

User no.	Bill payer	Land use	Existing flows in May 2003	Avg. flows in 2003	Avg. flows in 2002
110	Iolani Ct. Plaza	Multi-Unit	2571	2703	2269
111	HI Inst.Marine Biology	State	1532	2686	3048
112	Waikele Comm. Assoc.	Irrigation	2607	2685	3561
113	Div. of State Parks	State	3260	2672	2654
114	Waikiki Beach Marriott Resort	Hotel	2196	2635	2886
115	Department of Environmental Services–Makalena	Golf Course	458	2619	8924
116	Palolo Valley Homes LP	Multi-Unit	2611	2617	3200
117	Waipuna Assoc.	Multi-Unit	2141	2615	2908
118	Lalea at Hawaii Kai	Commercial	2565	2607	2644
119	Sutter Health Pac	Hospital	1891	2577	1915
120	Punahou School	School	4738	2565	0
121	Hale Pauahi	Multi-Unit	2627	2565	2644
122	Century Center Condo	Mixed Comm/Multi	2469	2546	2742
123	HCDA	Multi-Unit	2342	2538	2353
124	Chateau Waikiki	Multi-Unit	2410	2529	2504
125	Treatment & Disposal Div.	City	3361	2524	2179
126	Hoomaka Villages	Multi-Unit	2321	2520	2284
127	Castle & Cooke Prop.	Commercial	2132	2509	2625
128	Haseko Homes	Irrigation	2876	2503	2676
129	Blue Stone	Multi-Unit	3353	2490	2275
130	Mauna Luan	Multi-Unit	2515	2479	2571
131	Kapiolani Hospital	Hospital	2287	2475	2493
132	Victoria Ward	Commercial	2085	2454	2891
133	Aloha Tower Market	Commercial	2247	2434	2220
134	HPC Foods Ltd.	Industrial	2210	2430	3437
135	Mott Smith AOAO	Multi-Unit	2182	2419	2539
136	Hawaiian Monarch AOAO	Hotel	2068	2400	2331
137	Gentry Homes Ltd.	Commercial	3255	2381	1019
138	Ameron H C & D	Industrial	1790	2380	1473
139	Villa on Eaton Sq.	Mix Comm/Multi	1856	2369	2065
140	House Foods Hawaii Corp.	Industrial	2426	2367	2404
141	Miramar Hotel Inc.	Hotel	2116	2364	2032
142	Aston Waikiki Sunset	Hotel	2130	2343	2234
143	Harbor Square Assoc.	Multi-Unit	2051	2336	2483
144	Waikiki Beachcomber	Hotel	1581	2330	2571
145	Outrigger Hotels	Hotel	2108	2330	2488
146	Liliuokalani Gdns.		1838	2330	2316
147	Radford HS	School	1591	2327	2765
148	Kulana Knolls AOAO	Multi-Unit	3198	2311	2053
149	Directorate PF Resource	Military	1885	2309	2071

User no.	Bill payer	Land use	Existing flows in May 2003	Avg. flows in 2003	Avg. flows in 2002
	Managem.				
150	Waipahu High School	School	2390	2296	2152
151	Waikiki Landmark	Mix Comm/Multi	2446	2293	2511
152	Olaloa Assoc	Commercial	1721	2277	2088
153	Chaminade University	Commercial	2940	2272	1931
154	HCDA	Multi-Unit	2664	2268	2771
155	Palm Villas II	Multi-Unit	3015	2247	2384
156	Pacific Grand AOAO	Commercial	1961	2247	2148
157	Jowa Hi Co. Ltd.–Ilikai	Hotel	1910	2247	1732
158	Royal Iolani AOAO	Multi-Unit	2395	2235	2354
159	HCDA	Multi-Unit	2225	2214	1975
160	Executive Center AOAO	Hotel	1724	2200	1943
161	Coca Cola Bottling Co.	Commercial	1866	2187	2298
162	Outrigger Hotels	Hotel	1924	2168	1896
163	Village on the Green	Multi-Unit	1887	2159	2265
164	Mt. View Dairy Inc.	Agriculture	—	2148	2020
165	Div. of Pks., Mtn., & Rec.	City	319	2136	236
166	Kukui Plaza AOAO		2036	2097	1882
167	Castle Medical Ctr.	Hospital	1302	2090	2363
168	HCDA		2138	2080	2056
169	Kahala Beach	Multi-Unit	1952	2080	2116
170	Pearl I	Multi-Unit	781	2077	2163
171	Aston Waikiki Beach Hotel	Hotel	2381	2069	1397
172	GGP Ala Moana LLC	Commercial	4250	2054	1669
173	Harbour Ridge AOAO	Multi-Unit	2117	2000	2166
174	Nanakuli I & HS	School	1977	1997	2427
175	State Hospital	Hospital	2007	1986	2276
176	Waterfront Management	Commercial	1899	1986	2609
177	1350 Ala Moana Assoc.	Multi-Unit	1975	1984	2027
178	Kukui Gardens	Multi-Unit	1682	1963	1865
179	Imperial Plaza	Commercial	1967	1944	1990
180	Farrington HS	School	1519	1939	1130
181	Royal Kuhio Condo	Multi-Unit	1544	1935	1661
182	Dept. of Transportation	State	2480	1928	2326
183	Haw. Convention Ctr.	State	1820	1924	1984
184	Mid-Pac. Institute	School	3070	1907	1731
185	University of Hawaii	State	2442	1887	1653
186	Grosvenor Prop.	Commercial	1495	1877	1662
187	Harbor Court Dev.	Multi-Unit	1692	1860	2203
188	Kukui Gardens	Multi-Unit	1908	1859	1723
189	AOAO 1450 Young St.		1325	1855	1568

User no.	Bill payer	Land use	Existing flows in May 2003	Avg. flows in 2003	Avg. flows in 2002
190	Pearl Two Condo	Multi-Unit	1660	1838	2465
191	Century Park Plaza	Multi-Unit	1597	1838	2589
192	Hawaiki Tower	Multi-Unit	1729	1833	1809
193	HI Stevedores Inc.	Industrial	2558	1821	1258
194	Dust. Tex. Hon. Inc.	Industrial	3326	1819	1215
195	Haiku Point AOAO		2013	1812	1849
196	Pearlridge Center	Commercial	1680	1809	2009
197	Kalele Kai AOAO	Multi-Unit	1702	1797	1860
198	U.S. Veterans Admin.	Cemetery	7005	1794	1480
199	Leeward CC	State	2090	1791	1952
200	Dept. of Env. Svcs.	WWTP	1355	1779	2278
201	Waikele Center L P	Commercial	—	1779	1621
202	Ala Wai Plaza Condo	Multi-Unit	1817	1776	1823
203	Outrigger Hotels	Hotel	1426	1766	1777
204	Pagoda Hotel Inc.	Hotel	1664	1725	1619
205	Regency Park AOAO	Multi-Unit	1743	1714	1812
206	Waikiki Parc Hotel	Hotel	1274	1711	1789
207	Outrigger Hotels	Hotel	2465	1705	1917
208	HHA	Multi-Unit	1741	1678	2082
209	Stadium Authority		3545	1675	1096
210	Ala Wai Condo	Multi-Unit	1725	1660	1746
211	Menehune Water Co.	Industrial	3249	1653	1459
212	Lele Pono Condo	Multi-Unit	3039	1634	1960
213	Plaza Landmark	Multi-Unit	1724	1629	1585
214	Century Park Plaza	Multi-Unit	1437	1612	2376
215	Outrigger Hotels	Hotel	1247	1610	1263
216	Puualii Comm. Assoc.	Multi-Unit	1397	1606	2085
217	Koolina Fairway AOAO	Commercial	1394	1595	1459
218	Arcadia Retire Res.	Multi-Unit	1447	1592	1809
219	Waikiki Resort Hotel	Hotel	1283	1535	1412
220	Makaha Surfside	Multi-Unit	1490	1535	1488
221	GTE Haw. Tel.	Commercial	1306	1526	1463
222	Westridge Shopping Center	Commercial	1420	1520	1825
223	Waimea Falls Park	Commercial	1331	1511	1430
224	Kokusai Kogyo Co.	Hotel	413	1495	986
225	US Coast Guard	Military	1413	1492	1446
226	MPCC	Golf Course	1473	1464	1444
227	Ameron H C & D	Industrial	1790	1447	1179
228	HCC	State	1413	1443	2013
229	Waikele Comm. Assoc.	Irrigation	2607	1438	1614
230	Windward Mall Shop	Commercial	1401	1428	1557

User no.	Bill payer	Land use	Existing flows in May 2003	Avg. flows in 2003	Avg. flows in 2002
231	Moanalua Golf Course	Golf Course	485	1415	902
232	Greenwood AOAO	Multi-Unit	1342	1400	1473
233	Kokea Gardens AOAO	Multi-Unit	1385	1376	1333
234	Dept. of Transportation	State	772	1352	1244
235	Land Trans. Fac. Div.	State	—	1326	858
236	Rehab Hosp. of Pac.	Hospital	1374	1326	1444
237	Campbell Estate	Commercial	—	1299	1607
238	HHA	Multi-Unit	630	1280	2424
239	Country Club Plaza	Multi-Unit	1234	1269	1219
240	Varona Village	City	2299	1256	1546
241	Central Service Div.		1804	1245	882
242	Kuola AOAO	Multi-Unit	1295	1226	1046
243	Five Regents	Multi-Unit	1366	1224	1167
244	Kuakini Medical Center	Hospital	1122	1215	1512
245	Kapiolani Terrace	Multi-Unit	1198	1213	1390
246	Pearl Horizon AOAO	Multi-Unit	1193	1203	1426
247	MRGC LLC (Sheraton Makaha)	Hotel	1038	1201	—
248	Div. Boating & Ocean	State	1341	1181	1198
249	Sea Life Park	Commercial	713	1169	1074
250	D/E Haw. Jnt. Venture	Commercial	1100	1144	1137
251	Kukui Gardens Corp.	Multi-Unit	1069	1134	1027
252	Hawaiian Cement	Industrial	822	1099	1593
253	Gdn. Towr. Pearlridge	Multi-Unit	578	1055	1932
254	Frito-Lay	Commercial	3068	1054	1106
255	Aloha Tofu Factory	Commercial	2040	1041	1081
256	Meadow Gold Dairies	Commercial	583	1038	2042
257	Dept. of Parks and Rec.– Ala Moana	City	1506	988	965
258	Pearlridge Sq. AOAO	Multi-Unit	961	979	1015
259	Castle & Cooke Homes HI		—	975	—
260	Fleming Foods	Commercial	—	956	1037
261	Castle & Cooke Prop.		2464	949	1050
262	Meridien Pacific	Commercial	856	893	994
263	Teofilo Duldulao		—	843	876
264	Outrigger Hotels	Hotel	187	837	1103
265	Aikahi Park Shpg. Ctr.	Commercial	529	747	545
266	Hawaiian Cement	Industrial	947	659	1333
267	U.S. Coast Guard	Military	705	657	740
268	Dept. of Parks and Rec.– Pali	Golf Course	646	624	1767
269	Kalaeloa Partners	Commercial	1125	615	907
270	HECO	Commercial	1262	560	542

User no.	Bill payer	Land use	Existing flows in May 2003	Avg. flows in 2003	Avg. flows in 2002
271	Grace Pacific	Commercial	—	513	817
272	Div. of Pks., Mtn., & Rec.–Maili	City	445	437	460
273	Oceanic Institute	Commercial	414	412	517
274	Marco Polo Management		1341	366	407
275	Dept. of Env. Svcs.	City	246	323	201
276	Dept. of Parks and Rec.–Waipahu Bot.	City	21	310	398
277	Westview	Commercial	—	252	640
278	Ameron H C & D	Industrial	1790	245	191
279	The Gas Company	Industrial	75	128	1221
280	AES Barbers Pt.	Industrial	20	105	1913
281	Div. of Pks. Mtn.	City	3699	59	0
282	Div. of Parks, Mtn., & Rec.	City	18	23	412
283	Kokusai Kogyo Co.	Hotel	0	5	1615
284	Dept. of Air Force	Military	0	0	2885
285	Dept. of Transportation	State	—	0	0
286	US Filter (RO Water)		—	0	—
287	Marriott Vac. Club		1299	0	0