ONSITE WASTEWATER TREATMENT SURVEY AND ASSESSMENT

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Table of Contents

Glossary

Activated Sludge – a slurry-type biological treatment process including a aeration tank followed by a sedimentation tank.

Aerobic Treatment Unit (ATU) – an IWS that is designed to retain solids, aerobically decompose organic matter over a period of time, and allow effluent to discharge into an approved disposal system.

Biochemical Oxygen Demand (BOD) – an indication of the amount of oxygen required to oxidize (treat and stabilize) wastewater. Used as a measurement of the amount of organic material found in wastewater.

Biological Treatment – the use of microorganisms to consume organic material found in wastewater.

Blackwater – wastewater collected from toilets that is high in BOD and fecal or total coliforms.

Collection System – the conveyance system, which includes the building and street sewer laterals or connections to individual properties, interceptor sewer, sewage pump station and force main, used to transport sewage to a treatment facility.

Constructed Wetland (CW) – a man-made, marsh-like system that employs natural processes, like sedimentation, filtration and plant uptake to treat wastewater.

Critical Wastewater Disposal Area (CWDA) – an area, designated by the Department of Health, where the disposal of wastewater has or may have adverse effects on human health or the environment due to hydrogeological conditions.

Denitrification – the reduction of nitrate (NO_3^-) to nitrogen (N_2) by bacteria. This biochemical process removes nitrogen, a nutrient that causes algae blooms, from wastewater.

Disinfection – a treatment process which inactivates or kills microorganisms including pathogens in water by chemical or physical means.

Disposal System – any seepage pit, cesspool, injection well, soil absorption system or other facility used in the disposal of wastewater or wastewater sludge.

DOH – State of Hawaii Department of Health; in this report, usually specifically the Wastewater Branch of the Department of Health.

Domestic Sewage – waste and wastewater from humans or household operations that:

(1) Is discharged to or otherwise enters a treatment works; or
(2) Is of a type that is usually discharged to or otherwise enters a treatment works or an individual wastewater system.

It can also be defined as a type of wastewater normally discharged from or similar to that discharged from plumbing fixtures, appliances and other household devices including, but not limited to toilets, bathtubs, showers, laundry facilities, dishwashing facilities, and garbage disposals. "Domestic wastewater" has the same meaning as "domestic sewage".

Effluent – the liquid leaving a treatment or disposal system.

EPA or USEPA – United States Environmental Protection Agency.

Evapotranspiration or Evapotranspiration-Infiltration (ET/ETI) – the loss of water by the combination of evaporation from free water surfaces and following plant uptake. ETI includes the disposal of wastewater by infiltration to the ground.

Fecal Coliform – an indicator bacteria, common to the digestive systems of warm-blooded animals, that are quantified in standardized tests to indicate either contamination with wastewater or the level of disinfection performed by a treatment system.

Graywater – wastewater from a dwelling or other establishment produced by bathing, washdown, minor laundry and minor culinary operations, and specifically excluding toilet waste.

Groundwater – the water below the land surface that generally supplies wells and springs.

Household Treatment Unit – see Aerobic Treatment Unit (ATU).

Hydraulic Loading – the amount of wastewater (effluent) applied per unit area of a disposal system, usually measured in gallons per square foot per day (gal/ft^2-d).

Hydraulic Retention Time – the period of time that the liquid portion of wastewater is retained in a system or part of a system

Individual Wastewater System (IWS) – a facility which is designed to receive and dispose of no more than 1,000 gallons per day of domestic wastewater.

Kilowatt-hour – a measurement of the energy consumption of an appliance or other electrical equipment. One kilowatt-hour (kWh) is the energy consumed by ten 100-watt light bulbs burning for one hour.

Nitrification – the oxidation of dissolved ammonia to nitrate (NO_3^-). This is the first step in the biological removal of nitrogen from wastewater.

Onsite Wastewater Treatment System (OWTS) – a system relying on natural processes and/or mechanical components that is used to collect, treat, and disperse/discharge wastewater from single dwellings or buildings.

Organic Loading – the amount of organic material delivered to a treatment or disposal system per unit area. Usually measured in pounds of BOD per square foot per day (lb/ft^2-d).

Preloader – a preliminary physical treatment unit that is used primarily to separate large solids or trash from the liquid portion of wastewater.

Primary Treatment – the use of sedimentation to remove floating and settleable materials found in wastewater.

Reused, Recycled, or Reclaimed Water – treated wastewater that, by design, is intended or used for a beneficial purpose. Recycled water is categorized, in increasing quality, as R3, R2, or R1 waters. R3 water is oxidized (biologically treated water). R2 water is oxidized water that has been disinfected to a point where the average fecal coliform count is less than 23 per 100 mL and R1 water is oxidized water that is filtered and then disinfected to a point where the average fecal coliform count is less than 1 per 100 mL.

Rotating Biological Contactor (RBC) – an attached-growth type of biological treatment process in which the partially submerged supporting media rotates through the wastewater that is being treated. Must be followed by a sedimentation tank.

Secondary Treatment – the use of a Biological Treatment process to remove biodegradable organic material and suspended solids. Disinfection is also typically included in the definition of secondary treatment.

Solids Retention Time – the period of time that biological solids are retained in a treatment system.

Suspended Solids or Total Suspended Solids (TSS) – solid matter in wastewater that can be partially removed by sedimentation. Measured as the dry weight of residue retained on a 1.5 micrometer filter.

Tertiary Treatment – the enhanced removal of suspended solids via filtration and/or nutrients by various methods following secondary treatment of wastewater.

Total Coliform – the group of bacteria consisting of several *genera* belonging to the family *Enterobacteriaceae*, which includes fecal coliform bacteria.

Trickling Filter (TF) – an attached-growth type of biological treatment process in which the wastewater is spread on the top of support media and allowed to trickle through. Must be followed by a sedimentation tank.

Underground Injection Control (UIC) Line – a graphical control line, developed by DOH, delineating where treated wastewater cannot be injected into the ground in order to prevent contamination of groundwater. In Hawaii, the UIC occurs near the coasts, where groundwater is likely to be brackish and not used for potable water. Household aerobic units can discharge directly to groundwater makai of the UIC provided the effluent is disinfected.

Wastewater Treatment Works – any collection of treatment units and associated collection and disposal systems with an average design flow greater than 1,000 gallons per day; excluding an individual wastewater system.

Chapter 1 Introduction

BACKGROUND

In most urban settings in the State of Hawaii, the management of wastewater involves the collection and conveyance of wastewater in a County's public sewer system. The County typically treats the collected wastewater in a centralized facility and either beneficially reuses the effluent or disposes of it in subsurface soil systems or ocean outfalls. The Counties employ highly trained and licensed professional staff to manage, operate, and maintain the collection, treatment, and disposal systems on a 24-hours per day, 7 days per week, 52 weeks per year basis.

In some locations, however, there are no public sewers, and homeowners or developers must assume the responsibility of wastewater management. The tasks involved include selecting, designing, constructing, operating, and maintaining the appropriate treatment and disposal systems.

The State of Hawaii, Department of Health (DOH) regulates onsite wastewater treatment systems (OWTS) in Hawaii. An OWTS generally consists of a treatment unit and a disposal unit. A 1999 survey by DOH found that there were approximately 176,026 cesspools and 4,560 septic tanks in the State of Hawaii. This represents approximately 19% of the households in the State. Cesspools are considered disposal devices since they are designed for direct infiltration of wastewater into the subsurface without prior treatment. Septic tanks provide solids removal and minimal treatment of liquid and solid waste fractions prior to disposal via a separate unit. There are also an unknown number of aerobic treatment units (ATUs) in Hawaii which provide higher levels of treatment. Disposal devices employed downstream of septic tanks and ATUs include leach fields, infiltration wells, and evapotranspiration devices and these must be properly matched to ensure proper function.

Individual Wastewater System (IWS) permit requests in the State almost quadrupled between 2002 and 2006, indicating increasing development in areas—primarily rural areas—not served by public or private sewer systems. Residential and commercial development in rural areas require reliable and effective onsite wastewater treatment systems; therefore, there is a need for public education on the capabilities and limitations of OWTSs. Unlike centralized treatment works and disposal systems, there is currently no official guidance in the selection of an appropriate onsite wastewater system for a given site in Hawaii.

PURPOSE AND INTENDED AUDIENCE

The goal of this document is to provide broad guidance as to the various treatment and disposal systems that are currently available, and to describe their advantages and constraints so that those involved in the selection, design, construction, operation, maintenance, and permitting of these facilities can make informed decisions. Ultimately, the purpose of this document is to ensure the protection of valuable water resources and the environment through the effective use of onsite wastewater treatment and disposal systems in rural and urban settings within the State of Hawaii.

This document is intended for landowners, prospective homeowners, or small developers and their architect/engineers, and regulators on the selection and operation of appropriate onsite wastewater systems for smaller residential applications in areas where no public sewers are available in Hawaii. This survey aims to provide this audience with information on a range of feasible, permanent, and reliable onsite wastewater treatment and disposal options that conform to current environmental regulations within the State of Hawaii. This document does not provide solutions for specific site applications, but attempts to provide the user with a better understanding of the technology available and the factors that need to be considered in seeking DOH approval of an onsite wastewater system for any particular site.

This document was developed based on a review of applicable regulations, discussions with DOH staff, and engineering experience in the design and construction of onsite wastewater treatment systems in Hawaii. This report provides general guidance based on past experience, but is not a legally binding document. Readers are encouraged to review the current version of Hawaii Administrative Rule 11-62, to discuss their options with DOH staff, and consult with a professional engineer prior to attempting to select an OWTS.

REPORT ORGANIZATION

The popular means of organizing textbooks or reports on wastewater is to describe the wastewater as it would flow (that is describe the collection system, then the treatment system, and finally the disposal system). This document is organized contrary to that norm. This document is organized on the premise that site conditions or characteristics determine the appropriate disposal system, and the disposal system in turn determines the appropriate treatment system, given that the wastewater is assumed to be only domestic sewage. In light of that premise, this handbook begins with how site conditions drive system selection and describes those systems in the order that planning dictates. Specific topics covered in the following chapters are:

Chapter 2 of this document provides an introduction to wastewater treatment and the regulatory framework governing OWTSs. This is intended to facilitate a basic understanding of DOH's perspective in approving OWTS installations.

Chapter 3 outlines the many factors that influence OWTS performance and describes systems that are suitable for addressing these factors.

Chapter 4 presents the various wastewater disposal methods for OWTSs. Disposal options generally dictate the level of treatment required.

Chapter 5 discusses the various treatment methods available for low flow systems. These include individual wastewater systems.

Chapter 6 describes the various treatment methods available for wastewater treatment works that would be applicable to larger flow capacity OWTSs.

Appendices cover A) operation and maintenance considerations, B) lists and contacts for numerous equipment vendors, and C) information on Critical Wastewater Disposal Areas in Hawaii.

Chapter 2 Introduction to Wastewater

WASTEWATER TREATMENT

This report is about selecting a suitable treatment and disposal system for domestic wastewater, but what is domestic wastewater? That is not an easy question to answer. To begin with, this document is concerned with domestic wastewater rather than industrial wastewater. Domestic wastewater is wastewater generated by household sinks, toilets, showers, and laundry facilities. Sources included households, churches, parks, and community centers.

Wastewater, whether industrial or domestic, is made up of many different constituents. It is made of solids and dissolved gases, as well as liquid. The main constituent of wastewater is water. However, the other parts of the wastewater are harder to quantify. They are even hard to define. If one were to try to list all the chemicals that comprise the wastewater, dozens of chemical analyses would have to be performed. In order to simplify the process of characterizing wastewater, the list of parameters needed has been reduced to a handful: biochemical oxygen demand (BOD), total suspended solids (TSS), total nitrogen, total phosphorus, and total or fecal coliform bacteria.

In nature, the organic constituents of wastewater are stabilized by chemical decomposition or by biological consumption. Both of these processes *oxidize* the constituents in the wastewater. The most abundant oxidizing agent is dissolved oxygen. Oxygen dissolved in wastewater is consumed by the biological and chemical processes that stabilize the constituents. By measuring the demand for oxygen, an indirect measurement of organic materials can be made. Because the oxygen is consumed in both biological and chemical reactions, it is called biochemical oxygen demand. BOD is measured in mg/L, and the greater the BOD, the higher the concentration of organic material in the wastewater.

In addition to the liquid portion of wastewater, there is a solid portion as well typically quantified as total suspended solids (TSS). TSS is dry filter residue measured in mg/L. The higher the TSS, the more solid material in the wastewater.

Other constituents in wastewater include nutrients. The most common nutrients of concern are nitrogen and phosphorus. When either of these nutrients is introduced to nutrient limited waters, it can cause an algae bloom or eutrophication. Algae blooms deplete the water of dissolved oxygen, and can result in the death of aquatic or marine life. In addition to adverse environmental effects, some nutrients have adverse health effects, notably “Blue Baby Syndrome” due to nitrate in drinking water. High concentrations of nutrients affect disinfection efficiency and the suitability of wastewater reuse, as well. Nitrogen and phosphorus can be measured as different chemical compounds, as in the amount of nitrogen in the form of ammonia, nitrite, or nitrate, or they may be measured in terms of the total amount of each element. In any of the cases, the measured concentration is usually in mg/L.

In addition to the chemicals and solids present in wastewater, microorganisms thrive in wastewater. Like the many chemical constituents, the number of microorganisms is too numerous to quantify individually. Therefore, only a fraction of microorganisms are studied to determine the characteristics of wastewater. Pathogens exist in wastewater, but again, it is too difficult to determine the number of each individual species. To give a good indication of how many microorganisms are thriving in wastewater, two categories of indicator organisms are quantified. The first is total coliforms and the second is fecal coliforms. Fecal coliforms are a good indication that the wastewater contains fecal matter generated by warm-blooded animals, and helps indicate the wastewater as domestic sewage as opposed to naturally occurring waters. In this report, fecal coliform counts are the parameter that characterizes the wastewater. Fecal coliforms are most commonly reported in colony forming units (CFU) per 100 mL of wastewater, which is a direct count of the number of organisms in the sample.

Table 2-1 lists typical values for the above-mentioned parameters in raw domestic wastewater.

Table 2-1 Typical Characteristics of Raw Domestic Wastewater

BOD (mg/L)	100-400
TSS (mg/L)	100-400
Total Nitrogen (mg/L)	14-40
Total Phosphorus (mg/L)	5-20
Fecal Coliforms (CFU/100 mL)	100 million

In order for the wastewater to be returned to the environment, without detrimental effects, the wastewater must be cleansed or treated. Treatment takes advantage of physical, chemical, and biological mechanisms to stabilize the wastewater. The degree of treatment is dependent on the characteristics of the wastewater as well as the discharge requirements, which are typically dictated by the disposal method and receiving environment. Treatment systems are categorized by the mechanisms used to cleanse the wastewater as follows:

- **Preliminary treatment:** Typically consists of the physical treatment of the wastewater using bar racks or screens and grit chambers to remove rags, sticks, flotables, grit, grease, and objects that could damage downstream equipment.

- **Primary treatment:** A physical sedimentation process where settleable solids and flotables are collected and separated in basins (typically called clarifiers).

- **Secondary treatment:** A biological process employs microorganisms to consume biodegradable organic materials that are dissolved or suspended. These processes also remove suspended solids via sedimentation. Microorganisms in the wastewater are stimulated by the addition of oxygen to metabolize organic material and nutrients in the wastewater. Secondary treated water without disinfection, represents the lowest level of recycled water in Hawaii (R-3 recycled water). Secondary treated water coupled with disinfection, represents the next level of recycled water in Hawaii (R-2 recycled water).

    - **Biological nutrient removal:** In some instances, it may be necessary to remove more and different types of nutrients than are removed in typical secondary treatment. Biological nutrient removal is typically called for in cases where the disposal method has the potential to impact inland surface or coastal waters (leading to algae blooms) or groundwater (leading to blue-baby syndrome). In most of these instances, nitrogen and phosphorus are the excessive nutrients. Treatment of these contaminants requires microorganisms that thrive under anaerobic (no oxygen) or anoxic (little oxygen) conditions. With specialized designs, this can be accomplished during secondary treatment. Or it can be accomplished after secondary in a tertiary process.

- **Tertiary Treatment:** Tertiary treatment entails the filtration of secondary treated wastewater. Filtration can be accomplished through granular media such as sand or through synthetic membranes. Tertiary treatment, coupled with disinfection, represents the highest level of recycled water in Hawaii (R-1 recycled water).

- **Disinfection:** All of the treatment methods listed above remove particulate and dissolved contaminants, but none are intended to destroy pathogenic organisms. To accomplish this, disinfection processes such as chlorination or UV disinfection are typically employed. Disinfection either kills the pathogenic organisms via oxidation or inactivates their reproductive capability, rendering them harmless to human health.

Generally, the goal of treating wastewater is to achieve BOD and TSS concentrations of 30 mg/L and 30 mg/L (on an average basis), with a pH of 6-9, and fecal coliforms less than 23/100 mL. This is the definition given by the United States Environmental Protection Agency for secondary treated wastewater. It is the same standard used by NSF International, a clearinghouse for treatment systems, when it certifies treatment systems. The role of NSF is discussed in more detail later in this chapter.

In general, there are two forms of wastewater treatment – centralized and decentralized. Centralized treatment consists of a relatively large wastewater collection system conveying wastewater flows to a single wastewater treatment facility with subsequent disposal. Decentralized or onsite wastewater treatment encompasses a much smaller service area – typically a single parcel or several adjacent parcels. When several adjacent parcels are serviced in a single facility, the treatment and disposal system can also be referred to as a cluster system.

The term Onsite Wastewater Treatment System (OWTS) is used to describe a decentralized system. An OWTS is a system that collects, treats, and disposes of domestic wastewater from a single or multiple dwellings or buildings, relying on physical, mechanical, and/or biological processes. The treated wastewater is disposed or reused essentially on the same premises that it was generated. For the purposes of this document, OWTSs include the entire wastewater train including collection, treatment, and disposal systems. The treatment and disposal components of OWTS are addressed in Chapters 4-6. Onsite disposal systems with the function of discharging the treated wastewater into the environment are referred to as "disposal systems." Systems that treat the wastewater by mechanical or biological means are referred to as "treatment systems," and are not to be confused with the more general and inclusive onsite wastewater treatment system (OWTS) definition.

Hawaii's regulations do not use the terms centralized, decentralized, or OWTS, but instead refer to them as wastewater treatment works and individual wastewater systems (IWS). For the purposes of this document, the term OWTS is utilized to encompass systems that are legally defined as IWSs and wastewater treatment works, but provide onsite wastewater treatment. The DOH recognizes OWTSs as Individual Wastewater Systems when flows are less than 1,000 gallons/day.

OWTSs use the same treatment concepts as conventional, large publicly-owned municipal wastewater treatment plants, but on a smaller scale. A basic OWTS includes a septic tank and an absorption-type disposal system. The septic tank provides physical (primary) treatment of wastewater using gravity settling and flotation to remove solids from the wastewater.

Onsite disposal systems provide for the disposal of wastewater. Disposal of wastewater involves the return of the wastewater to the surrounding environment. Generally, disposing of wastewater involves the percolation of wastewater into the ground. In most cases, treatment continues in the disposal system. For example, it is assumed that pathogens and some organic material are removed from wastewater while it is absorbed in a leachfield. Occasionally, treated wastewater is introduced into the environment through evapotranspiration, the combined uptake of water by evaporation and plant uptake (transpiration).

Generally, an OWTS is comprised of a treatment system and a disposal system (systems discussed in Chapters 4-6). There are many possible combinations of these systems, and part of the profession of engineering is to determine the correct combination that yields acceptable effluent quality economically. This selection process usually starts with an investigation of the wastewater characteristics. For this report, the assumption is that the wastewater being treated is domestic wastewater, with characteristics that are generally given throughout engineering literature. The second step in the selection of acceptable treatment is to determine the required effluent quality. This report assumes that the required effluent quality is mandated by the site conditions and characteristics. The site conditions dictate the allowed disposal system, which in turn dictates the performance capabilities of the treatment system. Thus, the selection process for an OWTS with the correct capabilities is a backward planning process.

In addition to the performance capabilities of an OWTS, consideration should be given to the operation and maintenance requirements of each component. The placement of treatment systems must consider criteria such as access and surface loads. For tanks that will collect sludge or scum, pumping must be performed on a regular basis, so inspection and pumping ports should be readily accessible to maintenance technicians and tank-trucks. If the tanks are not easily accessible, pumping fees may increase due to the need for increased hose length and general inconvenience incurred when pumping. Aerobic units and any units that utilize pumps require the availability of power and must have accessible control and power panels. Tanks and piping placed underground in areas that may be traversed by vehicles must be structurally rated for appropriate wheel loads and properly backfilled. Placement of treatment systems is also dependent on the location of other units such as disposal systems. Minimum separation from other treatment systems, property lines, structures, drinking water wells, and water bodies are given in HAR 11-62, Appendix F, Table 2, and they are summarized in Chapter 3 of this handbook.

GUIDELINES AND REGULATORY FRAMEWORK

Federal Level

The U. S. Environmental Protection Agency (EPA) has relinquished authority to the State Department of Health (DOH) for the regulation, overseeing, and enforcement of OWTS planning, design, construction, inspection, and maintenance in Hawaii. However, they continue to provide valuable guidance and remain committed to elevating the standard of onsite wastewater management practices and acceptance of onsite treatment technologies as a viable alternative to centralized treatment in small and rural communities. The EPA is also involved with the regulation of the Underground Injection Control (UIC) program (Part C of the Safe Drinking Water Act) involving the Class V injection wells, including large capacity cesspools, and the management, reuse, and/or disposal of wastewater sludge or biosolids, through Part 503 Rules of the Federal Clean Water Act. Both of these areas impact OWTSs.

State and Local Level

The State Department of Health (DOH), Environmental Management Division, Wastewater Branch formulates and enforces all wastewater rules and regulations in Hawaii. Hawaii Administrative Rules, Title 11, Chapter 62, "Wastewater Systems," is the codification of these regulations and covers all public wastewater treatment and disposal systems as well as private wastewater treatment plants (WWTPs) and OWTS throughout the State, from individual cesspools to major municipal wastewater treatment plants. Hawaii Administrative Rules Title 11, Chapter 55 "National Pollutant Discharge Elimination System Permitting" regulates the permitting of minor and major wastewater treatment facilities. Under these regulations, which were last amended on December 9, 2004 and July 14, 2005 respectively, the following provisions for OWTSs are incorporated:

1. Selection of appropriate, conventional wastewater treatment and disposal systems is outlined in the regulations. No effluent requirements are specified. However, National Sanitation Foundation (NSF) class certification is required for aerobic treatment units. There are provisions in the rules allowing approval for innovative and alternative technologies based on testing and monitoring on a case-by-case basis.

2. The State of Hawaii does not require permits for onsite wastewater systems. Hawaii rules require that new OWTS plans be reviewed and approved by the DOH prior to construction. Once constructed, written authorization for use must also be obtained from the DOH. The actual construction permits are integral to the individual County building permit processes. It is important to note that the design of OWTS must be carried out by a ***Hawaii licensed professional engineer*** (PE), and the system must be installed by a ***licensed contractor***, according to these Administrative Rules.

3. Routine inspections of OWTSs are not required following construction. However, DOH requires the engineer-of-record to submit a final inspection report, certifying the OWTS was constructed in accordance with approved plans. DOH also requires an operation and maintenance manual and owner certification that they will follow the manual. DOH will then issue a written approval to use the OWTS.

4. State law does not require recordkeeping and monitoring of management and maintenance programs for OWTS with the exception of ATUs. ATUs require ongoing maintenance/service contract/agreements.

5. Any alternative/experimental/innovative technologies proposed and conditionally approved by DOH require certification and testing by NSF International or third party certification and testing, using NSF and DOH approved testing protocol.

By HAR 11-62, ATUs must meet the standards set by the National Sanitation Foundation (NSF). The NSF is a non-profit, non-governmental organization that develops standards and certifies products to protect public health and safety. ATU performance is just one of the many certifications NSF issues. NSF Standard 40 provides protocols for testing ATUs, as well as, criteria for minimum acceptable performance. Minimum performance for production of a NSF Standard 40 Class I Effluent requires that:

1. The 30 consecutive day mean effluent concentration of five-day BOD be no greater than 30 mg/L with at least 85% removal of BOD. The mean value of BOD must be less than 45 mg/L for any seven consecutive days;

2. The 30 consecutive day mean effluent concentration of TSS shall be no greater than 30 mg/L, with no mean value greater than 45 mg/L for any seven consecutive days.

3. The effluent pH must always be between 6.0 and 9.0.

4. This is essentially equivalent to the Environmental Protection Agency (EPA) definition of “secondary treatment.”

Individual wastewater systems, according to the HAR 11-62, are regarded as a “…temporary on-site means of wastewater disposal in lieu of wastewater treatment works…”. The designation of “temporary” is indicative of the DOH’s preference that property owners connect to County-owned wastewater treatment service where such service exists.

> “The department of health [sic] seeks to migrate towards an ultimate goal of regional sewage collection, treatment and disposal systems which are consistent with state and county wastewater planning policies. Off-site treatment and disposal systems, followed in priority by on-site systems, meeting health and environmental standards will be allowed whenever they are consistent with state and county wastewater planning policies and on the premise that these systems will eventually connect to regional sewage systems. Individual wastewater systems may be utilized in remote areas and in areas of low density.” (HAR §11-62-01)

Although the regulations specify that the IWS is to be considered temporary, unless there are specific plans for a new wastewater treatment works or an extension of a sewer system to be built to service a development, the IWS should be considered a permanent means of wastewater treatment. It should be constructed and maintained as a permanent component of wastewater infrastructure. However, the expectation is that upon sewer system expansion or WWTP construction, the use of IWS will be discontinued in favor of using the sewer system and treatment plant.

Individual wastewater systems are applicable to dwelling and non-dwellings as follows:

- Dwellings:
  - Must have 10,000 square feet of area per IWS wastewater system;
  - Total development of an area shall not exceed fifty single family residential lots or exceed fifty dwelling units, except for developments consisting of one dwelling unit per acre or greater;
  - Area of the lot shall not be less than 10,000 square feet except for lots created and recorded before August 30, 1991. For lots less than 10,000 square feet which were created and recorded before August 30, 1991, only one individual wastewater system shall be allowed; and
  - The total wastewater flow into one individual wastewater system shall not exceed 1,000 gallons per day, and one individual wastewater system shall not serve more than five bedrooms, whether they are in one dwelling unit or two.

- Non-Dwellings
  - There shall be 10,000 square feet of usable land area for each individual wastewater system. Usable land area shall not include the area under buildings;
  - The total wastewater flow of the development shall not exceed 15,000 gallons per day;
  - Area of the lot shall not be less than 10,000 square feet except for lots created and recorded before August 30, 1991. For lots less than 10,000 square feet which were created and recorded before August 30, 1991, only one individual wastewater system shall be allowed; and
  - The total wastewater flow into each individual wastewater system shall not exceed 1,000 gallons per day.

There is a gray area in the regulations that encompasses the servicing of between two and fifty dwelling units with an IWS. DOH reviews each of these situations on a case-by-case basis, sometimes allowing a single IWS to serve more than one dwelling at a flow rate exceeding 1,000 gallons per day. Site factors, such as those discussed in Chapter 3, are critical to DOH's determination whether to allow such practice or not.

HAR 11-62 identifies Critical Wastewater Disposal Areas (CWDA) for each of the islands and is a critical component for any new development without convenient access to public sewer systems. OWTSs constructed in these areas may be imposed with more stringent requirements than those specified in the rules for other OWTSs located outside of these areas. Requirements may include, but are not limited to:

1. Meeting stricter effluent standards, including nutrient removal;

2. Limiting the method of effluent disposal; and

3. Requiring flow restriction devices on water fixtures.

In addition, an Underground Injection Control (UIC) Line is shown for each island on the maps provided in Appendix C. This UIC line is part of the State of Hawaii, Hawaii Administrative Rules, Title 11, Chapter 23, "Underground Injection Control" (HAR 11-23) regulations, which protect drinking water aquifers from potential contamination by discharges of wastewater and other fluids. This aquifer designation line is subject to review and revision every 3 years. Discharge of treated or untreated wastewater mauka of this line is prohibited. Any injection well, including all subsurface disposal options listed in Chapter 4 of this report, unless otherwise noted, shall be sited makai of the UIC line and 50 feet above the contact between the artesian volcanic aquifer and the overlying confining material where there is an artesian aquifer. Additionally, any new injection well shall be at least ¼ mile from any part of a drinking water source. Additional construction and operational requirements are outlined in HAR 11-23, including UIC permit application requirements. These permits are good for up to 5 years and require wastewater monitoring and reporting. Individual cesspools and seepage pits have been unofficially exempted from the monitoring and reporting requirements as well as renewal requirements by DOH.

On Oahu, the Honolulu Board of Water Supply created a "No Pass" Line around the perimeter of the island, above which (mauka) treated and untreated wastewater is not allowed to be discharged to the ground. This line was hand-drawn in the 1970s on the old Tax Map Key (TMK) maps and are still are being utilized and enforced today by the DOH Wastewater Branch. While no formal criteria for the establishment of the line was ever documented, it is generally based on the island's hydrogeology, proximity to groundwater, soils conditions, location of water wells, and vertical distance to bedrock. This No Pass Line is more conservative than the UIC line in that it does not allow for shallow injection wells. The two lines deviate at Waimanalo Gulch and Makaiwa to take into account landfill sites and down Mango Tree Road in Ewa, where the UIC line preserves the brackish "caprock" water for future desalination.

In the arena of water recycling, the DOH Wastewater Branch enforces their "Guidelines for the Treatment and Use of Recycled Water" (DOH, 2002). The DOH recognizes three types of recycled water: R-3 water is an undisinfected secondary effluent (suitable only for certain types of restricted agricultural irrigation); R-2 water is a disinfected secondary effluent with fecal coliform < 23 per 100 ml (suitable for multiple uses with restrictions such as subsurface irrigation and provision of buffer zones between irrigated areas and adjacent properties); and R-1 water is filtered and disinfected secondary effluent with fecal coliform < 1 per 100 ml (suitable for numerous types of unrestricted reuse including spray irrigation of golf courses, parks, and fresh market food crops).

Although the State of Hawaii does not currently follow the EPA guidelines, a potential change to Section 6217(g) of the Coastal Zone Act Reauthorization Amendments (CZARA) may include a management measure for new and operating onsite disposal systems designed to protect Hawaii's coastal waters from contamination by implementing stricter regulations. The measure includes the banning of new cesspools, plans to develop a program to inspect operating onsite systems at a frequency adequate to ascertain failure, and requirements to upgrade onsite systems for nitrogen removal when necessary. The requirement regarding nitrogen removal is that 50% nitrogen removal shall be required when either (a) conditions such as location, poor soils, shallow groundwater, fractured bedrock, or existing contamination would indicate that surface waters may be adversely affected by groundwater nitrogen loadings from onsite systems, or (b) nitrogen loadings from the onsite system are delivered to groundwater that is closely hydrologically connected to surface water. The nitrogen rule applies to new systems and to upgrade of existing systems.

The regulatory framework currently governing the protection of Hawaii drinking water aquifers and public health and safety requirements for treatment and disposal of wastewater, dictates the appropriate selection and utilization of OWTS for a given site as further outlined in this report.

Chapter 3 Treatment and Disposal Method Selection

INTRODUCTION

Hawaii is a unique state – no other can boast such a wide diversity in climatologic and geologic conditions. The Big Island, for instance, provides both wet (Hilo) and dry (Kau) climates, and even snowy areas (Mauna Loa, Mauna Kea), all underlain by volcanic rock. The factors that make Hawaii unique also need to be considered when developing an onsite wastewater treatment and disposal system as they can have a pronounced effect on each system's suitability and effectiveness.

This chapter discusses some of the factors that can influence the operation of an OWTS and provides some general guidelines for selecting the proper OWTS for a given site.

These are general guidelines and are not intended to be absolute answers applicable to each and every situation. Because of Hawaii's wide range of geologic and climatologic diversity, it is impossible to offer specific onsite wastewater treatment and disposal recommendations for every location in Hawaii. Ultimately, an engineer registered in the State of Hawaii will need to be consulted to develop the drawings necessary for approval and construction of the OWTS and his/her professional opinion will need to be respected in that regard.

SITE CONDITIONS

Nine site conditions were judged to have significant influence over the selection of onsite wastewater treatment and disposal systems. Each should be investigated prior to selecting wastewater treatment and disposal methods. They are:

- Depth to water table (both potable and non-potable – e.g., high water table);
- Impermeable soil or rock formation;
- Steep terrain;
- Flood zones;
- Proximity to inland surface waters (both streams and other bodies of water);
- Protection of coastal waters from excessive nutrient inputs;
- Areas with high density of cesspools and/or areas with high rates of cesspool failures;
- Protection of groundwater resources; and
- Hydrogeology.

Each of these conditions is discussed below.

<u>Depth to Water Table</u>

Most OWTSs rely on discharging the treated wastewater at or near the surface of the ground and allowing it to percolate into and through the soil and away from the site. During percolation, some contaminants are removed via filtration, sorption, and biodegradation and other mechanisms. The extent of removal is dependent upon soil characteristics and time/distance of travel through the soil. In cases where groundwater is only a short distance below the ground surface (less than about 10 feet), the expected removals during percolation are diminished. If the groundwater is very shallow, the discharge is essentially directly into the groundwater. Shallow groundwater can reduce the percolation zone and hence the degree of contaminant removal and may result in groundwater contamination. Wastewater can also back up into the treatment system if percolation is slower than the application rate.

Treatment systems should generally be installed above the groundwater table to prevent inflow of groundwater into the system and reduce uplift forces that can damage the treatment tanks rendering them non-watertight and possibly even mechanically nonfunctional. In cases where treatment tanks must be installed in groundwater or where groundwater levels may rise seasonally, subsurface tanks must be anchored down to a concrete foundation slab called a "deadman". Another option, in this case, is to locate the treatment tanks above ground in which case public access must be strictly controlled to prevent public health risk. In such cases, the combined treatment/disposal system must generally prevent contamination by pathogens (requiring disinfection), nitrogen (requiring enhanced nitrogen removal), and trace organics (requiring tertiary treatment and effective removals in the disposal system).

Elevated mound systems, evapotranspiration systems, and water recycling are some means of overcoming this problem, but in general, shallow groundwater conditions call for a non-subsurface disposal method. An engineer should be consulted to determine the depth to groundwater and design an appropriate disposal system that will prevent groundwater contamination.

Impermeable Formations

This condition is similar to the first condition, but manifests itself differently. Rather than shallow groundwater impeding the percolation process, the underlying soil itself is the culprit. Impermeable subsurface formations cause overlying material to saturate when effluent is applied and eventually stop percolating wastewater, causing unacceptable ponding and surface runoff from the site (overflow or spill). If this occurs, the disposal system will have failed and public health will be at risk.

In cases where the soil has low permeability, but is not impermeable, it is possible to increase the size of the disposal system so that the treated wastewater is spread out over a larger area or the disposal area is rotated among several sites so that the water can percolate before additional water is applied. The Department of Health specifies minimum percolation rates for the various disposal options to specifically avoid this problem. It is necessary to consult an engineer who can measure the site-specific percolation rate and then design an appropriate percolation system size and configuration.

Steep Terrain

Most onsite wastewater treatment systems rely on gravity-driven methods for disposal (downward percolation). Steep terrains complicate disposal of treated wastewater because the area required for disposal must typically be terraced or stepped which increases the complexity of splitting flows between various disposal areas in order to ensure even application rates. Uniform application rates are necessary in order to ensure that percolation can occur at the designed rate and different sections of the system are not overloaded leading to ponding, runoff, and potential public health risks. Because of the terracing, care must also be taken to provide sufficient buffer to ensure that the water can percolate and will not resurface downslope where it could present a public health hazard. Steep terrains also impact the difficulty and therefore costs of excavation and installation of subsurface treatment tank systems. An engineer should be consulted to design treatment and disposal systems whenever the site slope is greater than 5% because absorption beds cannot be used with slopes greater than 8%, absorption trenches cannot be used with slopes greater than 12%, and installation costs will be greatly increased at slopes of 20% or more.

Flood Zones

Insofar as the construction of facilities in flood zones is generally disallowed due to personal safety and property loss considerations, so too is the construction of wastewater treatment and disposal systems. These systems are intended to operate reliably, but such operation will be curtailed during a flood due to inundation. This will lead to the discharge of untreated wastewater to the environment, which would pose a threat to public health. It is very unlikely that the Department of Health would allow any treatment or disposal system to be developed in a flood plain. An engineer should be consulted in situations involving flood zones.

Proximity to Inland Surface Waters

The primary concern regarding the siting of onsite wastewater treatment and disposal facilities near inland surface waters is that the native water quality must be maintained so that beneficial uses are preserved. Thus, if the surface water serves as a potable drinking water source, irrigation water source, recreational venue, etc., these uses must be preserved with corresponding water quality standards. Therefore, any onsite wastewater treatment and disposal systems must not contaminate nearby surface waters.

Onsite wastewater systems present two challenges based on proximity to surface water sources. First, if the treatment system were to backup or if a spill were to occur, then the potential exists to directly contaminate the surface water with untreated or partially treated wastewater containing organics, nutrients, and pathogenic microorganisms. Not only does this present a health risk to persons using the surface water for recreation or drinking purposes, but it also represents a potential to impact the aquatic environment, which could experience oxygen sags (lowered oxygen levels in the water) or high nutrient levels that could lead to algae blooms. Most recycled water systems are required to provide active means of retaining water on the site for this very reason. Second, if the water is disposed of using subsurface methods, then it is possible that it could discharge into the surface water faster than if it were to percolate into groundwater. Since travel through the vadose zone (soil layer between the ground surface and the groundwater table) provides some level of treatment, surfacing of the treated effluent, particularly in a nearby surface water source (which is typically indicative of shallow groundwater) could indicate that it is receiving insufficient percolation treatment. In such cases, the combined treatment/disposal system must generally prevent contamination by pathogens (requiring disinfection), nitrogen (requiring enhanced nitrogen removal), and trace organics (requiring tertiary treatment and effective removals in the disposal system). An engineer should be consulted to design any system to be located within 500 feet of any surface water (stream, river, drainage channel, wetland, or lake), and wherever depth to groundwater is less than 10 feet.

Protection of Coastal Waters

Similar to the issue of nearby inland surface waters, coastal waters can also be impacted by onsite wastewater systems. Wastewater disposed through subsurface methods can make its way to the ocean and show up as elevated total and fecal coliform readings at beaches. Because the diurnal tide fluctuations impact groundwater levels and because the soil in coastal areas tends to be either sandy (causing rapid percolation) or volcanic rock (impermeable), coastal areas are difficult settings for subsurface disposal.

In an effort to prevent the nitrogen-limited surface waters (inland and coastal) from excessive loading of nutrients, the Director of the Department of Health may direct that total nitrogen loading must be reduced by 50%. Therefore, parcels of land for development or onsite systems that are being replaced at the end of a life cycle may have an additional site condition that modifies which system can or cannot be used. Even parcels of land farther away from the ocean may be impacted by nitrogen removal requirements if those parcels have the potential to contaminant groundwater hydrologically connected to the surface water.

Care must be taken to ensure that adequate treatment in the treatment systems (such as enhanced nitrogen or phosphorous removal) and in the subsurface is provided prior to the discharged treated wastewater eventually infiltrating into the coastal ocean water. Sites within 500 feet of the coast should consult with an engineer and consider zero-discharge systems such as evapotranspiration and water recycling.

Areas with High Cesspool Density

Onsite wastewater systems are typically developed in rural areas where it is impractical or impossible to connect to a sewer collection network leading to a centralized wastewater treatment facility. In cases where there are numerous onsite wastewater systems, it may be in the best interest of the Department of Health to recommend the use of a clustered treatment system rather than to allow additional onsite systems. The stated preference of the Department of Health is to migrate towards regional treatment and disposal systems. Use of onsite systems is typically allowed in remote areas where regional treatment and disposal systems do not exist, or where making a connection to such a system would impose a financial hardship on the discharger.

However, if there are several onsite systems in close proximity, particularly those that are failing, then it does not make sense to add to the problem and degrade the environment. In such cases new dwellings should consider systems that provide enhanced levels of treatment such as ATUs providing enhanced nitrogen removal and disinfection (secondary and/or tertiary) as well as zero-discharge disposal systems such as ET/ETI and water recycling. An engineer should be consulted in such cases.

Protection of Groundwater Resources

Hawaii is blessed with high quality drinking water. The majority of the islands' potable supply comes from groundwater, which requires little or no treatment. Protection of this resource is one of the primary factors the Department of Health uses in its evaluation of onsite wastewater treatment and disposal systems. Working in conjunction with the County Water Departments, the Department of Health has taken a conservative approach in regulating onsite wastewater disposal over potable water aquifers. Critical Wastewater Disposal Areas, as defined in the Hawaii Administrative Rules, Title 11, Chapter 62, restrict where effluent may be disposed of into the subsurface. Although it is possible to petition for a variance from the regulations, it should probably not be pursued unless all other options have been exhausted. In such cases, the combined treatment/disposal system must generally prevent contamination by pathogens (requiring disinfection), nitrogen (requiring enhanced nitrogen removal), and trace organics (requiring tertiary treatment and effective removals in the disposal system). An engineer must be consulted in such cases in order to design an appropriate system and to obtain Department of Health approval, which is scrutinized on a case-by-case basis.

Hydrogeology

Hydrogeology encompasses the distribution and movement of groundwater through the soil. Many of the items discussed above could be considered as falling under hydrogeology. The nature of groundwater is such that it is slow moving and difficult to predict without detailed studies. Even with geotechnical investigations, it can be difficult because subsurface conditions can and do change, but it is not possible to see those changes without digging exploratory holes or borings at close intervals. Such testing is typically beyond the means of most single-family homeowners, so rather than require them, the Department of Health typically takes a conservative stance that provides sufficient redundancy to ensure public heath and safety. In cases where treatment and disposal systems may potentially impact groundwater used for potable supply or non-potable groundwater that can then impact surface waters, treatment requirements must be restrictive enough to protect public health (e.g., disinfection and enhanced nitrogen removal).

There are other conditions that can also impact treatment and disposal system performance, so care must be taken by the owner and the engineer to fully evaluate their site prior to selecting and installing any onsite wastewater system.

WASTEWATER CHARACTERIZATION

In the process of evaluating OWTS alternatives, it is necessary to develop some very basic information regarding the system. These include estimates of flow rate and typical wastewater quality. Each of these is discussed below

Flow Rate Estimates

Each of the Counties has methodologies for estimating OWTS flow rates, typically based on the number of water fixtures (faucets, sinks, showers, etc.) or bedrooms. Care must be taken to ensure that these estimates properly characterize the amount of flow to be treated and disposed of. By nature, the County's methodology produces conservative estimates, but excessively conservative numbers can complicate both the treatment process and the disposal method. If the property is more than just a residential unit, then it may be appropriate to reevaluate the flow estimation method. If a future expansion of the residence/building is possible (e.g. bedroom addition), then it may be beneficial to consider sizing the OWTS for the ultimate flow.

Wastewater Quality

Domestic wastewater is readily treatable with OWTS. Pollutants in the wastewater are readily degradable using fairly simple processes (settling, biological assimilation, filtration). However, if the facility generating the wastewater, is other than a typical residence that would introduce higher concentrations of biological material (e.g., a cottage industry type bakery) or unusual chemicals (e.g., a photographic developer) then a typical OWTS may not be adequate. Failure to consider what is to be treated could ultimately lead to failure of the treatment and/or disposal system, risk to public health, and expensive maintenance or replacement costs.

SPECIFIC DESIGN CONSIDERATIONS

Prior to selecting a system, it is appropriate to do a preliminary evaluation of the site characteristics to determine if it is suitable for the various disposal methods. The purpose of the site evaluation is to identify, qualify, and possibly quantify the nine site conditions previously mentioned. These conditions are investigated by analyzing or evaluating each of the following: soil properties, terrain and flood potential, minimum spacing, water budget, and aesthetics.

Soil Properties

Preliminary information on soil characteristics can be obtained from the following documents:

- Soil Survey of the Islands of Kauai, Oahu, Maui, Molokai, and Lanai, State of Hawaii, USDA, Soil Conservation Service, 1972.

- Soil Survey of the Island of Hawaii, State of Hawaii, USDA, Soil Conservation Service, 1973.

Both of these publications are no longer published, but are available on-line electronically on the U.S. Department of Agriculture website (http://soils.usda.gov/survey/printed_surveys/state.asp?state=Hawaii&abbr=HI1). Alternatively, the Natural Resources Conservation Service (formerly the Soil Conservation Service, maintains an on-line soil survey which provides similar information for those who are more computer savvy.

These soil surveys provide general information (not necessarily site specific information) that can be used for screening purposes. Information such as depth to bedrock, depth to high water table, and permeability can all be obtained from these reports.

Permeability is a measure of how quickly the wastewater can percolate through the soil. It is a key factor in evaluating the suitability of subsurface disposal methods. In areas with very clay-like soil, percolation of the treated wastewater may be too slow to allow for the practical disposal of wastewater effluent. On the other hand, very rapid percolation through course, sandy soil may result in insufficient treatment occurring before the effluent comes in contact with groundwater. The procedure for the percolation test is given in HAR 11-62, and is known as the falling head test. The test is designed to determine percolation rates in saturated soils. Percolation rates are determined at least five feet below the surface. Even if a preliminary investigation is done at three feet below the surface, prior to construction the test results must be confirmed at five feet below the surface.

The supporting rock or substratum may also play a role in determining which treatment/disposal system combination is chosen. The structure of the substratum has as much influence as the composition, as well. Solid rock, like a *confining* layer of basalt or limestone, may impound the effluent, making disposal hard at one site, while *fractured* basalt or limestone at another location may enhance the movement of effluent, making disposal problematic due to reduced soil treatment at the second site.

In addition to the soil and substratum composition and structure, the highest seasonal groundwater depth influences the method of treatment and disposal. Highest seasonal groundwater can be observed in the mottling of the soil test pit. A minimum vertical separation of three (3) feet is required between the bottom of the disposal system and the highest seasonal groundwater level. If this minimum spacing cannot be obtained with a trench or bed, then an elevated mound should be used. For areas below the UIC, aerobic treatment systems can dispose of the effluent into the groundwater, provided the effluent is disinfected.

The overall geological site conditions that must be considered (at least three feet below the absorption system) are:

- Thickness of layers or horizons of the soil;
- Texture of the soil layers;
- The general color or mottling of the soil (indicating possible composition and presence of water);
- Depth to water, if observed;
- Depth to the seasonal high groundwater table;
- Depth to and type of bedrock, if observed;
- Structure, stoniness, roots, etc of each layer; and
- Percolation tests.

Terrain and Flood Potential

In addition to the parcel's geologic characteristics, it is important to understand how the existing and post-development terrain might impact which system is selected. For example, absorption trenches can be used in terrain with a final slope of up to 12%. However, absorption beds can be used in terrain with a final slope of only 8%. For areas with steeper slope, options for disposal may be a seepage pit or very complex terracing.

In addition to the final slope of the terrain, the potential for flooding in the area must be analyzed. It is recommended that wastewater treatment systems be installed to minimize the effects of flooding, for example, on the upper slopes of a hill as opposed to a valley.

Minimum Spacing Requirements

Once the property size, location, geology, and terrain have been accounted for, the wastewater treatment systems are still restricted by regulations to prevent contamination of drinking water, groundwater, and other personal property. In order to prevent contamination and allow for ease of maintenance, minimum horizontal distances have been determined between wastewater systems and other structures, property lines, and water sources. The minimum horizontal separations from HAR 11-62 are summarized in Table 3-1.

Table 3-1. Minimum Horizontal Separations

Item	Minimum Horizontal Distance from (ft)			
	Cesspool	Treatment Unit	Seepage Pit	Soil Absorption System
Wall line of any structure	5	5	5	5
Property Line	9	5	9	5
Stream, ocean (taken from the vegetation line), pond, lake or other surface water body	50	50	50	50
Large trees	10	5	10	10
Treatment unit	5	5	5	5
Seepage pit	18	5	12	5
Cesspool	18	5	18	5
Soil absorption system	5	5	5	5
Potable water sources serving public water systems (potable wells)	1,000	500	1,000	1,000

Water Budget

For certain systems (evapotranspiration, constructed wetlands, water reuse, etc.), it is necessary to have an understanding of the water budget for a site. A water budget is an accounting of precipitation, evaporation, transpiration, surface runoff, and percolation that affect discharged effluent. Evaporation is determined by pan evaporation data, but is generally grouped together with transpiration as evapotranspiration. An area that is high in precipitation and low in evaporation is less ideal for an evapotranspiration disposal system than a very arid area is. In some cases, mauka of the UIC for example, a water budget must be computed to demonstrate that wastewater discharged to the surface or subsurface will be evapotranspired before it can percolate to the groundwater.

Aesthetics

One intangible factor that must be considered is aesthetics. This includes finished appearance, disruption during construction, equipment noise, and odor potential. If these factors are not considered in advance, the system may suffer from neglect due to owner dissatisfaction.

GUIDELINES FOR SELECTING ON-SITE SYSTEMS

Table 3-2 indicates how the various site conditions described above influence the suitability of disposal options generally available in Hawaii. These disposal options are described in greater detail in Chapter 4. Tables 3-3 and 3-4 indicate how the site conditions affect selection of various onsite and small-flow treatment systems. These treatment systems are described in greater detail in Chapters 5 and 6. In cases where there are multiple restrictive site conditions, it is necessary to consider alternatives that are suitable for all of the requisite conditions. Also, the total system design consisting of a treatment system and a disposal system, must consider various combinations that will achieve overall treatment objectives at economical costs. In general, the treatment systems can be used with any of the disposal systems, but some combinations will provide greater pollutant reductions than others and costs will be different. Where strict treatment objectives are required to protect public health and the environment, it becomes necessary to choose treatment and disposal systems with higher removal rates. Removal rates and costs are discussed in Chapters 4, 5, and 6.

It must be noted that there are multiple equipment suppliers for each of the different type of treatment systems described herein. There are differences in materials of construction, size, mechanical design, component complexity, operating modes and warrantees, just to name a few. Suffice to say, not all systems are created equal in terms of expected performance, durability, ease-of-operation, as well as manufacturer experience, presence, representation-in-Hawaii, etc. and a good measure of buyer beware is advised. It is highly recommended to consult a Hawaii-registered professional engineer with onsite treatment system design experience prior to purchase of any treatment or disposal system. Such an engineer will also be required to sign-off on the design in order to obtain a building permit.

In general, there will usually be several different acceptable combinations of treatment and disposal systems for any given site needing an OWTS. Selection of the "best" option could be based on any number of criteria including cost, degree of treatment, familiarity, expert or other recommendation, etc. This report attempts to give multiple types of information to assist in this effort (see chapter 4, 5, and 6). Additional assistance is provided below in the form of examples to illustrate how to use the information to make a selection. For these examples, three different alternatives will be considered if feasible, as follows: (1) the MIN alternative; a minimally acceptable alternative which meets requirements; (2) the ENHANCED alternative; an enhanced treatment alternative that is more protective of public health and the environment; and (3) the GREEN alternative; a sustainable or "green" alternative that is most protective of human health and the environment, possibly with reduced impacts on natural resources.

Example 1. Single family home, 5 BR, 1,000 gallons/day design wastewater flow, 15,000 square foot lot, 1 to 2% slope, 50 ft depth to groundwater, 5000 ft distance to nearest potable well, makai of UIC and no-pass lines, 1,700 feet from ocean, not in flood zone, low cesspool density, good draining soil.

This is the least restrictive case. Nearly any combination of treatment and disposal systems will be adequate. Some alternatives are as follows:

MIN: Septic tank and absorption trench/bed, cost: $12,000-$30,000
Notes: because the septic tank provides only minimal treatment, this alternative relies on the absorption bed to provide substantial additional treatment in order to protect the public health. This can only be the case under favorable conditions of soil characteristics and distance to groundwater.

ENHANCED:

Combined attached and suspended growth ATU and absorption trench/bed, cost: $27,000-$48,000

Notes: the ATU provides full secondary-level treatment and the absorption bed provides additional treatment, making this alternative highly protective of the environment and public health.

GREEN:

Septic tank and evapotranspiration, cost: $20,000-$37,000

OR

Septic tank, Recirculating Sand Filter, Disinfection and Water reuse, cost: $31,000-$50,000 (assuming $5,000-6,000 for water reuse)

OR

SBR, Disinfection and Water reuse, cost: $26,000-$38,000 (assuming $5,000-6,000 for water reuse)

Notes: the septic tank and ET system is zero discharge (highly protective of the environment and public health) and very low energy use requiring only a small dosing pump to supply the ET system. The septic tank plus RSF provides the same full secondary treatment with high degrees of nitrogen removal as the SBR but with lower energy use. The water reuse disposal method conserves potable water resources.

Example 2. Same as Example 1, but with depth to groundwater of 8 ft and 100 ft from drainage ditch that flows into a stream and then the ocean.

This is a more restrictive case. Here there are two site conditions (shallow groundwater and proximity to inland/coastal water), which limit the alternatives. Some alternatives are as follows:

MIN: Septic tank and elevated mound or evapotranspiration, cost: $15,000-$37,000

Notes: because the septic tank provides only minimal treatment, this alternative relies on a properly designed elevated mound (or the zero-discharge ET system) to provide substantial additional treatment in order to protect the public health.

ENHANCED:

Suspended growth ATU and evapotranspiration, cost: $35,000-$55,000

Notes: the ATU provides full secondary-level treatment and the ET system provides zero discharge, which is highly protective of the environment and public health.

GREEN:

Same as Example 1.

Example 3. Same as Example 1, but with location mauka of UIC and no pass line, with poor draining soils, 150 ft depth to groundwater, and 2 miles from the ocean.

This is a restrictive case. Here there are two site conditions (poor soils and protection of drinking water), which limit the alternatives. Some alternatives are as follows:

MIN: Suspended growth ATU and elevated mound, cost: $30,000-$55,000

Notes: because the septic tank provides only minimal treatment, this alternative relies on a properly designed elevated mound to provide substantial additional treatment in order to protect the public health.

ENHANCED:

Suspended growth ATU and evapotranspiration, cost: $35,000-$55,000

Notes: the ATU provides full secondary-level treatment and the ET system provides zero discharge, which is highly protective of the environment and public health.

GREEN:

Same as Example 1.

These examples only considered an individual wastewater system, but a similar selection process would be used for situations corresponding to a small flow system (1,000 to 50,000 gallons/day). In general, the process consists of checking Table 3-2 to find a suitable onsite disposal method based on site conditions, then checking either Table 3-3 or 3-4 to find a suitable treatment method based on site conditions, then considering the desired level of environmental protection and overall system cost to choose an acceptable combination of treatment and disposal systems for a specific design scenario.

Table 3-2. Suitability of Onsite Disposal Methods to Varying Site Conditions

Onsite Disposal Method	High Water Table	Impermeable Soil	Steep Terrain	Flood Zone	Inland Surface Water	Coastal Water	High Cesspool Density	Protection of Groundwater	Protection of Drinking Water (CWDA)	Hydrogeology
Holding Tank	P	P	P	NR	P	R	P	R	R	P
Injection Well	P	P	P	NR	P	P	P	P	P	P
Seepage Pit	NR	P	R	NR	NR	P	NR	P	NR	P
Adsorption Trenches	NR	NR	NR	NR	P	P	P	P	NR	P
Adsorption Beds	NR	NR	NR	NR	P	P	P	P	NR	P
Elevated Mounds	P	P	P	NR	P	P	P	P	P	P
Evapotranspiration	P	R	NR	NR	P	P	P	R	R	P
Water Reuse	R	R	R	NR	R	R	R	R	R	R

Legend:
R – Recommended
P – Possible
NR – Not Recommended

Table 3-3. Suitability of Onsite Treatment Methods (<1,000 gpd) to Varying Site Conditions

Onsite Treatment Method	High Water Table	Impermeable Soil	Steep Terrain	Flood Zone	Inland Surface Water	Coastal Water	High Cesspool Density	Protection of Groundwater	Protection of Drinking Water (CWDA)	Hydrogeology
Septic Tank	P	P	P	NR	NR	P	P	P	P	P
Low water/Waterless Toilets	R	R	R	NR	R	R	R	R	R	R
Continuous Flow, Suspended Growth	R	R	R	NR	R	R	R	R	R	R
Continuous Flow w/ Fixed Integral Packing	R	R	R	NR	R	R	R	R	R	R
Sequencing Batch Reactor ATU	R	R	R	NR	R	R	R	R	R	R
Single Pass Sand Filter	R	R	R	NR	R	R	R	R	R	R
Recirculating Sand Filter	R	R	R	NR	R	R	R	R	R	R
Enhanced Phosphorus Removal	R	P	P	NR	R	R	P	P	P	P
Enhanced Nitrogen Removal	R	P	P	NR	R	R	P	P	P	P
Emerging Trace Contaminant Removal	P	P	P	NR	P	P	P	P	P	P
Chlorine Disinfection	P	P	P	NR	NR	NR	P	R	R	R
UV Disinfection	P	P	P	NR	R	R	P	R	R	R

Legend:
R – Recommended
P – Possible
NR – Not Recommended

Table 3-4. Suitability of Small Flow Treatment Methods (1,000-50,000 gpd) to Varying Site Conditions

Small Flows Treatment Method	High Water Table	Impermeable Soil	Steep Terrain	Flood Zone	Inland Surface Water	Coastal Water	High Cesspool Density	Protection of Groundwater	Protection of Drinking Water (CWDA)	Hydrogeology
Cluster Systems	P	P	P	NR	R	R	R	P	R	P
Lagoons	NR	R	NR	NR	P	P	P	P	P	P
Oxidation Ditches	P	P	P	NR	R	R	R	R	R	P
Attached Growth Aerobic Reactors	P	P	P	NR	R	R	R	R	R	P
Constructed Wetlands	NR	R	NR	NR	P	P	P	P	P	P
Membrane Bioreactors	P	P	P	NR	R	R	R	R	R	P

Legend:
R-Recommended
P-Possible
NR-Not Recommended

Chapter 4 Individual Wastewater Systems-Disposal Technologies

SUMMARY AND FACT SHEETS

The characteristics and conditions of a homeowner or developer's site determine which disposal systems are appropriate. Chapter 3 guided the reader to a few specific disposal systems based on nine critical characteristics of a site. This chapter is dedicated to the summary of those disposal systems and the corresponding fact sheets for some common disposal systems. Each fact sheet is summarized by a smart box like the example shown below.

<u>Absorption Trenches Summary</u>		
Use in Steep Terrain		<12% slope
Use in High Ground Water Areas		No
Allowable percolation rate		< 60 min/in
Relative Footprint when compared to conventional drainfield		Medium
Maintenance Level:		Low
Power Required:		No
Typical Installed Cost:	$7000-$18,000	/1,000 gallons

Use in Steep Terrain: Gives the finished slope limitations of each system

Use in High Ground Water Areas: Indicates whether or not the system can be used where ground water is within 3-6 feet of the system

Percolation Rate: Gives the minimum percolation rate (min/in) that the soil must have in order for the system to be used

Footprint: Indicates whether the system is small, medium or large when compared to the size of a conventional absorption trench system disposing of the same amount of wastewater

Maintenance Level: Indicates whether the system has a low, medium or high level of maintenance (low = low frequency and low technical difficulty, medium = high frequency and low technical difficulty or low frequency and high technical difficulty, high = high frequency and high technical difficulty)

Power Required: Indicates if power is required for the system to operate

Typical Installed Costs: Gives an estimate of cost based on conditions described in detail below

Fact sheets are provided for simple disposal devices that do not provide treatment, including containment systems (holding tanks (D-1)), cesspools (D-2), and seepage pits (D-3). Fact sheets are also included for devices that provide significant treatment, such as, subsurface wastewater infiltration systems (SWIS), including absorption trenches (D-4), absorption beds (D-5), and elevated mounds (D-6). A fact sheet is also included for a zero-discharge system using evapotranspiration (D-7). A fact sheet containing information on wastewater reuse (D-8) is also included. It is noted that, with only very limited exceptions, all of the disposal systems included herein require an upstream treatment system, a variety of which are described in Chapters 5 and 6. It is further noted that cesspools are included in this chapter as disposal devices rather than Chapter 5, since they are not considered a treatment system.

COSTS

A typical, current construction cost for each disposal system is provided on the fact sheets as a budgetary guideline.

Cost Assumptions

The following assumptions have been made regarding the probable cost of construction:

- The size of the treatment system is to treat 1,000 gallons of domestic wastewater;
- The cost index is based on RS Means for January 2007;
- Expected annual cost inflation is 5% per year; and
- The costs are those associated with installation of a system on the island of Oahu, Hawaii.

Costs Included

The typical installed cost estimates include estimated labor, materials, equipment, mobilization, contractor's overhead and profit, as well as construction contingencies. The typical construction cost estimates are based on preliminary quotes from manufacturers, analysis of bid prices for similar projects, and current 2007 construction cost averages from cost reference data. Contingent costs allow for uncertainties that are unavoidably associated with generic site conditions.

Factors Affecting Cost Escalation

Factors such as unforeseen conditions, changing conditions, special construction methods, permitting, and new regulations are a few of many items that may impact and cause an increase in the actual construction cost and for which allowances are made. A contingency factor of 20 percent has been applied to the basic estimated cost in an attempt to minimize the effects of the many unknowns. Because of the unknown factors and unpredictability of the future construction climate, the typical installed cost estimates presented are to be used for budgetary and comparison purposes only, and may not necessarily be an accurate representation of the true cost of construction. Actual cost of construction will take into account varying soil conditions, accessibility and slope of the site, construction climate, island location, etc. It is suggested the following multipliers be applied to the typical installed costs to get a budgetary cost of construction:

1. Escalation rates - 5% per year;
2. Excavation in rock – multiply cost by 3;

3. Outer island work due to limited contractors and equipment – multiply cost by 1.5;
4. Limited or restricted accessibility to site – multiply cost by 3;
5. Steep terrain, greater than 20% - multiply cost by 1.5.

SUMMARY OF ONSITE WASTEWATER DISPOSAL SYSTEMS

Table 4-1 Summary of Typical Disposal System Effluent Water Quality

DISPOSAL SYSTEM	BOD mg/L	TSS mg/L	Total Nitrogen mg/L	Total Phosphorus mg/L	Fecal Coliforms Per 100 mL	COMMENTS
Holding Tank (Septic Tank effluent in parathesis)	100-400 (132-217)	100-400 (49-161)	14-40 (39-82)	5-20 (11-22)	1 – 100 million	
Cesspool	100-400	100-400	15-90	5-20	1-100 million	
Seepage Pit			78 mg/kg soil		~10,000	Reported by Field et al at 3 m below pit and 30 cm from edge
Absorption Trenches	<30	4	1	<2	13	
Absorption Beds	<30	4	1	<2	13	
Elevated Mounds	<30	<20	<15	<2	13	
Evapotranspiration	Varies	Varies	Varies	Varies	Varies	
Water Reuse	< 30 mg/L	< 30 mg/L	No specs.	No specs	< 23	Requirements for R-2 water

Table 4-2 Summary of Typical Installed Costs for Disposal Systems

DISPOSAL SYSTEM	Typical installation Costs ($/unit)	Annual Maintenance Fees ($/yr) (Including pumping and labor)	Energy Consumption (kW-h/yr)	Energy Costs ($/yr) (At HECO rate of 20.06 cents per kW-h)	Annual Replacement Parts ($/yr) (Including chemicals)	Annual Amortized Cost over 5 years ($/mo) (At nominal 6% annual interest rate, compounded monthly)
Holding Tank	5,000-12,000	400-2,000	-	-	-	35-400
Cesspool	15,000	50-200	0	0	0	290-310
Seepage Pit	>10,000	-	None	None	-	>190
Absorption Trenches	7,000-18,000	-	None	None	-	130-350
Absorption Beds	7,000-18,000	-	None	None	-	130-350
Elevated Mounds	10,000-25,000	-	110-365	20-75	-	195-490
Evapotranspiration	15,000-25,000	-	-	20-75	-	300-570
Water Reuse	Varies	-	-	-	-	Varies

Table 4-3 Advantages and Disadvantages of Typical Disposal Systems

Disposal System	Advantages	Disadvantages or Limitations
Holding Tank	▪ Zero discharge to surrounding area	▪ Generally a temporary solution to a problem ▪ Must be pumped on regular basis ▪ Possible odors
Cesspool	▪ May already exist ▪ No power consumption	▪ Minimal treatment of sewage
Seepage Pit	▪ Can be easily installed where a cesspool once existed ▪ Can be used in very steep terrain locations	▪ Surface area needed for percolation may make pit so deep it discharges to groundwater ▪ Large percolation area may require multiple pits, increasing price drastically
Absorption Trenches	▪ Most common means of disposal ▪ Excavation does not disturb soil properties	▪ Limited by steep terrain and land area ▪ Sides of the trenches are not credited to percolation area
Absorption Beds	▪ Area of the entire bed bottom is credited to percolation area	▪ Extremely limited by steep terrain
Elevated Mounds	▪ A soil absorption system to overcome limitations regarding poor soil or proximity to groundwater	▪ Increased cost due to additional backfill requirements. ▪ Requires energy consumption due to pumping wastewater to above ground dispersion system
Evapotranspiration	▪ Non-leaching system ▪ Can be used above UIC line with approval	▪ Works well in arid areas where the rate of evaporation is greater than the rate of precipitation ▪ Requires energy ▪ Requires additional storage capacity ▪ Requires lysimeter monitoring
Water Reuse	▪ Reduces water demand for potable water for irrigation ▪ Considered zero discharge	▪ May be best suited to daily flow rates larger than the scope of this study ▪ Requires backup disposal or storage

Table 4-4 Typical Design Criteria for Disposal Systems

Disposal System	Percolation Rate		Minimum Separation from Ground Water	Land Slope Gradient	Absorption Area
	Minimum Rate	Maximum Rate			
Absorption Trench	60 min/inch	Rapid, 1 min/in	3 feet	<12%	Bottom area of trench
Deep Absorption Trench	60 min/inch	Rapid, 1min/in	3 feet	<12%	Bottom area of trench
Absorption Bed	60 min/inch	Rapid, 1min.in	3 feet	<8%	Bottom area of bed
Seepage Pit		30 min/in	3 feet	≥12% Minimum Slope	Vertical wall area between bottom of inlet pipe and bottom of pit, excluding strata with percolation rates slower than 30 min/in
Elevated mound system	Reviewed by DOH on a case-by-case basis for systems outside percolation rate range of trenches and beds		3 feet		Bottom area of distribution piping (not the base of the mound)
Evapotransporation	Reviewed by DOH on a case-by-case basis.				
Water Reuse	Reviewed by DOH on a case-by-case basis				

CONTAINMENT SYSTEMS FACT SHEET

Holding Tanks Fact Sheet D-1

A holding tank is a watertight concrete or plastic tank that receives either raw or treated wastewater and stores it until a pumping contractor can haul the wastewater away. Typically, holding tanks are used only as a temporary disposal system until a connection to a public system is established or an existing disposal system can be repaired or upgraded. The tank should be able to hold 2-3 days worth of storage, requiring a hauler to remove wastewater every other day before it becomes septic or overflows. Holding tanks are only allowed in public facilities.

Considerations and Restrictions

Holding tanks must be structurally sound and must remain watertight. Holding tanks are considered a temporary system until a better system can be installed. Consideration should be given to providing venting for odor control and sizing of the tank to account for any gases that may be produced due to anaerobic reactions occurring in the tank. Alarms for overflow or strict monitoring of the holding tanks is necessary to prevent overflowing wastewater.

Effluent Quality

If any treatment occurs, it is anaerobic in nature, producing odorous gases. No treatment can be assumed.

Typical Installed Costs (2007)

Assuming the excavation and cost of the tank itself are the slightly higher than septic tanks, the cost of installing a complete holding tank is $10,000-$25,000.

Operation and Maintenance Costs

Periodic pumping is required in order to prevent backups into the plumbing leading to the holding tank. For pumping up to 2 to 3 times per week, the cost would be $1,600 -$2,400 per month or $19,200 to $28,800 per year.

Holding Tanks Summary

Use in Steep Terrain	Any terrain
Use in High Ground Water Areas	Yes
Percolation Rate	N/A
Relative Footprint When Compared To Conventional Drainfield	Small
Maintenance Level:	High
Power Required:	No
Typical Installed Cost: $10,000 -$25,000	/1,000 gallons

SUBSURFACE DISPOSAL SYSTEMS FACT SHEETS

INJECTION WELLS AND SUBSURFACE DISPOSAL

According to the HAR 11-23, the definition of an injection well is a well in which subsurface disposal of a fluid occurs. A well is any bored, dug, or driven shaft that is deeper than the widest surface dimension. Injection wells are used for the disposal of many types of fluids, but for the purposes of this handbook, injection wells are only discussed in reference to domestic wastewater. Injection wells include those drained by gravity and wells that have applied pressure to force wastewater into the soil. Because of that broad definition, they include cesspools and seepage pits, which are discussed in the following fact sheets. Only Class V injection wells are permitted to be constructed in Hawaii. Of these wells, injection wells receiving wastewater have been further classified as:

1) Subclass A, if injecting fluid mauka of the UIC line and into an underground source of drinking water; and
2) Subclass AB, if injecting fluid makai of the UIC line.

For a single family residence or a public place that serves fewer than 20 people per day, the onsite wastewater disposal system is not required to be regulated under Code of Federal Regulations Title 40, Part 144.

Injection wells are only allowed makai of the Underground Injection Control (UIC) line, or more formally in any exempted portions of aquifers. The location of the injection wells is limited to prevent the contamination of drinking water. Injection wells can be used to recharge brackish water near the coast and help prevent saltwater intrusion into the fresh groundwater lens.

The Department of Health has provisions for minimum setbacks for injection wells. Generally, the injection wells must be more than one-quarter mile from a drinking water source or its conveyance system. Injection wells that pierce voids or lava tubes in the soil must be mitigated to prevent effluent from entering the void. Injection wells should never discharge into a void. Operating wastewater injection wells must be permitted. Permits may be issued for any amount of time, not to exceed five years.

The quality of effluent from an injection well varies with the type of injection well and the soil. A more distinguishing characteristic of an injection well is the quality of influent that it receives. For example, a seepage pit receives treated wastewater whereas a cesspool receives raw wastewater. The conditions in which the injection well is constructed also impact the quality of influent it can receive. For example, seepage pits constructed where discharge to groundwater will occur must have aerobically treated, disinfected influent to comply with DOH standards. If the groundwater is closely connected to surface water, enhanced nitrogen removal (50%) should also be required.

In addition to injection wells, wastewater can be disposed of beneath the ground using a subsurface wastewater infiltration system (SWIS). SWIS allow for treated wastewater to percolate through the soil, where varying degrees of physical, chemical, and/or biological treatment occurs. The wastewater will eventually reach the groundwater, but, given the proper amount of unsaturated soil, the wastewater may be well treated by the time it reaches the groundwater. The most important part of a SWIS is the biomat, the layer of organic, inorganic, and biological material that forms at the interface of the SWIS and the soil. The biomat is the portion of the SWIS that provides a large part of the physical, chemical, and biological treatment of the wastewater. SWISs include absorption trenches and absorption beds.

Cesspools Fact Sheet D-2

Cesspools are generally large, cylindrical, lined excavations used to receive untreated wastewater. Solids are retained and the liquid percolates into the surrounding soil. A cesspool is either lined with rock, or constructed with mortar-less brick or perforated concrete rings. Cesspools are not considered a treatment system because virtually no treatment occurs that would protect the surrounding environment. Therefore, cesspools are considered to be only a disposal device.

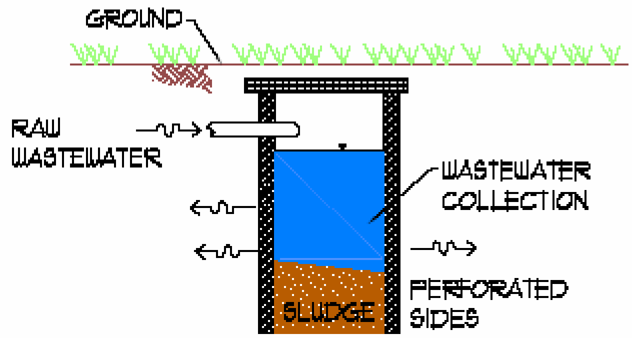


Figure 4-1 Cesspool

<u>Considerations and Restrictions</u>

New cesspools are severely restricted and prohibited in designated critical wastewater disposal area on all islands as defined in the HAR 11-62. New cesspools are currently still legal in specific areas of Hawaii County. Refer to the CWDA maps in Appendix C. Because of the slow decomposition rate, the solids in the wastewater will eventually clog the cesspool. The pores of the lining can be re-opened using caustic soda or a very strong acid. However, even these solvents will eventually fail to open the pores, and the cesspool will have to be closed and replaced.

<u>Effluent Quality</u>

Effluent quality is only slightly better than the quality of raw wastewater as only large solids are removed from the wastewater. When used following a treatment system, no treatment is assumed and the cesspool functions as a seepage pit (see D-3).

<u>Typical Installed Costs (2007)</u>

$15,000 for excavation, lining and backfill.

<u>Operation and Maintenance Costs</u>

The organic solids that settle to the bottom of the cesspool decompose at a very slow rate, resulting in accumulation of solids. Because of this accumulation, periodic pumping is required, ranging from $150 to $550 per visit, depending on site conditions and volume pumped.

<u>Cesspools Summary</u>

Use in Steep Terrain	Yes
Use in High Ground Water Areas	No
Percolation Rate	Designated by DOH
Relative Footprint When Compared To Conventional Drainfield	Small
Maintenance Level:	Low
Power Required:	No
Typical Installed Cost:	up to $15,000 /1,000 gallons

Seepage Pits Fact Sheet D-3

The construction of a seepage pit is similar to that of a cesspool. The difference between the two is that the seepage pit receives treated wastewater, whereas a cesspool receives untreated wastewater. The effective absorption area of a seepage pit is measured along the sidewalls of the pit. No allowance is made for the bottom of the pit according to HAR 11-62.

Considerations and Restrictions

Seepage pits should be considered when the land area available to dispose of effluent is insufficient for absorption beds/trenches, when the terrain is too steep for other disposal systems or when an impermeable layer overlies more suitable soil. Design criteria should be referenced in HAR 11-62.

Seepage pits are often found where cesspools once existed. The addition of a septic tank or other treatment system upstream from the cesspools enables the owner to consider converting the cesspool into a seepage pit, if the cesspool does not have any problems like spills or overflows. However, in cases where a new seepage pit is to be installed, it may be more expensive than other systems due to the greater depth of excavation. Seepage pits may also be sited such that they are below the aerobic zone in soil, resulting in little or no oxidation of organic compounds as compared to shallower systems such as absorption systems.

Effluent Quality

There have been few studies that have investigated the effluent characteristics of seepage pits. It is commonly believed that seepage pits do not provide the same level of treatment as other disposal systems. However, in a 2007 study, it was shown that seepage pits in loamy soil eliminated E. Coli, a fecal coliform, from wastewater as well as absorption trenches did. Organic loads adjacent to the absorption trenches were actually higher than they were for the seepage pits. Effluent from seepage pits was also lacking in ammonia nitrogen, indicating effective nitrification. Total nitrogen was similar to background levels within six feet of the bottom of the seepage pits.

Typical Installed Costs (2007)

Conversion of a cesspool into a seepage pit will cost approximately $5,000. Installing a new seepage pit is much more expensive, depending on the soil conditions, but will generally cost approximately $10,000 each. Multiple seepage pits may be required, depending upon site-specific percolation rates.

Operation and Maintenance Costs

The overwhelming issue for seepage pits is not the maintenance of the pits themselves, but the maintenance of the treatment systems preceding the pits. Proper operation and maintenance of the septic tank(s) or ATU(s), extends the life of the seepage pit and decreases the likelihood of solids clogging in the seepage pit. If upstream processes allow passage of solids to the seepage pit, periodic sludge pumping will be required.

Seepage Pits Summary	
Use in Steep Terrain	Yes
Use in High Ground Water Areas	Usually no
Percolation Rate	Faster than 60 min/in
Relative Footprint When Compared To Conventional Drainfield	Small
Maintenance Level:	Low
Power Required:	No
Typical Installed Cost:	$10,000 /1,000 gallons

Absorption Trenches and Gravelless Systems

Fact Sheet D-4

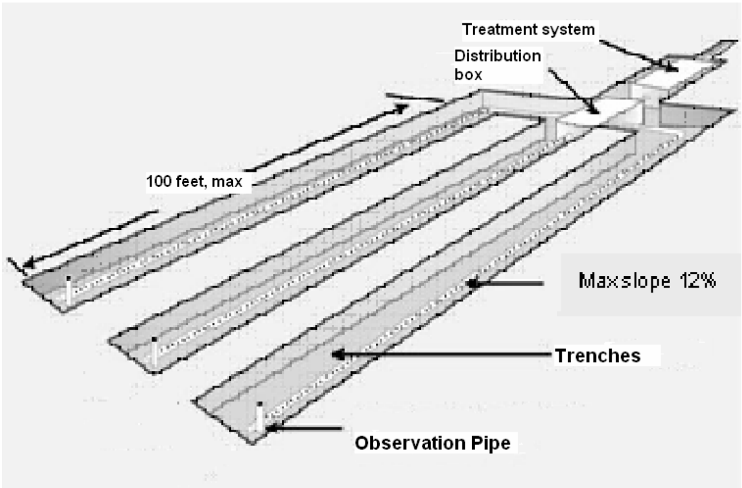


Figure 4-2 Trench disposal system (Adapted from Kent County, DE DPW)

Absorption trenches are subsurface wastewater infiltration systems (SWIS) that utilize trenches between 18 and 36 inches wide.

Typically, trenches have been built with perforated pipe in a gravel bed. The gravel bed provides structural support for the pipe and a more infiltrative surface for the wastewater. Recently, however, other materials (plastic chambers, storage panels, etc.) have been substituted for the gravel bedding (allowing for *gravelless* trenches). These materials allow for structural stability and hydraulic flow, while potentially decreasing the costs associated with fill.

Usually, trenches are constructed with the bottom of the absorption area no more than three (3) feet to five (5) feet below grade. This ensures that oxygen transfer from the air can continue down to the bottom of the trench, and the drainfield will remain aerobic. However, it is sometimes necessary to excavate to a greater depth in order to reach more suitable soil for percolation of the wastewater. In these cases, the trenches are referred to as "deep trenches" and may be regulated differently than the shallower absorption trenches.

Considerations and Restrictions

Percolation rate and depth to groundwater must be considered in the design of absorption trenches. Trenches cannot be used in terrain where the natural slope is too steep. Because the effective absorption area is at the bottom of each individual trench, absorption trenches can require large amounts of land. Root intrusion has an adverse impact on the performance of the trenches, and root barriers should be considered. Grading should be designed so that stormwater runoff flows away from the absorption trenches.

Effluent Quality

The septic tank and drainfield treatment/disposal system combination has been shown to meet the same effluent qualities provided by biological treatment systems under optimal conditions. Under ideal conditions, quality can be as good as BOD of 4 mg/L, TSS of 1 mg/L and fecal coliforms of 13 per 100 mL. However, overloaded systems, rainfall, and unsuitable soils, will result in contaminants (BOD, TSS, coliforms/pathogens, nitrogen and phosphorus) escaping treatment and passing into the surrounding soil/groundwater/surface water.

Typical Installed Costs (2007)

These costs include excavating the drainfield, installing bedding, and laying distribution piping or plastic chambers/storage panels, etc. Typical construction costs range between $7,000 and $18,000 per 1,000 gpd of treated wastewater.

Operation and Maintenance Costs

There is very little maintenance needed to maintain a drainfield. Inspection/observation ports should be provided in the drainfield to determine whether water is accumulating in the trenches rather than percolating out. If solids overflow from a septic tank or other treatment process into the absorption system, these solids will rapidly clog the voids in the soil, reducing or eliminating the percolation capability. Nothing can be done to restore the performance of the soil except for time and rest, which may also be insufficient. In such cases, a new soil absorption system may need to be constructed for continued service, which is costly and disruptive to the property. Emphasis, therefore, should be placed on the strict maintenance requirements of the upstream treatment processes.

Absorption Trenches Summary		
Use in Steep Terrain		<12% slope
Use in High Ground Water Areas		No
Percolation Rate		Faster than 60 min/in
Relative Footprint When Compared To Conventional Drainfield		Medium
Maintenance Level:		Low
Power Required:		No
Typical Installed Cost:	$7,000-$18,000	/1,000 gallons

Absorption Beds Fact Sheet D-5

Absorption beds are subsurface wastewater infiltration systems (SWIS) that have beds at least three feet wide. Absorption beds are similar to absorption trenches. For an absorption trench system, there is a distinct section of undisturbed soil between the absorption trenches. With an absorption bed, the area designated for disposal is excavated, and a layer of gravel is installed with the distribution pipe laid atop. In the case of gravelless systems, the plastic chambers are laid on the exposed soil. In essence, the wastewater will be spread over the entire area, instead of restricted to beneath the distribution pipe.

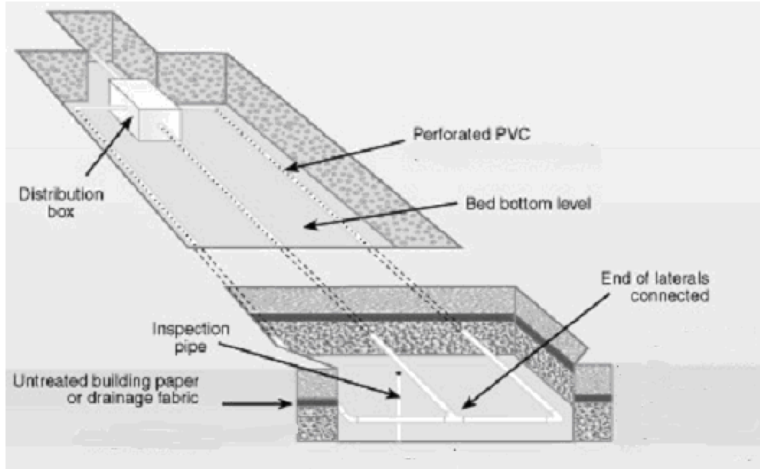


Figure 4-3 Bed disposal system (Adapted from Kent County, DE DPW)

Considerations and Restrictions

Beds are not allowed in terrain with slopes exceeding 8%. Since the entire area of the bed is considered as absorption area the total amount of land required is smaller compared to an absorption trench system. Roots from bushes and trees will damage the performance of the absorption system, therefore, root barriers should be utilized.

Effluent Quality

Effluent quality from an absorption bed will be similar to that of absorption trenches (see D-4).

Typical Installed Costs (2007)

These costs include excavation, gravel, piping, and/or plastic chambers/storage panels. Typical costs are about $7,000-$18,000 per 1,000 gpd of treated wastewater.

Operation and Maintenance Costs

Operational and maintenance issues are the same as for trenches. See Appendix A for tips extending the functional life of SWIS.

Absorption Beds Summary

Use in Steep Terrain	<8% slope
Use in High Ground Water Areas	No
Percolation Rate	Faster than 60 min/in
Relative Footprint When Compared To Conventional Drainfield	Medium
Maintenance Level:	Low
Power Required:	No
Typical Installed Cost: $7,000-$18,000	/1,000 gallons

ALTERNATIVE DISPOSAL SYSTEMS FACT SHEETS

Elevated Mounds Fact Sheet D-6

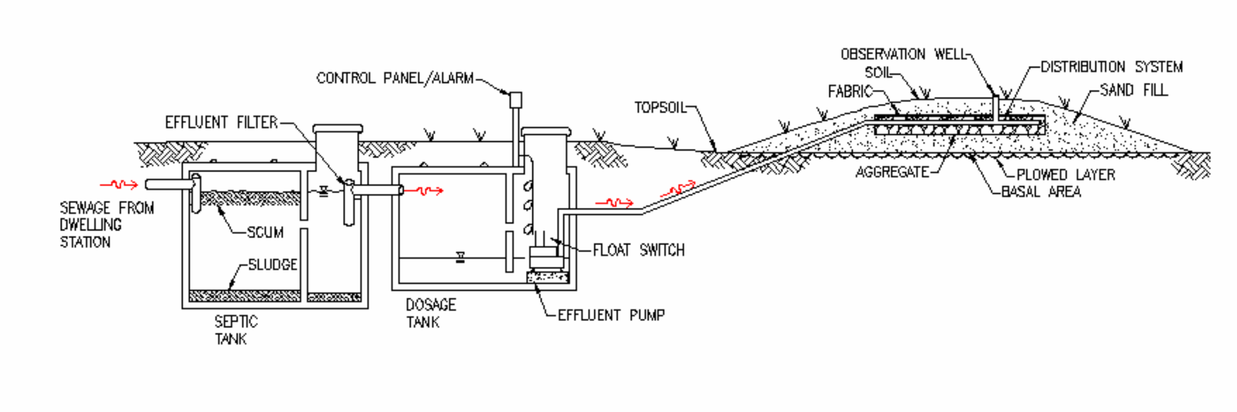


Figure 4-4 Elevated Mound System

Elevated mound systems are engineered mounds of sand/soil used to create acceptable soil conditions for effluent disposal and/or to create vertical separation from groundwater. The land on which the mound will be placed is first tilled, and a layer of sand and distribution system is placed over the tilled surface. The top of the mound is covered with surrounding soil and aesthetically landscaped.

Considerations and Restrictions

Mounds are commonly used in areas where absorption trenches and beds cannot be used, such as when the terrain is excessively steep, when there is a high groundwater table, or when the soil percolation rate is not conducive for a SWIS. Landscaping is required as the mounds could reach a height of three feet. As shown in the figure above, the disposal point is higher than the treatment system, therefore a pump system will be required.

Effluent Quality

Effluent quality for an elevated mound system is similar to that of an absorption trench or bed (see D-4).

Typical Installed Costs (2007)

Construction costs range from $10,000 to $15,000, but can go as high as $25,000 per 1,000 gpd of treated wastewater in Hawaii.

Operation and Maintenance Costs

Since the elevated mound system requires a pump to lift the effluent to the specific elevation, the pump's power costs need to be budgeted. The estimated power consumption is approximately 100 – 300 kW-h per year. The same care must be provided to the mound as would be provided to trenches or beds. See Appendix A for tips on maintenance.

Elevated Mounds Summary

Use in Steep Terrain	Yes
Use in High Ground Water Areas	Yes
Percolation Rate	All
Relative Footprint When Compared To Conventional Drainfield	Large
Maintenance Level:	Medium
Power Required:	Yes
Typical Installed Cost:	up to $25,000 /1,000 gallons

Evapotranspiration Fact Sheet D-7

Evapotranspiration (ET) is the combined effect of wastewater disposal by direct evaporation and by plant transpiration. ET is the discharge of pretreated effluent to a porous bed containing water-tolerant plants. Wastewater effluent is discharged into the bed, and wicking or capillary action draws the water to the surface where it is either taken up by the plants and transpired or evaporated from the surface of the bed. These systems may or may not be designed with an impermeable liner. If the system is designed with a liner, the system is considered “zero-discharge”, and disposal is strictly dependent on transpiration through the plants and evaporation. However, if the liner is not used, the disposal system sizing criteria can also account for absorption via the soil. This type of system is known as evapotranspiration-infiltration (ETI). ET and ETI require large surface areas for year round disposal and are most suited for very arid climates where evaporation rates are much higher than precipitation rates.

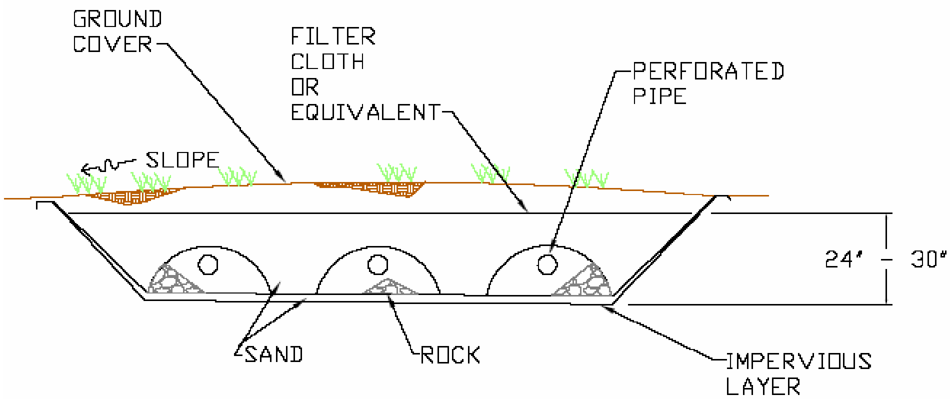


Figure 4-5 Cross Section of an ET Bed

Typical components of an ET system may include drip or distribution lines, a flushing and filtering mechanism, a controller to automate the dosing cycles, a distribution pump, and several alternating drainfields. DOH approves these systems on a case-by-case basis, and systems exist in the State of Hawaii. Record keeping of lysimeter (soil pore water sampler) data is required to ensure that this alternative system is operating effectively.

<u>**Considerations and restrictions**</u>

These systems are considered non-standard/alternative systems by DOH. Evapotranspiration is best suited for environments where the rate of evaporation significantly exceeds the rate of precipitation. Zero discharge systems, like evapotranspiration, that prevent wastewater from leaving the site (and/or reaching groundwater) can be used above the UIC line, pending approval from DOH on a case-by-case basis. Other considerations include:

- Stormwater runoff should drain away from the system. Gutters and drainpipes shall be directed away from the system.
- Use high transpiration plants suitable for the wetness at ground level.
- Consider additional ET/ETI beds as required to enable owner to deal with operating difficulties or system failures and alternate loads.

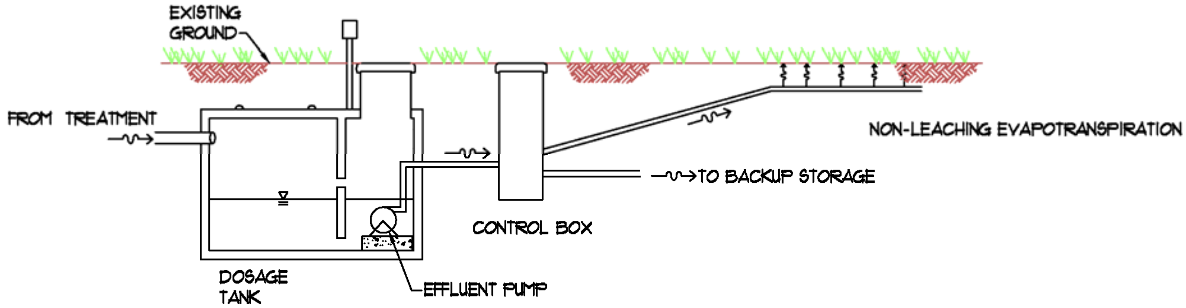


Figure 4-6 Subsurface Evapotranspiration Profile of Typical ET System

Effluent Quality

Few studies have adequately quantified the quality of the effluent from this disposal system. Trial and error has been the norm for these types of systems, so success rates are very hard to determine, as well as quality of effluent.

Typical Installed Costs (2007)

Because of the large surface area used, ET/ETI systems can be expensive. Values can range between $15,000 and $25,000 per 1,000 gpd of treated wastewater.

Operation and Maintenance Costs

Operational costs are on the order of $20 a year for simple inspection of observation wells, plus electrical costs for pumping when needed. Other maintenance requirements include minor landscape work, such as trimming the vegetation. Upstream treatment operations and processes should be properly maintained and pumped as needed to avoid overflow of solids into the ET bed.

Evapotranspiration Summary

Use in Steep Terrain		No
Use in High Ground Water Areas		Yes
Percolation Rate		
Relative Footprint When Compared To Conventional Drainfield		Large
Maintenance Level:		High
Power Required:		Yes
Typical Installed Cost:	up to $25,000	/1,000 gallons

Wastewater Reuse   Fact Sheet D-8

The reuse of wastewater for non-potable needs can offset potable water use thereby reducing overall demand on the potable water supply. Therefore, water reuse or reclamation has become increasingly popular. If an effluent meets certain Department of Health water quality requirements, then the recycled water can be utilized in landscaping, agricultural irrigation, and even toilet flushing.

The highest level quality of recycled water defined by DOH is R-1, and is the only level of recycled water that may be used above the UIC line, on a case-by-case basis. The requirements for R-1 recycled water are quite strict and fairly expensive to achieve with a small flow onsite treatment system. However, the requirements for R-2 and R-3 water are less stringent making recycling of effluent less difficult.

Considerations and Restrictions

Care should be taken to ensure that there is no crossing of recycled water lines and potable water lines. Distinguishing markings (standard purple pipe) should be used to identify recycled water lines. Strict monitoring and record keeping are required. The frequencies and types of parameters to be monitored are determined by the level of effluent quality and the method of application of the recycled water. Daily, weekly, and annual records of the treatment and water reuse project may be required. The State of Hawaii Department of Health has published *Guidelines for the Treatment and Reuse of Recycled Water*, available at the DOH website http://www.hawaii.gov/health/environmental/water/wastewater/forms.html. These guidelines will help in the planning and design of any wastewater recycling system. The frequency of monitoring and reporting may be reduced for on-site systems by DOH on a case-by-case basis.

Effluent Quality

Recycling of water does not improve the quality of the effluent, but it does have minimum standards that must be met to be safe for human health and the environment.

Typical Installed Costs (2007)

The costs associated with the specific concept of recycling water are too specific to give a general price range

Operation and Maintenance Costs

Without a definitive concept of a proposed system, operation and maintenance costs cannot be generalized.

Wastewater Reuse Summary

Use in Steep Terrain	Approval needed
Use in High Ground Water Areas	Possible
Percolation Rate	All
Relative Footprint When Compared To Conventional Drainfield	Unknown
Maintenance Level:	Unknown
Power Required:	Unknown
Typical Installed Cost:	Unknown

Chapter 5 Onsite Wastewater Systems-Treatment Technologies

SUMMARY AND FACT SHEETS

The characteristics and conditions of a homeowner or developer's site determine which disposal systems are appropriate. Chapter 3 guided the reader to a few specific onsite treatment systems based on nine critical characteristics of a site. This chapter is dedicated to descriptions of those treatment systems listed in Table 3-3. First, there are three summary tables for the systems included in this chapter. They serve as a rapid means to compare different systems. Table 5-1 allows comparison of effluent quality among the systems, Table 5-2 allows comparison of the costs associated with each system, and Table 5-3 summarizes the relative advantages and disadvantages of each system. The following fact sheets serve to describe the function of the each system in more detail, the costs associated with the construction, operation, and maintenance of the system, and the considerations/restrictions associated with each treatment system. A summary "smart box" is included in each fact sheet. An explanation of the smart box follows:

SBR Summary		
Meets NSF 40 Standards	Yes	
Effluent BOD:	5-15	mg/L
Effluent TSS	10-30	mg/L
Removes 50% total influent nitrogen	Yes	
Effluent Nitrogen:	7-45	mg/L
Effluent Phosphorus:	2-10	mg/L
Effluent Fecal Coliform:	1,000,000	/100 mL
Maintenance Level:	Quarterly	
Power Required:	Yes	
Typical Installed Cost:	$20,000-$30,000	/1,000 gallons

Figure 5-1 Smart Box

Meets NSF 40 Standards: Indicates whether the typical system can achieve 30 mg/L BOD, 30 mg/L TSS, and a pH of 6-9

Effluent BOD: Gives the range of expected effluent BOD

Effluent TSS: Gives the range of expected effluent TSS

Removes 50% total influent nitrogen: Indicates whether the system (with or without modification) is capable of nitrifying and denitrifying 50% of the total nitrogen that is found in the influent

Effluent Nitrogen:	Gives the range of expected total nitrogen in effluent
Effluent Phosphorus:	Gives the range of expected total phosphorus in effluent
Effluent Fecal Coliform:	Gives the estimated MPN per 100 mL of indicator organisms (fecal coliforms) in effluent
Maintenance Level:	Indicates the recommended maintenance frequency
Power Required:	Indicates if power is required for the system to operate
Typical Installed Costs (2007):	Gives an estimate of costs for the single system (does not include disposal components or additional treatment components) based on conditions described in below

Fact sheets are provided for simple treatment systems that provide only primary treatment using physical processes, including septic tanks (P-1). Low water and waterless toilets, such as composting toilets are included in fact sheet P-2. Fact sheets are also included for treatment systems that include secondary treatment using biological processes, including suspended-growth flow-through aerobic treatment units (ATUs) (B-1), attached-growth flow-through ATUs (B-2), sequencing batch reactors (SBRs) (B-3), and packed-bed reactors (B-4). Fact sheets for tertiary processes that provide enhanced removal of phosphorus (T-1), nitrogen (T-2), and trace chemicals (T-3) are included. Fact sheets for disinfection systems, including tablet chlorination (C-1) and ultraviolet light disinfection (C-2), are also included. It is noted that all of the treatment systems described in this chapter require a disposal system that may provide additional treatment (see Chapter 4). It is further noted that cesspools are not considered a treatment system and are, instead, included in Chapter 4 with other disposal systems.

It must be noted that there are multiple equipment suppliers for each of the different type of treatment systems described herein. There are differences in materials of construction, size, mechanical design, component complexity, operating modes and warrantees, just to name a few. Suffice to say, not all systems are created equal in terms of expected performance, durability, ease-of-operation, as well as manufacturer experience, presence, representation-in-Hawaii, etc., and a good measure of caveat emptor, “buyer beware,” is advised. It is highly recommended to consult a Hawaii-registered professional engineer with onsite treatment system design experience prior to purchase of any treatment system. Such an engineer will also be required to sign-off on the design in order to obtain a building permit.

COSTS

A typical, current construction cost for each treatment system is provided on the fact sheets as a budgetary guideline. The same assumptions, included costs, and escalation factors described in Chapter 4 (Disposal Systems) apply to the cost estimates provided in this chapter.

SUMMARY OF ONSITE WASTEWATER TREATMENT SYSTEMS

Table 5-1 Summary of Typical Onsite Wastewater Treatment System Effluent Water Quality

TREATMENT SYSTEM	BOD mg/L	TSS mg/L	Total Nitrogen mg/L	Total Phosphorus mg/L	Fecal Coliforms Per 100 mL	COMMENTS
Septic Tank	132 - 217	49 - 161	39 - 82	11 - 22	40,000 – 160 million	(USEPA, 2002 and Hallahan, 2002)
Low water/Waterless Toilets	-	-	-	-	-	No effluent. By-products require disposal/use outside scope of this handbook
Continuous Flow, Suspended Growth	10 - 50	15 - 60	30 - 40% removal	10 - 20% removal		(USEPA, 2002)
Continuous Flow w/ fixed internal packing	10	15	7 - 22			
Sequenced Batch Reactor ATU	5 - 15	10 - 30				
Single Pass Sand Filter	2 - 4	3 - 16	0.5 - 6	40% removal	60-1500	
Recirculating Sand Filter	3 - 10	3 - 9	3 - 8		10-25	
Enhanced Phosphorus Removal	-	-	-	1 - 2 mg/L	-	
Enhanced Nitrogen Removal	-	-	40 - 80% removal	-	-	
Emerging Trace Contaminant Removal	-	-	-	-	-	
Chlorine Disinfection	-	-	-	-	Reduction of 99.0-99.9%	
UV Disinfection	-	-	-	-	Reduction of 99.9%	

Table 5-2 Summary of Typical Onsite Wastewater Treatment System Costs

TREATMENT SYSTEM	Typical Installed Costs ($/system) Unless noted, costs are for treatment system only.	Annual Maintenance Fees ($/yr) (Including pumping and labor)	Energy Consumption (kW-h/yr)	Energy Costs ($/yr) (At HECO rate of 20.06 cents per kW-h)	Annual Replacement Parts ($/yr) (Including chemicals)	Annual Amortized Cost over 5 years ($/mo) (At nominal 6% annual interest rate, compounded monthly)
Septic Tank	5,000-12,000	50-200	0	0	0	100-250
Low Water/Waterless Toilets	4,000 – 14,000	50 – 200	Up to 750	Up to 150	0	100-300
Continuous Flow, Suspended Growth	20,000-30,000	200-300	1,100-3,650	220-730	0	420-670
Continuous Flow w/ Fixed Packing	20,000-30,000	200-300	1,100-3,650	220-730	0	420-670
Sequenced Batch Reactor ATU	20,000-30,000	200-300	915-3,650	180-730	0	420-670
Single Pass Sand Filter	15,000-30,000	150-200	110-150	20-30	300-600 (media replacement every 4-5 years)	300-600
Recirculating Sand Filter	15,000-30,000	150-200	110-300	20-60	300-600 (media replacement every 4-5 years)	300-600
Enhanced Phosphorus Removal	5,000-11,000	-	-	-	450-750 (media replacement every 4-5 years)	110-230
Enhanced Nitrogen Removal	-	-	-	-	-	-
Emerging Trace Chemicals Removal	-	-	-	-	0.60-1.00 per lb of activated carbon	
Chlorine Disinfection	800-1,000	100-125	0 (Assuming tablet feeder)	0	30-50	25-40
UV Disinfection	1,000-2,000	50-100	307	60-65	70-80	35-60

Table 5-3 Summary of Advantages and Disadvantages of Typical Onsite Wastewater Treatment Systems

Treatment System	Advantages	Disadvantages or Limitations
Septic Tank	▪ No moving parts ▪ Easily maintained with periodic pumping	▪ Only primary treatment provided
Low water/Waterless Toilets	▪ Incinerators – waste is sterile and can be thrown away like household rubbish ▪ Composting toilets – offer recycling of waste ▪ Chemical – viable temporary system	▪ Incinerators – require other utilities such as electricity or natural gas ▪ Composting – long periods of treatment ▪ Chemical – usually temporary, must be pumped often
Continuous Flow, Suspended Growth ATU	▪ Habitually meets Class I effluent standards	▪ Continuous energy requirements ▪ Poor maintenance leads to degraded effluent quality ▪ Requires long startup times-not good for seasonal flows
Continuous Flow, w/ Fixed Packing	▪ Habitually meets Class I effluent standards	▪ Energy consumption ▪ Requires long startup times-not good for seasonal flows
Sequenced Batch Reactor ATU	▪ Habitually meets Class I effluent standards ▪ High Nitrification/Denitrification	▪ Energy consumption is costly ▪ Requires computer controls
Single Pass Sand Filter	▪ High TSS removal ▪ Proven technology	▪ High cost associated with media ▪ Maintenance required to prevent biomat clogging and ponding
Recirculating Sand Filter	▪ High denitrification	▪ Energy consumption with recirculating pump ▪ Cost of media ▪ Maintenance required of the bed and the pump
Enhanced Phosphorus Removal	▪ Removes phosphorus in areas that have low calcium, low iron, or low aluminum soils ▪ Helps protect surface water in soils that fail to remove phosphorus	▪ For media filters, construction costs can double due to expense associated with phosphorus attenuating media
Enhanced Nitrogen Removal	▪ Helps prevent groundwater contamination ▪ Prevents eutrophication of surface waters	▪ Requires aerobic and anoxic cycles or stages for biological removal of nitrogen ▪ Plumbing code does not regulate separate black- and graywater plumbing
Enhanced Emerging Contaminant Removal	▪ Necessary to remove medication and hormones that are not consumed by biological treatment	▪ Added expense associated with powdered activated carbon or other chemical absorbants
Chlorine Disinfection	▪ Safest and simplest with chloride tablets ▪ Cheapest means of disinfection	▪ Requires monitoring to ensure chloride tablets are always present to provide chloride ▪ Residual chlorine may harm downstream organisms
UV Disinfection	▪ No residual chemicals disposed in environment	▪ Bulbs are expensive ▪ Requires power ▪ Can be ineffective in high TSS environments

PHYSICAL (PRIMARY) TREATMENT TECHNOLOGY FACT SHEET

Septic Tanks Fact Sheet P-1

A septic tank is a tank that serves as both a settling and skimming tank. Grit and other solids settle to the bottom of the tank and create a layer of sludge. Oil, grease, fat, and other floatables rise to the top creating a layer of scum. Accumulated sludge and scum must be removed on a regular basis; failure to do so will lead to carryover of these materials into downstream systems leading to their failure. Where site conditions indicate higher quality effluent is required, septic tanks are used as pretreatment for other treatment systems, including biological treatment systems.

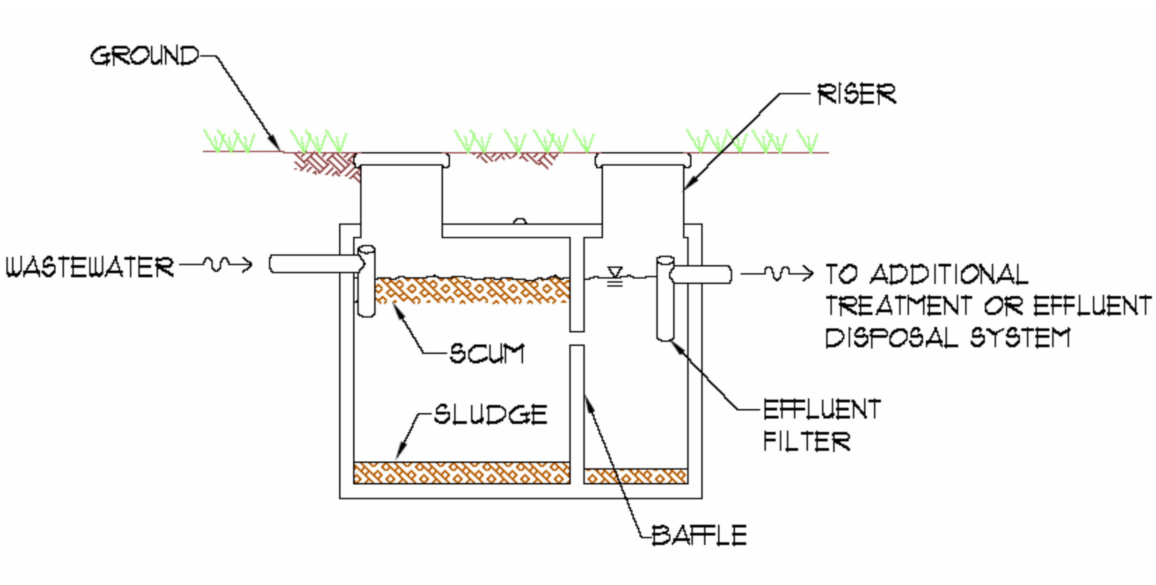


Figure 5-2 Typical Double Chambered Septic Tank

Considerations and Restrictions

A septic tank is purchased prefabricated, made of concrete or fiberglass, and it must meet the International Association of Plumbing and Mechanical Officials (IAMPO) material and property standards for prefabricated septic tanks. However, depending on site conditions, sometimes it is easier to construct a tank in-place. A constructed in-place septic tank must be designed in accordance with IAPMO specifications and stamped by a licensed structural engineer. Regardless of how a tank is constructed, it must be waterproof to prevent leakage and protected from corrosion in accordance with HAR 11-62, Subchapter 3.

The capacity of a septic tank is an important aspect in the treatment of wastewater prior to disposal. The required capacity of residential septic tanks can be referenced using HAR 11-62, Subchapter 3. The City and County of Honolulu "Design Standards of the Department of Wastewater Management" or the applicable county publication must be consulted.

A septic tank must be installed by a licensed contractor to comply with spacing and minimum distance requirements, as described in Chapter 3 of this document. Use of a septic tank requires the selection of a downstream disposal system (see Chapter 4).

Effluent Quality

In accordance with HAR 11-62, Subchapter 33, septic tank effluent must be discharged into a soil absorption system, a sand filter, a subsurface irrigation system (with director approval), or another treatment system. Septic tanks remove approximately 30% of BOD and 30% of TSS from typical domestic wastewater resulting in effluent quality of BOD ranging between 138 mg/L and 240 mg/L, and suspended solids in the range of 49 to 155 mg/L.

The DOH requires the installation of a screen on the effluent end of the septic tank to enhance solids removal and thereby prevent clogging of disposal systems. The effluent filter can be installed on the effluent tee on the inside of the septic tank, or in a separate structure outside the tank to facilitate access for required periodic cleaning, without which backups will occur.

Typical Installed Costs (2007)

A 1,000-1,250 gallon residential septic tank costs approximately $5,000-$12,000 installed, including material, equipment, and labor. An effluent filter is about $200-$700 installed. The cost of a septic tank does not include the disposal system (see Chapter 4).

Operation and Maintenance Costs

The decomposition rate of the solids that settle to the bottom of the tank and those that accumulate in the scum layer on the surface is slow, resulting in the accumulation of solids in the septic tank. Because of the accumulation of solids and scum, periodic pumping is required (every 2-3 yrs) to keep the tank functioning as designed and prevent solids from breaking and overflowing to the soil absorption system. The estimated cost for these pumping services range between $150 and $550 per visit. Assuming that the septic tank is pumped every 2-3 years, the equivalent cost is about $50-$200 per year. Pumping costs vary due to difficulty accessing the tank, haul distances, and limited pump truck capacity. Minimal use of kitchen sink grinders will help reduce the solids load, and extend the time between pumping of the septic tank and any downstream treatment units.

The effluent filter must be cleaned on a regular basis because of the growth of bacteria that will clog the filter. Frequency of cleaning is dependent on the size of the screen, environmental conditions, and type of wastewater entering the septic systems. Some manufacturers recommend cleaning every 1-3 years depending on level of use and site conditions. Cleaning consists of hosing off the filter into the septic tank and can be done by the homeowner.

Septic Tank Summary

Meets NSF 40 Standards	No	
Effluent BOD:	132-217	mg/L
Effluent TSS	49-161	mg/L
Removes 50% total influent nitrogen	No	
Effluent Nitrogen:	39-82	mg/L
Effluent Phosphorus:	11 -22	mg/L
Effluent Fecal Coliform:	1,000,000	/100 mL
Maintenance Level:	2-3 yrs	
Power Required:	No	
Typical Installed Cost:	$5,000-$12,000	/1,000 gal

Waterless/Low Water Systems — Fact Sheet P-2

Low water or waterless system is a broad, generic term given to a range of treatment systems that use little water or no water in collecting or treating human waste. It includes incinerating toilets, composting toilets, and chemical toilets.

Incinerating toilets use heat or combustion to degrade human waste into water, carbon dioxide, and ash. Incinerating toilets are one of a few treatment technologies that do not require a soil disposal system. However, the ash from the incineration must be disposed of, usually with municipal refuse in a landfill. Incinerating toilets may use natural gas, liquid propane, or electricity to incinerate the human waste, and are usually designed to handle only feces, urine, and paper. Ventilation for the toilet must be supplied.

Composting toilets receive human waste and stabilize it through natural degradation. The waste is mixed with starting mulch, and allowed to degrade and dehydrate for a period of up to 12 months, depending on usage. The composted material removed from composting toilets is suitable as a soil amendment, however, such use is restricted as described in HAR 11-62 in order to protect public health. The toilets come in automatic, semi-automatic, and manual versions. The automated models usually include heaters, ventilation fans, and a mechanical means to mix or aerate the compost.

Chemical toilets are toilets which have a chemical reservoir beneath them that catches the human waste. The chemicals in the toilet slightly disinfect the human waste and also provide a deodorant. Chemical toilets do not completely break down human waste and must be pumped frequently due to a very limited holding capacity. The contents of chemical toilets must be taken to a local wastewater treatment facility. The contents should not be poured into a home septic tank or aerobic treatment unit as the chemicals will have adverse effects on the biology of the treatment system.

Considerations and Restrictions

Incinerating toilets are acceptable, long-term treatment systems, but they are typically only found in temporary or seasonal housing. The by-products (ash) must be periodically removed, but because it is sterile after incineration and poses no nutrient threat to the environment, it can generally be disposed of as household garbage. Without proper ventilation, odors may be generated (both from the human waste and the process of combustion.) Additional utilities are required (natural gas, propane, or electricity).

Composting toilets are also acceptable long term treatment systems, but are also an item typically only found in seasonal housing, campsites or other locations not occupied fulltime. Composting requires long periods of time to stabilize the human waste and may create odor problems. Those systems that do not use electricity for evaporative fans or mixing require more attention from the operator to maintain function. The produced compost is suitable as a soil applied fertilizer, but cannot be used for crops meant for human consumption, and its use is restricted by HAR 11-62.

Chemical toilets are a temporary means of treatment. The limited capacity and frequent pumping lend the system for uses that are of short duration, such as a few days. As anyone who has been to a large public gathering knows, chemical toilets are also a good augmentation to existing restroom facilities during short events or festivities.

Effluent Quality

The waste from an incinerating toilet is sterilized and can be thrown away with normal household refuse. It lacks nutrient value and has no use as a fertilizer.

The compost from a composting toilet can be used to grow plant life, but is never used to grow food that is to be consumed by humans or livestock that will be butchered. Composting generally sterilizes the waste; however, it takes 2 - 12 months for this to occur. It is also safer if composting does not mix new human waste with material already composting. Additional restrictions are found in HAR 11-62.

Chemical toilets produce an effluent that must be treated by a wastewater treatment plant. The chemicals usually are a combination of deodorants and anti-bacterial chemicals, and they stabilize the human waste until it is treated in a central wastewater treatment works. The mixture, therefore, has characteristics that are dissimilar to most domestic wastewater.

Typical Installed Costs (2007)

The material cost for incinerator toilets is approximately $2,000-$4,000. Composting toilets cost $2,500 - $7,000 for just the toilet. Total installation for each system will usually double the cost of each. Chemical toilets can be rented for approximately $150 per month. Installation of chemical toilets is rare, and permanent installation costs are difficult to predict.

Operation and Maintenance Costs

Incinerator toilets require utilities such as natural gas or electricity to function, and operational costs associated with incinerators include these utilities. Incinerators using electricity use 1.5-2.0 kW-h per day or about $120-$150 per year in electricity.

Composting toilets have less operating costs than incinerators, but will still require energy to power fans for drying compost and ventilation. Electrical costs are approximately $100 per year.

Waterless/Low Water Systems Summary		
Meets NSF 40 Standards	No	
Effluent BOD:	-	mg/L
Effluent TSS	-	mg/L
Removes 50% total influent nitrogen	No	
Effluent Nitrogen:	-	mg/L
Effluent Phosphorus:	-	mg/L
Effluent Fecal Coliform:	-	/100 mL
Maintenance Level:	2-3 yrs	
Power Required:	Possibly	
Typical Installed Cost:	$4,000 -$14,000	

Chemical toilets require pumping and renewal of chemicals periodically. Rental agreements usually include the cost of service in them. Privately owned chemical toilets that require a pumping service to service them will cost approximately $30 per visit (usually weekly).

BIOLOGICAL (SECONDARY) TREATMENT TECHNOLOGY FACT SHEETS

Suspended Growth Aerobic Treatment Systems — Fact Sheet B-1

A suspended growth aerobic treatment system (one type of ATU) is a biological treatment system where microorganisms are kept in suspension by mixing air with wastewater influent and concentrated underflow or sludge (from a clarifier) in an aeration tank.

From the aeration tank, the mixture is passed into a settling basin (clarifier), where microorganisms settle to the bottom forming a layer of sludge. The liquid is passed to a disposal system or another process for additional treatment. Some of the sludge solids in the settling basin will undergo decomposition, while the remainder accumulates and must periodically be removed (pumped out) and properly/legally disposed of offsite.

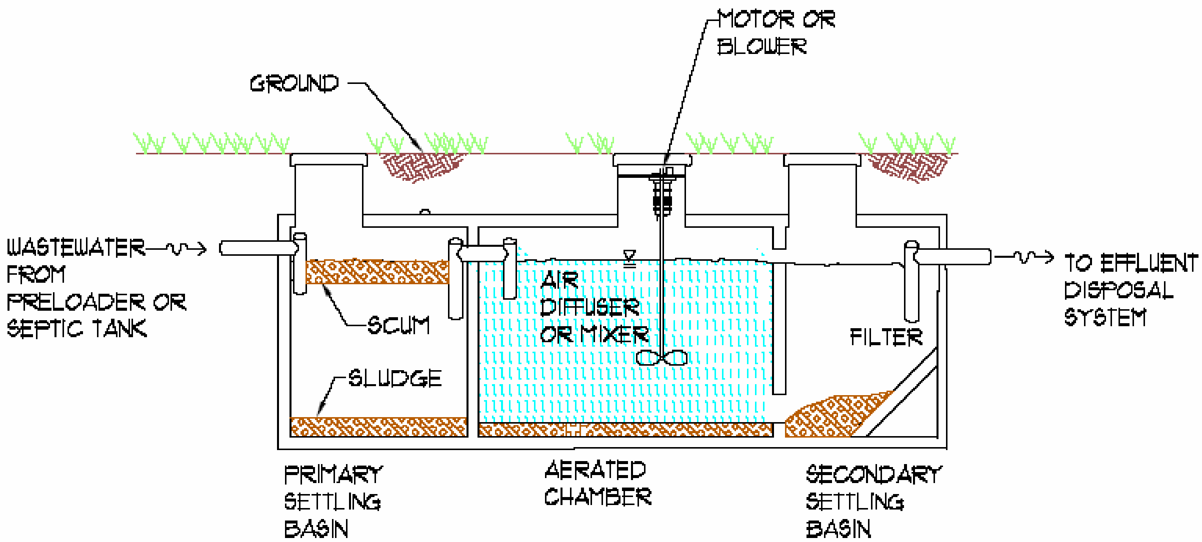


Figure 5-3 Continuous Flow, Suspended Growth Aerobic System with Settling Basins

<u>Considerations and Restrictions</u>

If the suspended-growth aerobic treatment system does not include an integral primary settling basin, a separate septic tank or pre-loader should be installed upstream of the aerobic treatment unit. The purpose of this additional tank is to remove readily settleable solids and floating matter that will reduce suspended solids loading and protect downstream mechanical equipment.

Consideration should be given to determine how best to use the existing grades to allow gravity flow from septic tank to aerobic treatment system to disposal system.

Power is needed to serve the blowers, pumps, controls, and monitoring and alarm systems in the ATU.

Use of a suspended-growth ATU requires the selection of a disposal system (see Chapter 4).

Effluent Quality

Suspended-growth aerobic treatment systems can treat domestic wastewater and achieve effluent quality of BOD concentrations in the range of 5-50 mg/L and TSS concentrations of 5-60 mg/L. However, it should be noted that suspended-growth ATUs are not the most optimal to reduce nitrogen or phosphorus.

Typical Installed Costs (2007)

Complete installation including materials, equipment and labor can range between $20,000-30,000. This cost does not include the cost for a preloader/septic tank, if required, or the cost for a disposal system. See Septic Tanks (Sheet P-1) for a cost range for preloaders. See Chapter 4 for the costs of disposal systems.

Operation and Maintenance Costs

Operation and maintenance costs are dependent on labor costs and electricity but range from $400 to $600 a year. Trained professionals should manage the aerobic system which should be inspected every 3-4 months with sludge/scum pumping performed as needed.

These systems are sensitive to high and low temperatures, heavy loading of solids, toxic chemicals (including chemical cleansers and the like), power failures, and influent flow variability.

Suspended Growth Summary		
Meets NSF 40 Standards	Yes	
Effluent BOD:	5-50	mg/L
Effluent TSS	5-60	mg/L
Removes 50% total influent nitrogen	No	
Effluent Nitrogen:	10-60	mg/L
Effluent Phosphorus:	4-18	mg/L
Effluent Fecal Coliform:	1,000,000	/100 mL
Maintenance Level:	Quarterly	
Power Required:	Yes	
Typical Installed Cost:	$20,000-$30,000	/1,000 gallons

Combined attached and suspended growth systems are a type of ATU in which microorganisms form a slime layer on the surface of submerged or semi-submerged media. Treatment occurs as the wastewater passes over the microorganisms.

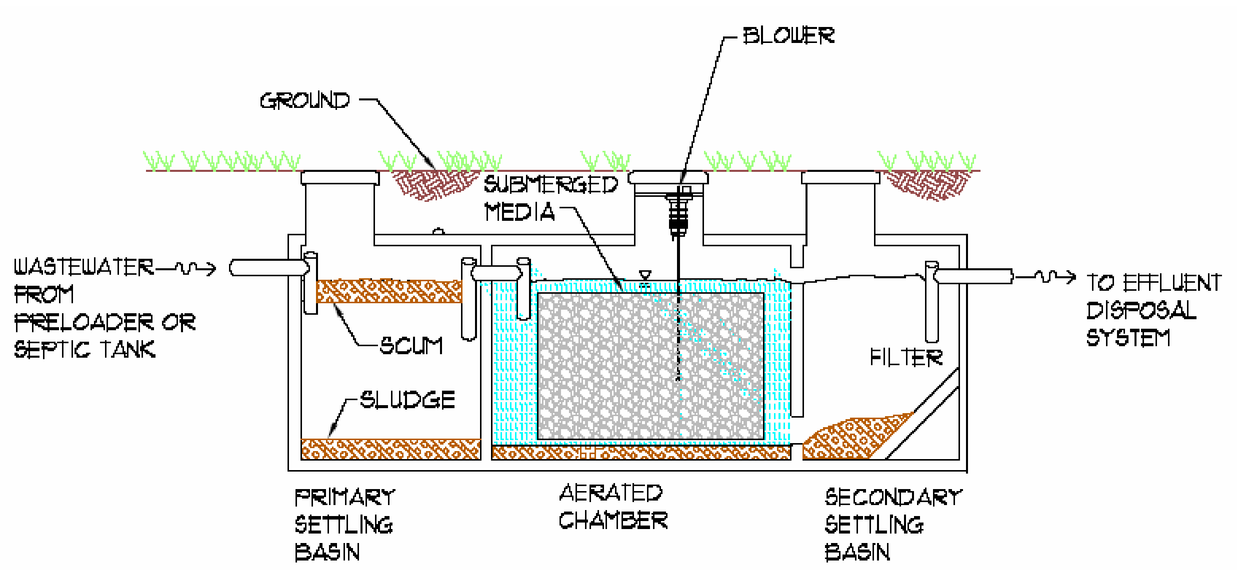


Figure 5-4 Combined Attached and Suspended Growth Reactor

Considerations and Restrictions

If the combined growth ATU does not include an integral primary settling basin, a separate septic tank or pre-loader should be installed upstream of the aerobic treatment unit. The purpose of this additional tank is to remove readily settleable solids and floating matter that will reduce suspended solids loading and protect downstream mechanical equipment.

Consideration should be given to determine how best to use the existing grades to allow gravity flow from septic tank to aerobic treatment system to disposal system. In addition, the system should be sited such that it can easily be accessed and inspected.

Use of a combined attached and suspended growth ATU system requires the selection of a disposal system (see Chapter 4).

Effluent Quality

Effluent BOD and TSS concentrations of 5-40 mg/L are expected from a combined growth system. Complete nitrification is expected (conversion of ammonia to nitrate) and phosphorus removal is expected to be between 10 and 15%.

Typical Installed Costs (2007)

Installation costs range from $20,000 to $30,000. This cost does not include the cost for a preloader, if required, or the cost for a disposal system. See Septic Tanks (Sheet P-1) for a cost range for preloaders. See Chapter 4 for the costs of disposal systems.

Operation and Maintenance Costs

Costs to operate combined growth ATU systems range from $35-$100 per year in energy, and management (pumping, inspection, and analysis) can cost $100-$200 per year. Energy consumption is on the order of 1-8 kW-h/day. Extended power outages will result in odorous conditions. Trained professionals should manage the ATU system which should be inspected every 3-4 months with sludge/scum pumping as needed.

These systems are sensitive to high and low temperatures, heavy loading of solids, toxic chemicals (including chemical cleansers and the like), power failures, and influent flow variability.

Attached and Suspended Growth Summary

Meets NSF 40 Standards	Yes	
Effluent BOD:	10-30	mg/L
Effluent TSS	15-60	mg/L
Removes 50% total influent nitrogen		Possible
Effluent Nitrogen:	7-22	mg/L
Effluent Phosphorus:	2-10	mg/L
Effluent Fecal Coliform:	1,000,000	/100 mL
Maintenance Level:	Quarterly	
Power Required:	Yes	
Typical Installed Cost:	$20,000-$30,000	/1,000 gallons

Sequencing Batch Reactors (SBR) — Fact Sheet B-3

A Sequencing Batch Reactor (SBR) is a form of ATU in which all of the aerobic and clarifying processes occur within a single tank. The tank may be constructed from concrete, fiberglass, or high-density polyethylene (HDPE). A SBR is designed to operate by sequencing through at least four (4) steps as follows:

1) FILL: tank is filled with wastewater to a predetermined volume or time;
2) AERATION: aeration is started with the suspended microorganisms in the wastewater;
3) SETTLE: aeration is turned off and the microorganisms settle to the bottom of the tank; and
4) DECANT: decant the clarified portion as effluent.

After decanting, the cycle repeats with filling again. By allowing the tank water level to vary, providing influent stilling zones, and only decanting during aeration off cycles, these single-tank systems can be designed to operate continuously. Of great importance to the SBR process is the control system consisting of timers, level sensors, and microprocessors.

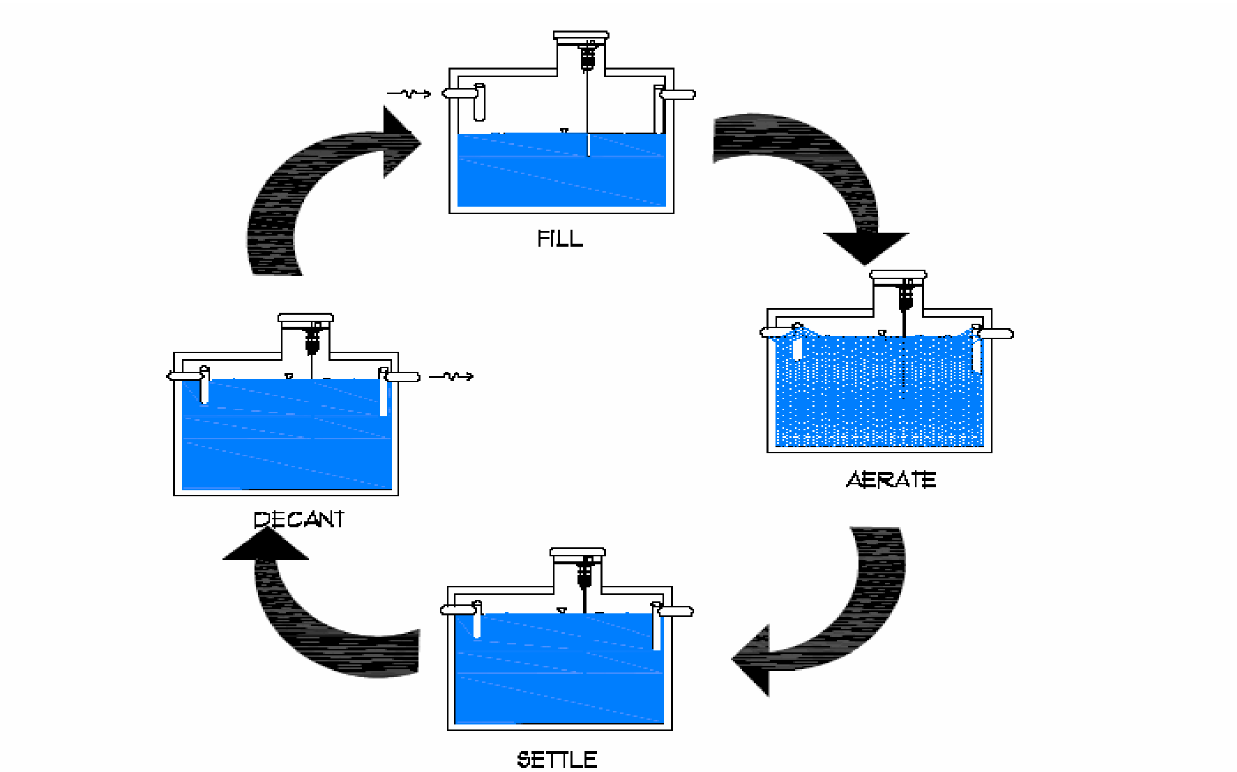


Figure 5-5 Cycles of an SBR / CBT

Considerations and Restrictions

SBRs are a type of suspended-growth ATU that can oxidize BOD and provide both nitrification and denitrification (enhanced nitrogen removal). SBRs require power, control, and monitoring and alarm systems. SBRs have mechanical equipment (pumps, blowers, decanters) which must be properly maintained to ensure optimal operation.

Use of an SBR system requires the selection of a disposal system (see Chapter 4).

Effluent Quality

Effluent from SBRs is of very good quality in terms of BOD and TSS. Typical ranges are from 5 –15 mg/L BOD and 10-30 mg/L of TSS.

SBRs will completely oxidize ammonia to nitrate via nitrification during the aeration cycle (aerobic cycle), and then facilitate nitrogen removal via denitrification during the settle and decant cycles (cycles that are anoxic). They can also provide enhanced biological phosphorus removal. The higher quality of effluent produced reduces the organic loading on the disposal system. SBRs also provide a consistent effluent, eliminating the fluctuations caused by varying influent loads.

Typical Installed Costs (2007)

Equipment costs range from $7,000-$9,000 with installation costs of $1,500-$3,000 based on Mainland costs. Current costs to install in Hawaii are in the range of $20,000 - $30,000. This cost does not include the cost for a preloader, if required, or the cost for a disposal system. See Septic Tanks (Sheet P-1) for a cost range for preloaders. See Chapter 4 for the costs of disposal systems.

Operation and Maintenance Costs

Annual energy costs are less than $600 and pumping and inspection costs are greater than $100. Trained professionals should manage the SBR system, which should be inspected every 3-4 months with sludge/scum pumping as needed. Homeowner neglect and/or interference can lead to operational malfunction. Alarms to warn of system failures are critical. Energy requirements are between 3 and 10 kW-h/day.

SBR Summary

Meets NSF 40 Standards	Yes	
Effluent BOD:	5-15	mg/L
Effluent TSS	10-30	mg/L
Removes 50% total influent nitrogen	Yes	
Effluent Nitrogen:	7-45	mg/L
Effluent Phosphorus:	2-10	mg/L
Effluent Fecal Coliform:	1,000,000	/100 mL
Maintenance Level:	Quarterly	
Power Required:	Yes	
Typical Installed Cost:	$20,000-$30,000	/1,000 gallons

Packed Bed Reactors Fact Sheet B-4

A packed-bed reactor is an attached-growth biological treatment process that can be aerobic or anaerobic, upflow or downflow, continuous or intermittent dosing, single-media or multi-media and arranged in one or multiple stages. The most common prefabricated packed-bed reactor is an aerobic, down flow, continuous dosing, and continuous media type reactor. The packed-bed filter is a large excavation lined with an impermeable material that is filled with sand or other media placed over an underdrain. Wastewater is dosed at the top of the media bed, and allowed to percolate through the media (filter) to an underdrain. The aerobic biological treatment usually occurs in the first six inches of the filter surface, and chemical treatment, in the form of adsorption, occurs throughout the filter.

Packed bed reactors can be single pass (intermittent sand filters) or they can recirculate the effluent to treat the wastewater multiple times (recirculating sand filters or RSF). Ultimately, the effluent is discharged to a disposal system, similar to those discussed in Chapter 4.

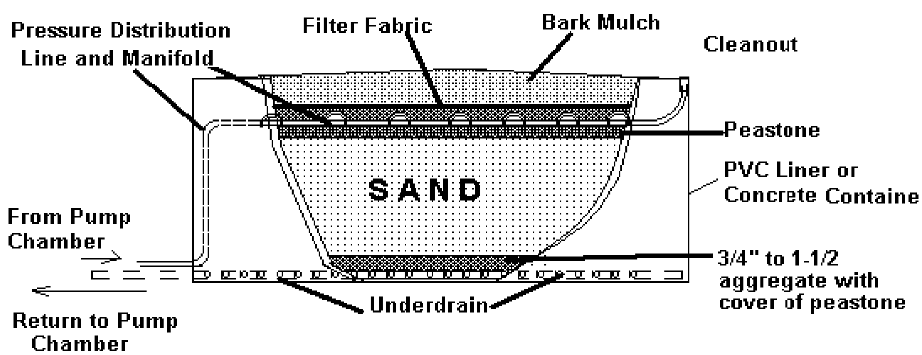


Figure 5-6 Packed Bed Filter (Adapted from USEPA)

<u>Considerations and Restrictions</u>
Sand filters are usually sized using hydraulic data, but consideration must also be given to the organic loading since it acts as a biofilm reactor. This type of system requires significant land area. Based on a typical application rate of 1-2 gallons per day per square foot (gpd/ft^2), it will require 500-1,000 square feet for the treatment of 1,000 gpd.

Filters may need to be covered to ensure protection against accumulation of debris from the surrounding environment, algae fouling, and an increased hydraulic load from precipitation. Coverings may be as simple as a tarp canopy, which allows ample ventilation of the bed. Otherwise, the filter may be buried in the ground to provide protection and aesthetic concealment. Extra care must be given to filters buried in the ground to ensure ventilation of the bed. Mechanical aeration (blowers) may be required.

A pump station or recycle tank is required prior to the packed-bed filters to assist with equal distribution in the dosing pipelines across the media bed area.

Use of a packed bed system requires the selection of a disposal system (see Chapter 4).

Effluent Quality

Effluent BOD is typically 5 mg/L and TSS is typically about 10 mg/L. Biological nitrogen removal is approximately 18-33%. Fecal coliforms are reduced by 99 to 99.99%.

Typical Installed Costs (2007)

This cost includes the excavation, the media, the underdrain, and the dosing pump. The price range for media is $10-$15 per square foot of bed area. For a 250-1,000 square foot media filter, costs should range between $15,000 and $30,000. This cost does not include the cost for a preloader, if required, or the cost for a disposal system. See Septic Tanks for a cost range for preloaders. See Chapter 4 for the costs of disposal systems.

Operational and Maintenance Costs

Operational costs include electricity for pumping and semi-skilled labor. Electrical costs can be estimated at $20-30 a year at 0.3-0.4 kW-h/day, and management costs at $150-200 per year. Every 3-4 months the filter should be inspected, and the top layer (1 inch) of media should be scraped off periodically (3 months-1 year) and properly disposed. Power outages affect the performance of sand filters, and extended outages may result in odors.

Packed-bed Reactor Summary

Meets NSF 40 Standards	Yes	
Effluent BOD:	2-10	mg/L
Effluent TSS	3-16	mg/L
Removes 50% total influent nitrogen		Possible
Effluent Nitrogen:	0.5-8	mg/L
Effluent Phosphorus:	3-12	mg/L
Effluent Fecal Coliform:	1,000	/100 mL
Maintenance Level:	Quarterly	
Power Required:	No	
Typical Installed Cost:	$15,000-30,000	/1,000 gallons

ENHANCED NUTRIENT AND CHEMICAL REMOVAL (TERTIARY TREATMENT) SYSTEM FACT SHEETS

Approximately 10-20% of phosphorus is removed from wastewater during primary settling and aerobic treatment. However, there are instances that require greater removals. In general, a special phosphorus removal system is not required for treatment of domestic wastewater. Studies have shown that phosphorus is removed in soil absorption systems, but the lifetime of these systems is unknown. To actively and continuously remove phosphorus, an intermittent sand filter with iron-rich media can be used.

Considerations and Restrictions

Phosphorus removal is necessary in situations where disposal could impact surface water, or when the disposal system is shown to be incapable of removing phosphorus. Additional treatment to remove phosphorus should be considered when subsurface infiltration occurs near fractured bedrock, or when transport of treated wastewater to groundwater would be rapid.

Effluent Quality

The combination of SBR and an iron-rich sand filter can reduce the amount of total phosphorus in effluents to 1 to 2 mg/L.

Typical Installed Costs (2007)

Construction costs are similar of an iron-rich media sand filter are approximately $5,000 - $11,000 for the media alone. For the iron-rich media, the costs are approximately twice that of normal washed sand.

Operation and Maintenance Costs

Depending on the replacement frequency of the media in the filter bed, operational and maintenance costs will vary. Operational costs would be approximately $200-$300 per year.

Phosphorus Removal Summary

Meets NSF 40 Standards	NA	
Effluent BOD:	-	mg/L
Effluent TSS	-	mg/L
Removes 50% total influent nitrogen	Yes	
Effluent Nitrogen:	-	mg/L
Effluent Phosphorus:	1-2	mg/L
Effluent Fecal Coliform:	NA	
Maintenance Level:	Quarterly	
Power Required:	Possibly	
Typical Installed Cost:	$5,000-11,000	/1,000 gallons

The EPA considers onsite wastewater systems to be the primary source of groundwater contamination with respect to nitrogen. The forms of nitrogen present in untreated wastewater are organically-bound nitrogen and ammonia. During preliminary and primary treatment, the forms of nitrogen remained largely unchanged. During secondary treatment, aerobic conditions result in aerobic microbial transformation of ammonia and organic nitrogen first into nitrite and then into nitrate. Discharge of secondary effluent typically contains mostly nitrate nitrogen, only small amounts of ammonia, and no organic nitrogen. Nitrate is a problematic groundwater contaminant because it causes methemglobanemia. Nitrate presence in groundwater can also be caused by leaching of ammonium-nitrate fertilizer. Nitrate is regulated in drinking water to a maximum of 10 mg/L as N. Through secondary aerobic treatment, there is very little total nitrogen removal from wastewater (except approximately 10-20% via incorporation into bacteria cells subsequently removed as sludge).

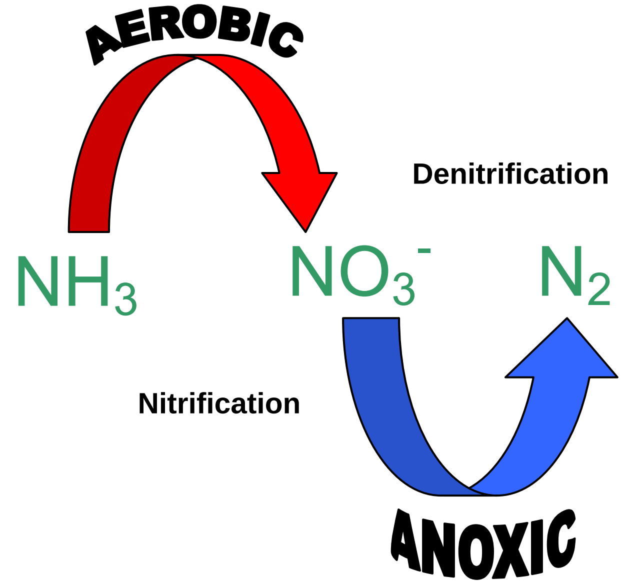


Figure 5-7 The Removal of Nitrogen from Wastewater

The most common method of total nitrogen removal from wastewater is through a two-step biological process. The first step, ammonia oxidation to nitrite and nitrate (nitrification), occurs in any correctly designed aerobic process. The second step, reduction of nitrate to nitrogen gas (denitrification) occurs in a system with an anoxic zone or cycle and enough organic material to allow the reduction of the nitrogen. Typical biological nitrogen removal treatment systems (that incorporate both steps) include aerobic/anaerobic trickling filters, sequencing batch reactors, intermittent sand filters with anaerobic filters, and recirculating sand filters combined with anoxic filters.

Chemical and physical removal of nitrogen is also possible in the form of ion exchange, high-pH ammonia stripping, and reverse osmosis, however, none of these are practical for onsite wastewater treatment.

Considerations and Restrictions

Any time an onsite wastewater system is to be located near inland surface water or coastal water, enhanced nitrogen removal must be considered. Nitrogen removal must also be considered whenever disposal may impact groundwater (especially that which serves as potable supply) especially where the seasonal high groundwater may come in contact with the disposal area. Nitrate, the form of nitrogen in the effluent of typical biological treatment systems not designed for enhanced nitrogen removal, is highly mobile in soils and will leach through soils into groundwater (and connected surface water) quickly, especially when saturated.

Effluent Quality
The biological treatment systems listed above can achieve 40% to 80% total nitrogen removal.

Typical Installed Costs (2007)
Biological treatment units are expensive but physical/chemical treatment systems would be more expensive. Modifications to aerobic systems to increase nitrogen removal typically cost $4,000 - $6,000.

Operation and Maintenance Costs
In order to remove nitrogen, the ammonia and organic nitrogen compounds must be oxidized to nitrite and nitrate through aerobic processes. Therefore, power and money are consumed in the process. In larger systems, a carbon source such as methanol may need to be added in order to promote conversion of nitrate to nitrogen gas. Therefore, there is an added cost of chemicals. By manipulating the process and recycling part or all of the treated wastewater, additional chemicals can be eliminated, but costs are incurred in pumping energy consumption.

Anoxic Summary

Meets NSF 40 Standards	Yes	
Effluent BOD:	NA	
Effluent TSS	NA	
Removes 50% total influent nitrogen	Yes	
Effluent Nitrogen:	<1/2 influent	mg/L
Effluent Phosphorus:	NA	
Effluent Fecal Coliform:	1,000,000	/100 mL
Maintenance Level:	Quarterly	
Power Required:	Yes	
Typical Installed Cost:	$2,000-$6,000	/1,000 gallons

Components of wastewater that are increasingly of concern are trace organic chemicals. These chemicals include prescription and non-prescription medicines, sex hormones, antibiotics, and industrial or household products. These chemicals pose a potential long-term health concern and are not effectively removed from wastewater by conventional primary, secondary, and tertiary treatment processes. In addition, the presence of these chemicals may affect the risks associated with reusing or reclaiming wastewater. A promising method to remove trace chemicals that may be economical for the small onsite treatment system is powdered activated carbon (PAC) added directly to the aeration chamber or unit. The addition of the PAC also allows for increased resistance to high organic loads, increased ammonia removal, and improved sludge settleability. A proprietary process known as PACT has been successfully used in large-scale treatment works and may be a solution for small onsite treatment systems.

Consideration and restrictions

The makers of PACT advertise their product for high strength industrial wastewater and it may not be economical for individual homeowners. Removal of pharmaceuticals and medicines may be beneficial for treatment of wastewater from hospitals and nursing homes, where the concentration of these chemicals is higher than for family residences.

Effluent Quality

PAC improves effluent quality in terms of BOD and reduces variability during transient conditions (found during start-up or after long durations of low flow) than aerobic treatment systems without activated carbon. The addition of PAC may not be economically justified because the quality of effluent is not significantly increased over aerobic treatment.

Removal of Trace Chemicals Summary

Meets NSF 40 Standards	NA	
Effluent BOD:	-	mg/L
Effluent TSS	-	mg/L
Removes 50% total influent nitrogen	NA	
Effluent Nitrogen:	-	mg/L
Effluent Phosphorus:	-	mg/L
Effluent Fecal Coliform:	-	/100 mL
Maintenance Level:	Quarterly	
Power Required:	No	
Typical Installed Cost:	$5,000	/1,000 gallons

Typical Installed Costs (2007)

For conventional aerobic systems, the addition of powdered carbon does not increase the costs of construction and emplacement.

Operation and Maintenance Costs

Replacement of powdered activated carbon costs about $1 per pound. Regeneration of the carbon can be $0.65 per pound, and incineration costs as little as $0.60 per pound. ("Recycling Activated Carbon", 2004) For small flow users, the most likely disposal of spent PAC would be removal with the sludge from aerobic treatment units during regular pumping services.

DISINFECTION TECHNOLOGIES FACT SHEETS

Chlorination Fact Sheet C-1

Chlorine is the most commonly used chemical and/or method for disinfection of water and wastewater, and has a long history of use in the US. Chlorine is effective against a wide range of pathogenic organisms. Common forms of chlorine include chlorine gas, solid or liquid chlorine (calcium hypochlorite and sodium hypochlorite), and chlorine dioxide.

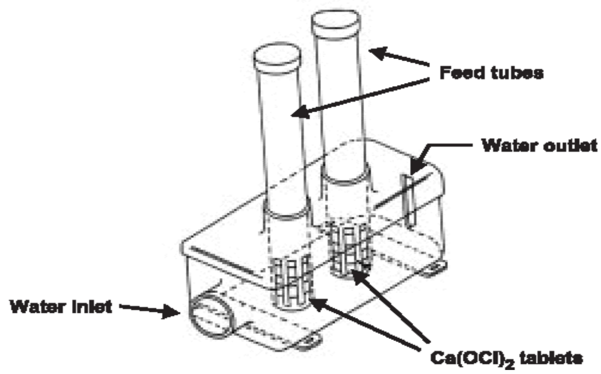


Figure 5-8 Tablet Chlorination Chamber (Adapted from USEPA)

Considerations and Restrictions

Gaseous chlorine is the most commonly used form; however, due to its highly corrosive nature and significant safety concerns, it is generally not recommended for onsite applications. Liquid hypochlorite solutions are commonly used at small treatment plants, where safety and simplicity are top priorities. Solid hypochlorite (powder or tablets) is common for onsite treatment systems (the same materials used for swimming pools and hot-tubs). All forms of chlorine are generally toxic and corrosive. They require careful handling and storage. The residual chlorine is effective as a disinfectant after the initial treatment. However, even at low concentrations, it can be toxic to aquatic life, and de-chlorination is necessary for discharges to (or impacting) surface waters.

Effluent Quality

One advantage of using chlorine as a disinfectant is its ability to exist as a residual in wastewater effluent even after initial treatment. Chlorine has been shown to reduce fecal coliforms by 99-99.99%.

Typical Installed Costs (2007)

A hypochlorite tablet feed system could cost $800-$1,000 for 1,000 gallons per day for the system itself. Labor and material costs vary depending on whether the tablet feeder is part of a pre-packaged system or added to an existing system. A gas chlorine system may cost $75,000 to treat 100,000 gallons per day.

Operation and Maintenance Costs

Operational costs for a tablet system are approximately $30-$50 per year for tablets, $75-$100 per year in labor, and $15-$25 per year in repairs and replacements.

Estimated cost for a gaseous chlorine system is approximately $4,500 for chemicals, $4000 for labor, $4,000 for power, and $6,000 for materials.

Operating and maintenance cost and tasks include power consumption, cleaning, chemicals and supplies, repairs, and labor.

Chlorination Summary

Meets NSF 40 Standards	NA	
Effluent BOD:	-	mg/L
Effluent TSS	-	mg/L
Removes 50% total influent nitrogen	NA	
Effluent Nitrogen:	-	mg/L
Effluent Phosphorus:	-	mg/L
Effluent Fecal Coliform:	1000-10000	/100 mL
Maintenance Level:	Quarterly	
Power Required:	No	
Typical Installed Cost:	$800-$1,000	/1,000 gallons

UV Disinfection Fact Sheet C-2

Ultraviolet (UV) light is a physical disinfection agent that takes advantage of the germicidal properties of UV in the range of 240-270 nm. This radiation penetrates the cell wall of organisms, preventing reproduction. The effectiveness of UV disinfection depends on the characteristics of wastewater (particularly clarity as measured by turbidity), UV intensity, time of exposure, and reactor configuration.

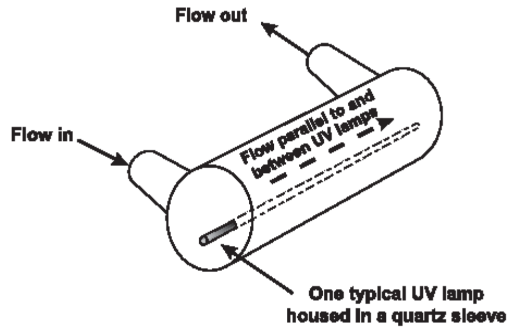


Figure 5-9 Ultraviolet Radiation Chamber (Adapted from USEPA)

Considerations and Restrictions

UV is effective in the inactivation of most viruses, spores, and cysts. UV eliminates the handling and storage of hazardous or toxic chlorine chemicals. However, UV performance is highly dependent on the quality of the wastewater it is disinfecting. High turbidity and total suspended solids will shield bacteria, making UV treatment ineffective.

Effluent Quality

UV disinfection is lacking in field studies, but typical units treating sand filter effluents can reduce fecal coliforms by 99.9%.

Typical Installed Costs (2007)

The component cost for a UV system is between $1,000-$2,000 per 1,000 gpd. Labor and material costs vary depending on whether the system is a built-in component of a packaged treatment system or added as an off-the-shelf component to enhance an existing system.

Operation and Maintenance Costs

Annual power costs are $35-$45, labor $50-$100, and lamp replacement $70-$80 per year. Power consumption is about 35 W or 307 kW-h/y.

UV Disinfection Summary

Meets NSF 40 Standards	NA	
Effluent BOD:	-	mg/L
Effluent TSS	-	mg/L
Removes 50% total influent nitrogen	NA	
Effluent Nitrogen:	-	mg/L
Effluent Phosphorus:	-	mg/L
Effluent Fecal Coliform:	~1,000	/100 mL
Maintenance Level:	Quarterly	
Power Required:	Yes	
Typical Installed Cost:	$1,000-$2,000	/1,000 gallons

TESTED AND APPROVED SYSTEMS MANUFACTURED IN HAWAII

Between 1998 and 2006, the Water Resources Research Center at the University of Hawaii conducted tests of two aerobic treatment units. In accordance with HAR 11-62, ATUs shall be approved by DOH and tested to demonstrate they meet the Class I effluent standard established by the National Sanitation Foundation (NSF). Both systems met the criteria, and serve as prime examples of products manufactured and sold in Hawaii.

Each unit had to meet the NSF Standard 40 Class I effluent standards. The standard states that in a 30 consecutive day period, the average BOD and TSS for the system must be less than 30 mg/L, and that the average in any 7 consecutive day period must never exceed 45 mg/L. The BOD removal must be at least 85% and the pH of the effluent must always be between 6.0 and 9.0. The NSF protocol calls for six months of continuous operation under standard conditions including a flow rate equal to the design capacity where 35% of the daily flow enters between 6 AM and 9 AM, 25% enters the system between 11 AM and 2 PM, and 40% enters between 5 PM and 8 PM. This closely approximates the flows an operating system would encounter in the average household during a workday. In addition to normal operation, a series of 4 stress tests is also required by the NSF protocol. These stress tests include: (1) a wash day stress test with normal daily flow plus 3 washer loads (35 gallons of hot water with detergent and bleach per load) between 8:30 and 11:30; (2) working mother stress test with 40% of the flow entering between 6 AM and 9 AM, 60% of the flow entering between 5 PM and 8 PM with one washer load; (3) a power failure stress test simulating a 48-hour period without power; and (4) a vacation stress test to simulate a seven-day vacation, followed by the return to normal flow operation plus wash day flows.

OESIS-750 SYSTEM

The OESIS-750 is a combined attached and suspended growth process. The fiberglass tank is 5 feet wide x 8 feet long x 6 feet tall (for a typical two bedroom house) and is separated into four internal chambers. The first is an anaerobic settling chamber that includes spherical media to enhance anaerobic growth. This chamber anaerobically degrades the solids that may enter the system. From the first chamber, the wastewater flows to the second anaerobic chamber where it is treated with attached growth. In addition, a recycled portion of treated water is returned to the second chamber where nitrified wastewater is denitrified. Wastewater then flows to the aeration chamber where the BOD is degraded and ammonia and organic nitrogen is nitrified. The aerobic chamber also has plastic media to enhance attached growth as well as suspended growth. Finally, the wastewater enters a settling chamber where the small organic particles that form in the aerobic treatment process are allowed to settle to the bottom of the chamber. In addition, the system is configured with a chlorine tablet canister to provide disinfection (if needed).

The influent and effluent characteristics for the 6-month standard performance period are listed in Table 5-4. The OESIS-750 also performed well during the required series of four stress tests. In each stress test, the unit recovered quickly from the stress event and continued to meet all of the NSF 40 Class I effluent standards.

Table 5-4 OESIS-750 NSF 40 Test Characteristics

Parameter	6-month average
Influent BOD (mg/L)	146.4
Effluent BOD (mg/L)	13.9
BOD removal (%)	91
Influent TSS (mg/L)	128.0
Effluent TSS (mg/L)	13.1
TSS Removal (%)	90

The University of Hawaii study showed that the OESIS-750 satisfies the NSF 40 standard for Class I effluent. In addition to meeting the NSF 40 standard, the OESIS system is designed to remove nitrogen, averaging about 19% removal of total nitrogen during the testing period.

CBT 0.8KF-210 SYSTEM

The CBT 0.8KF-210 can be categorized as a sequenced batch reactor. The CBT 0.8KF-210 uses a single fiberglass baffled tank, a floating decanter, effluent pump, blowers, aerators and control box. The tank itself is 6.0 feet in diameter by 10.5 feet, but has an average water depth of only 3.5 feet, yielding an average water volume of 1,000 gallons (sized for a typical 2 bedroom house). The blowers operate on a cycle of 2 hours on, 2 hours off. The cycles of on/off provide for the oxidation of BOD and nitrification of ammonia during the on cycles, and the denitrification, anaerobic removal of phosphorus, and solids settling during the off cycles. The floating decanter allows the effluent pump to avoid pumping sludge or any floatables reducing the amount of solids in the effluent.

Results from the six-month standard performance test are shown in Table 5-5, including the total nitrogen removal.

Table 5-5 CBT 0.8KF-210 NSF 40 Test Characteristics

Parameter	6-month average
Influent BOD (mg/L)	198.3
Effluent BOD (mg/L)	4.6
BOD removal(%)	98
Influent TSS (mg/L)	241.5
Effluent TSS (mg/L)	2.7
TSS Removal(%)	99
Influent Total Nitrogen (mg-N/L)	28.1
Effluent Total Nitrogen (mg-N/L)	5.2
Total Nitrogen Removal (%)	81

The CBT unit also performed well during the required series of four stress tests. In each stress test, the unit recovered quickly from the stress event and continued to meet all of the NSF 40 Class I effluent standards.

The University of Hawaii study indicates that the NSF 40 Class I effluent standards are easily met with the CBT, which is a local product. In addition, should the Department of Health require that total nitrogen removal be at least 50 percent, this system also fulfills that requirement.

Vendor information for the OESIS and CBT systems is provided in Appendix B.

Chapter 6 Small Flows Treatment Systems

SUMMARY AND FACT SHEETS

This chapter summarizes systems that may be economical for small flows (less than 10,000 gpd), but would not be appropriate for flows less than 1,000 gpd. These small flow systems provide additional options to those systems in Chapter 5 used to treat 1,000 gpd, which are also applicable to wastewater flows between 1,000 and 10,000 gpd. Small flows systems are used in small or rural communities to treat multiple and/or larger wastewater generators.

As with onsite systems, a professional engineer must be consulted to ensure proper permits, plans, and construction meet state and local regulations for small flows treatment systems. The construction of such systems becomes a collaborative effort between the owners, the engineers, the contractors, and the manufacturers or proprietary owners of the systems. In addition, the systems require operation and maintenance to be clearly delineated, and by state regulations, there must be an operator or supervisor of the wastewater systems with flows greater than 1,000 gpd.

Although no specific disposal systems are listed with the small flows treatment systems, there must be a means of discharging the treated wastewater back into the environment. In most cases, a disposal system similar in function to the IWS disposal systems would be adequate. The difference between the small flows disposal system and IWS system would be either size or number of disposal systems. For flows above 1,000 gallons per day, the use of an injection well may be the best option for disposal.

Water reuse may be a more economical means of disposal for small flows (<10,000 gpd) than with the IWS. Although water reuse is more economical, there is still the need for backup disposal systems or emergency power. Backup systems can be any of the systems discussed in Chapter 4 or can be as simple as a storage pond.

The following tables summarize the performance of small flow systems as well as the advantages and disadvantages of each system. Small flow systems include cluster/STEP systems (or ways of managing IWS in a central manner) (SF-1), lagoons (SF-2), oxidation ditches (SF-3), attached growth bioreactors (SF-4), constructed wetlands (SF-5), and membrane bioreactors (MBR) (SF-6).

In the case of small flows, the typical construction costs are given per 1,000 gpd of wastewater to be treated. The upper limit of construction cost for a 10,000 gpd system would be approximately 10 times the upper limit given in the smart box.

SUMMARY OF SMALL FLOWS SYSTEMS

Table 6-1 Typical Small Flows Wastewater Treatment System Effluent Water Quality

SYSTEM	BOD mg/L	TSS mg/L	Total Nitrogen mg/L	Total Phosphorus mg/L	Fecal Coliforms per 100 mL	COMMENTS
Cluster systems	132-217	49-161	39-82	11-22	1 – 100 million	Assuming STEP system
Lagoons	60-140	Variable	Up to 60% removal	Minimal Removal	Variable	
Oxidation Ditches	<10	<10 if settling tank is used	Total removal with designed anoxic zone	Minimal Removal	Variable	
Attached Growth Aerobic reactors	<30	<30	<30	~10	>2000	California Water Boards
Constructed Wetlands	2-7	<20	<30	Minimal removal	90-99% removal w/HRT of 3-7 days	
Membrane Bioreactors	<5	<2	3	0.5	<200	Data from manufacturers' websites

Table 6-2 Advantages and Disadvantages of Small Flows Wastewater Treatment and Disposal Systems

System	Advantages	Disadvantages or Limitations
Cluster systems	▪ May be economical for small communities without sewers ▪ Transfers non-point discharges to a point discharge that may be more easily monitored and managed ▪ Requires less space than reliance on IWS	▪ Concentrates pollutants in one location for disposal ▪ Requires very structured and delineated management system to assign responsibility to designated parties
Lagoons	▪ Passive system with little or no energy requirements ▪ Large volume able to buffer shock loads	▪ Vector control (mosquitoes) must be managed ▪ Nuisance odors may be caused by anaerobic conditions
Oxidation Ditches	▪ High BOD removal ▪ Can be engineered to remove almost all nitrogen	▪ Aeration or mixing require power consumption
Attached Growth Aerobic Reactors	▪ Can reduce energy costs per unit of organic removal	▪ Odors and poor effluent quality may result from poor design.
Constructed Wetlands	▪ Natural process ▪ Good process to treat wastewater prior to discharge to surface water ▪ Nitrification and denitrification occur	▪ Demands large land area ▪ If free surface wetlands are constructed, there is a threat of mosquitoes or other insect vectors.
Membrane Bioreactors	▪ Extremely high quality effluent in small space	▪ Costly to build ▪ Operating conditions may cause fouling which leads to more frequent and costly cleaning

SMALL FLOWS FACT SHEETS

Cluster Systems/STEP Systems Fact Sheet SF-1

Cluster systems are gaining popularity as a means to manage small to intermediate sized wastewater systems. They take advantage of “green” communal planning and development to integrate wastewater treatment and disposal into communities. Developers opt to set aside some common area with the express purpose of acting as either a satellite treatment facility or a common area disposal system. A typical cluster may have each residence on a septic tank, combine the effluent from those septic tanks in an equalization tank, and discharge to a soil absorption system in a common area. Communities may have one large, common septic tank or aerobic treatment system with a common disposal system. Some concern may arise about the amount of contaminants that are placed in a confined space as opposed to over the larger area individual systems would use. However, the communal system transfers the contaminants (nitrates, BOD, and TSS) from non-point sources (each residence) to a point source (a single treatment unit and disposal unit) that can be better controlled, more easily monitored, and take advantage of economies of scale. Another drawback to cluster systems, and something requiring additional site evaluation, is the degree that groundwater will pond under the cluster system. Specific site criteria used in conjunction with hydrogeologic simulation models can help engineers determine if the site is adequate for communal disposal. Common treatment and disposal systems used in cluster development include aerobic treatment units (ATUs), packaged extended aeration plants, lagoons, sand filters, constructed wetlands, drip and spray (after disinfection) irrigation, soil treatment mounds (elevated mounds), and common area absorption beds.

A classic example of a communal system is that of Cuyler, New York. In this system, each building (41 total) was equipped with a grinder pump that produced a slurry of water and suspend solids and provided pressure to the small diameter sewer system. Two 5000-gallon septic tanks were installed that could work as single, parallel, or serial tanks to receive the influent from the entire community. The septic tanks then drain to two of four different absorption beds. The absorption beds are rotated on a regular basis to “rest” or regenerate their biological capacity and oxygen content. As of 1994 (17 years into the life of the system), average TSS was 85 mg/L from the septic tanks, on par with normal septic tank functionality, proving that grinder pumps did not adversely affect the ability for solids to settle in the tanks. By using a cluster system, the community of Cuyler saved itself over $400,000 (1994 dollars) instead of utilizing a gravity sewer with conventional activated sludge treatment. Similar cluster systems have been approved in Hawaii.

Considerations and Restrictions

Several states have begun to codify how cluster systems can be utilized. Common to all the regulations is the need for persistent monitoring using groundwater wells upstream and downstream from the final disposal site, alternating absorption beds, and reserve land space for backup in case an absorption bed fails. The need for alternating absorption beds and backup space increases land requirements, however, this should be offset by the land area saved by not requiring each residence to have its own system. It also makes pollutant monitoring easier.

Effluent Quality

For a septic tank-effluent pump (STEP) system, the treatment quality could be taken as that of a septic tank. The Cuyler NY system showed that sustained rates of 85 mg/L of suspended solids are achievable. Similar BOD values are to be expected.

Typical Installed Costs (2007)

The construction costs for cluster systems with each home on its own septic tank will cost $5,000-$8,000 per residence. For the Cuyler NY example, construction costs of the cluster system (41 units) were about $170,000 compared to $570,000 for a conventional sewer collection and treatment system (1978 dollars).

Operation and Maintenance Costs

In one study, the most cost effective means of wastewater treatment (in terms of operation and maintenance) for total flows less than 5,000 gallons/day was individual septic tanks and soil absorption systems for each residence. However, for total flows between 5,000 and 15,000 gallons/day, the most economical system was one in which each residence had its own septic tank, with a shared soil absorption system.

Cluster Systems Summary

Meets NSF 40 Standards	Possibly	
Effluent BOD:	Varies	mg/L
Effluent TSS	Varies	mg/L
Removes 50% total influent nitrogen		Possibly
Effluent Nitrogen:	Varies	mg/L
Effluent Phosphorus:	Varies	mg/L
Effluent Fecal Coliform:	Varies	/100 mL
Maintenance Level:	Monthly	
Power Required:	Yes	(for STEP)
Typical Installed Cost:	$5,000-8,000	/1,000 gallons

Lagoons and Ponds Fact Sheet SF-2

In general, the terms "lagoon" and "pond" can be used interchangeably. Lagoon treatment systems are lined, earthen basins that are designed and constructed to treat wastewater for small rural communities or clusters of homes. Depending on the design, lagoons range in depth from shallow to deep, and are categorized by the presence or absence of oxygen. Lagoons can also be categorized by the frequency and duration of the effluent discharge and/or based on the type of influent (untreated, screened, etc.). The most common are facultative lagoons that are 4 to 8 feet deep and have no mechanical equipment. In these ponds, algae live in the upper layer using sunlight and CO2 to produce oxygen. Below the surface, bacteria use the oxygen produced by the algae during metabolism of wastewater organics and produce CO2 for the algae.

Considerations and Restrictions

Primary treatment upstream of lagoons should be considered, although it is not required. Upstream operations include screens and/or a comminutor to reduce the size of floatable and settleable materials.

Lagoons require more land space as compared to other treatment systems. Due to the open nature of the lagoons, some vector control must be implemented to prevent a population growth of insects (for example, in mosquito-infested areas, lagoons need pesticide applied to prevent outbreaks of mosquitoes and mosquito-borne diseases). Odor control must be considered. At the least, odors must be monitored to avoid nuisances. Security and public health and safety must be included in the design of the lagoons. The grading around the lagoons should be such that stormwater does not run into the lagoons.

Effluent Quality

Lagoons are simple, low-tech, low-energy, "natural" systems. BOD is removed by biological oxidation and TSS is removed by sedimentation. BOD removal can be as high as 75-95%, and effluent TSS ranges from 60 mg/L to 140 mg/L. Nitrogen removal is dependent on the uptake by algae and bacteriological growth, both of which depend on the chemistry of the lagoon.

The combination of a lagoon and downstream treatment (such as sedimentation or filtration) can improve both BOD and TSS removal. Nitrogen removal in facultative lagoons is as high as 60%, and nitrogen removal is about 10-20% for aerated lagoons.

Typical Installed Costs (2007)

A facultative lagoon will typically cost between $2,500-$7,500 per 1,000 gallons of flow treated per day.

Operation and Maintenance Costs

Vector control must be implemented to prevent uninhibited growth of mosquitoes and other potentially unhealthy insects. Sludge depth should be monitored annually and dredging conducted as necessary (every 10-20 years) to maintain lagoon volume.

Lagoons Summary

Meets NSF 40 Standards	Possibly	
Effluent BOD:	10-100	mg/L
Effluent TSS	60-140	mg/L
Removes 50% total influent nitrogen	No	
Effluent Nitrogen:	20-40	mg/L
Effluent Phosphorus:	3-5	mg/L
Effluent Fecal Coliform:	1,000,000	/100 mL
Maintenance Level:	Weekly to Monthly	
Power Required:	Yes	
Typical Installed Cost:	$2,500-7,500	/1,000 gallons

Suspended Growth Bioreactors- Oxidation Ditch — Fact Sheet SF-3

Suspended growth bioreactor is a broad category of wastewater treatment systems that utilize activated sludge to treat wastewater. Systems include completely mixed activated sludge, plug flow activated sludge, sequence batch reactors (SBR) and contact stabilization, as well as extended aeration processes such as oxidation ditches. The common principles associated with all the processes that utilize activated sludge are the following:

- Influent wastewater is usually pretreated (usually using a settling basin to accomplish primary treatment);
- Biological growth is suspended in the mixed liquor by mechanical means (mixing) or by vigorous aeration;
- The activated sludge process is followed a secondary clarifier to separate liquids and solids; and
- Solids from the secondary clarifier are returned to the bioreactor to aid in the treatment of influent wastewater.

Forms of suspended growth treatment systems include the suspended growth and combined attached and suspended growth treatment systems, and the sequenced batch reactors summarized in fact sheets B-1 to B-3 of Chapter 5. Although configurations may change, these systems operate in a similar manner at the higher flow rates as they do at the lower (1000 gpd) flow rates, and therefore, are not addressed a second time here. However, at higher flow rates (approaching 10,000 gpd), the introduction of oxidation ditches is economic.

An oxidation ditch is a form of the extended aeration, activated sludge biological treatment. The process occurs in a circular or race-track shaped channels in which pretreated wastewater is oxidized by aeration. Oxidation ditches are usually operated with long hydraulic retention times (approximately 24 hours or more) and solids retention times (30 days or more). They are generally equipped with a mechanical means to aerate and circulate the wastewater. With sufficient volumes, oxidation ditches can be designed to provide simultaneous nitrification/denitrification.

Considerations and Restrictions

Vector control measures must be implemented to prevent populations of unhealthy insects, like mosquitoes, from growing. Sedimentation tanks are required downstream from the oxidation ditch to separate suspended solids from the effluent. Security, public health, and public safety must be considered when designing and installing oxidation ditches.

Effluent Quality

Designed correctly, nitrogen reduction can be achieved. BOD and TSS concentrations less than 10 mg/L can be achieved with the use of sedimentation.

Typical Installed Costs (2007)

Construction costs are estimated at $2,500 to $8,000 per 1,000 gallons/day treated due to sophisticated mechanical requirements such as aeration equipment and clarifier mechanisms.

Operation and Maintenance Costs

Oxidation ditches use aeration, requiring power input. The velocity of the wastewater in the ditch must also be kept high enough to provide good mixing and to maintain the microorganisms in suspension. This requires energy.

Oxidation Ditch Summary		
Meets NSF 40 Standards	Yes	
Effluent BOD:	10	mg/L
Effluent TSS	5-10	mg/L
Removes 50% total influent nitrogen		Possibly
Effluent Nitrogen:	0-5	mg/L
Effluent Phosphorus:	3-5	mg/L
Effluent Fecal Coliform:	1,000,000	/100 mL
Maintenance Level:	Weekly	
Power Required:	Yes	
Typical Installed Cost:	$2,500-8,000	/1,000 gallons

Attached Growth Units   Fact Sheet SF-4

Attached growth treatment systems are available in a variety of types. They may be aerobic or anaerobic. Like suspended growth activated sludge processes, they take advantage of biological treatment. In the case of attached or fixed film systems (FFS), the biological mass grows as a biofilm (slime layer) on the surface of a media that is submerged or semi-submerged. There are two common types of FFS: trickling filters in which the wastewater runs over or through a stationary media, and rotating biological contactors in which the media moves relative to the wastewater, providing both aeration and biomass contact with the wastewater. As with suspended growth reactors, FFSs require a sedimentation tank to separate sloughed biomass and suspended solids from clear effluent.

Considerations and Restrictions

Trickling biofilters usually use less energy to remove BOD than conventional activated sludge processes. However, there is a greater chance for odor and poor effluent quality due to poor ventilation or design.

Effluent Quality

FFSs employ biological treatment. Trickling biofilters also allow for the simultaneous removal of BOD and ammonia via nitrification. Rotating biological contactors (RBC) also remove BOD to a range of 7-15 mg/L and reduce ammonia-nitrogen to <2 mg/L. Attached growth bioreactors have also been used after conventional secondary treatment to provide denitrification to effluent to a range of 2-4 mg/L. Fully submerged RBCs can also provide denitrification, with effluent nitrate-nitrogen concentrations in the range of 1-6 mg/L

Typical Installed Costs (2007)

Construction costs for trickling filters and RBCs can range from $5,000 to $10,000 per 1,000 gallons/day treated.

Operation and Maintenance Costs

Fixed film systems are generally low maintenance. Like other treatment systems, any mechanical components (blowers, fans, pumps, motor-driven chains on RBCs, rotating influent applicators, clarifier mechanisms, etc.) require regular inspection and maintenance.

Attached Growth Summary

Meets NSF 40 Standards	Yes	
Effluent BOD:	7-15	mg/L
Effluent TSS	<20	mg/L
Removes 50% total influent nitrogen		Possibly
Effluent Nitrogen:	2-4	mg/L
Effluent Phosphorus:	-	mg/L
Effluent Fecal Coliform:	1,000,000	/100 mL
Maintenance Level:	Monthly	
Power Required:	Yes	
Typical Installed Cost:	$5,000-$10,000	/1,000 gallons

Constructed Wetlands Fact Sheet SF-5

A constructed wetland (CW) is a man-made, marsh-like area that is designed and built to provide wastewater treatment. A lined bed of washed gravel is planted with hydroponic species whose roots absorb nutrients and create areas for aerobic treatment to take place. CWs can be designed for discharge to SWIS and will require disinfection for reuse or discharge to surface or groundwater. CWs can be generally categorized into two categories: subsurface and free flowing or surface constructed wetlands. Subsurface wetlands are designed for fluid flow that is below ground level, whereas free flow wetlands allow for wastewater to approach the surface.

Considerations and Restrictions

Wastewater pretreatment is required prior to the use of CWs. These operations include settling with a septic tank and/or screening mechanisms. CWs generally require more land space than other treatment methods, require a start-up period to establish the vegetation, must be designed such that rainfall runoff will not collect in the bed, and be designed to receive ample sunlight. Currently, there are no regulations in HAR 11-62 governing CWs, so the use of such systems requires approval. Safety issues and public access should be considered when designing and constructing CWs. Vector problems, such as mosquitoes, must be considered.

Effluent Quality

The expected BOD and TSS removal can be 60-80% for BOD and 50-90% for TSS, but depends on the nature and characteristics of the influent. Removal of nitrogen can be effective. For the typical constructed wetland located at the Riveredge Nature Center, effluent quality for a system receiving 2,000-9,300 gpd of wastewater is about 3.7 mg/L of BOD, 17.2 mg/L of TSS, and fecal coliforms of 54 per 100 mL.

Typical Installed Costs (2007)

According to the USEPA, a free flow, surface wetland should cost about $2,000-$4,000 per 1,000 gpd treated. However, for large disposal flows, the costs could approach $15,000 per 1,000 gpd treated.

Operation and Maintenance Costs

Operation and maintenance required for a CW is minimal and may include mosquito control. Occasional maintenance of the vegetation to promote growth of desired vegetation and maintaining hydraulic capacity is required. Proper maintenance of upstream processes is necessary to prevent clogging of the gravel bed.

Constructed Wetlands Summary

Meets NSF 40 Standards		No
Effluent BOD		<10 mg/L
Effluent TSS		<20 mg/L
Removes 50% total influent nitrogen		Possibly
Effluent Nitrogen		<20 mg/L
Effluent Phosphorus		- mg/L
Effluent Fecal Coliform		<100 /100 mL
Maintenance Level:		Medium
Power Required:		No
Typical Installed Cost:	$2,000-$15,000	/1,000 gallons

Membrane Bioreactors Fact Sheet SF-6

Membranes are currently the “hot” topic in the wastewater industry because of the promise of exceptional wastewater treatment within a small footprint. In wastewater treatment, microfiltration or ultrafiltration membranes are used to separate particles and organisms larger than 0.4 or 0.04 micrometer out of the water, providing very high quality effluent. In fact, membrane bioreactors (MBRs) remove the need for downstream processes including secondary clarification and tertiary granular media filtration. Long solids retention times and high biomass concentrations are maintained in the basin resulting in a small footprint to achieve exceptional BOD removals.

Considerations and Restrictions

The membranes must be protected from foreign debris that may damage or foul the membrane and shorten its life. Therefore, basic pretreatment requirements for MBRs include fine screens. MBRs can be installed in applications where an activated sludge process may be considered. However, they use 150% to 100% as much aeration energy as conventional activated sludge. They can be sized for flows ranging from individual homes up to greater than 10 million gallons/day (MGD). The major considerations for MBRs are the costs associated with the equipment and continued maintenance costs especially electricity for aeration equipment.

Effluent Quality

R-1 recycled water quality effluent can be obtained with the combination of MBR and disinfection, allowing for numerous and varied disposal options. However, monitoring and maintenance cleaning must take place in order to ensure proper functioning of the membranes.

Typical Installed Costs (2007)

MBRs are the most expensive of the systems listed in this handbook. Most of the cost is associated with the membranes and mechanical and control systems. One vendor quotes a price of $7-$20 per gallon of treated wastewater for equipment cost for one of its pre-packaged plants, not including labor or materials to install.

Operation and Maintenance Costs

Mechanical components of the system, including blowers and pumps, must be maintained. Periodic cleaning of the membrane is required, which may introduce minor chemical costs along with the safety provisions needed for chemical handling. Unit operation parameters may also influence the need for cleaning to control biofouling.

Membrane Bioreactors Summary

Meets NSF 40 Standards	Yes	
Effluent BOD:	<5	mg/L
Effluent TSS	<5	mg/L
Removes 50% total influent nitrogen	Yes	
Effluent Nitrogen:	<20	mg/L
Effluent Phosphorus:	<0.5	mg/L
Effluent Fecal Coliform:	100	/100 mL
Maintenance Level:	Weekly	
Power Required:	Yes	
Typical Installed Cost:	$14,000-$40,000	/1,000 gallons

Appendix A - General Considerations for the Maintenance and Operation of Individual Wastewater Systems

Each system listed in this handbook will have its own specific maintenance requirements. However, there are common operational and maintenance features that all the systems share. The most common reason for the failure of individual wastewater systems is inadequate maintenance. Homeowners and developers must budget for professional maintenance of the IWS in order to prevent system failure. With proper professional maintenance, these system will continue to function well for decades. In addition to financing the maintenance, consideration must be made for the logistics of operation and maintenance of the IWS systems. The following are some common issues encountered when installing the systems:

- Is the system accessible for pumping? How close can the pumping company park to the system? Most companies must be able to get within 50 feet of a system before they start charging extra for additional lengths of hose.

- What is the anticipated volume to be pumped out of the system? Some pumpers can only carry 1,000 gallons at a time, others up to 4,000 gallons. Once those volumes are reached, either a second trip will have to be made or a second truck with be needed. Both options add costs.

- Are the systems going to be buried in a manner such that they may be driven over? Do the pipes for the systems run under driveways? If so, there will be additional structural considerations, which will impact the price of the system.

- Are the manholes to the system accessible? Will they continue to be accessible in the future or will vegetation cover them?

- For systems using electricity, where is the power source for the system going to be? What are the requirements for the system? How does the system restart after a power failure? How is the system shut down for maintenance?

- Where is the control panel, and is it accessible?

- For disposal units, is an observation well needed? Where will the cleanouts be located?

- Are there trees or large bushes near the disposal unit that may need to be removed so that roots do not intrude on the system? Is there a need for root barriers on the disposal system?

In addition, the following checks should be performed on systems that are operating. (Not all systems will have the components listed).

- Check manhole covers for cracks.

- Check all visible piping for leaks.

- Check to ensure there are no obstacles around the system.

- Check for abnormal odors.

- Check the inside of tanks for obstructions or blockages (Never enter the tank. Use the "buddy" system to make sure that nothing happens during the inspection. Use proper tools to remove covers and follow the manufacturer's instructions).

- For tanks that have more than one chamber, check for abnormal water levels in the chambers (i.e., no water in one chamber and lots of water in another).

- Check for accumulation of scum or sludge (use the correct tools and procedures given by the manufacturer).

- Check the condition of walls, screens, filters, and media when available.

- Check the transparency of the water in the tank.

- When operating, the aerator should aerate evenly.

- Check the diffuser for even distribution of bubbles.

- Check for foaming.

- Listen to pumps and blowers for abnormal noise.

- Remove objects at least 2 feet from blowers to ensure adequate airflow.

- For blowers or motors that require oil, check the level of oil.

- Check belts on blowers and fans.

- Check air filters and clean or replace as necessary.

- Check any visible valves for cracks or damage.

- Check chlorination chambers or tubes for cracks or breaks.

- Check to make sure chlorination chambers have chemicals (calcium hypochlorite tablets for tablet feeders, bleach for liquid chlorine feeders).

- If the disposal system has clean-outs, check to ensure there is similar flow in each pipe (no flow in one pipe with excessive flow in another may be an indication of clogging).

- Check for ponding of water near the treatment system and near the disposal system.

The above checks could be done by a homeowner who has received training from the equipment vendor and is so inclined, but it is recommended to have a professional service technician check the system once a year, at least. The recommended frequency for preventive maintenance checks and services is based on the system in use, but may be as frequent as once every 3 months. In addition, the owner of the system should plan on the possibility of having to replace mechanical parts (pumps, blowers, compressors, diffusers, etc.) once every 2-5 years.

For soil absorption systems, the following tips will help reduce the likelihood of system failure:

- Divert excess rainwater runoff away from the drainfield. A saturated drainfield will not absorb and treat liquid waste. Plan landscaping, roof gutters, and foundation drains so that excess water is diverted away from the drainfield.

- Conserve water to prevent overloading the drainfield. Check faucets and toilets for leaks; make repairs if necessary. Apply water-saving technologies to save water, including aerators for faucets and displacers for toilets. Use water-saving practices to conserve water, i.e., run the dishwasher only when it is full.

- Keep excessive vegetation away from the drainfield. Tree roots damage the piping of a drainfield and should be kept 100 feet away from the field.

- Never flush cat litter, disposable diapers, sanitary napkins, tampons, paper towels, facial tissues, coffee grounds, or cigarette butts.

- Use garbage disposals or garbage grinders wisely and sparingly. Garbage disposals can double the amount of solids added to a septic tank and lead to carry-over into the drainfield.

- Do not pour grease or harsh chemicals (drain openers such as lye, disinfectants, insecticides, herbicides, cleansers, etc.) down the drain.

- Do not drive over the drainfield, build a structure on top of it, or cover it with concrete or asphalt. Plant grass on the drainfield to minimize soil erosion.

Perform regular maintenance on the septic tank or treatment system. Solids must eventually be pumped from the tank every 2-3 years. If solids are not pumped from the upstream treatment units, the solids will overflow into the drainfield, causing clogging/failure.

Appendix B - Manufacturers, Vendors, and Contractors[1]

[1] This list of vendors, manufacturers, and contractors is not meant to be exhaustive, nor does it represent an endorsement on the part of the authors, the Hawaii State Department of Business, Economic Development and Tourism or the Department of Health.

ACTIVATED CARBON SYSTEMS

Carbon Resources, LLC
5222 Rosewood Drive
Oceanside, CA 92056
USA
(760)-630-5724
Email sales@carbonresources.com
www.carbonresources.com

Ecologix Environmental Systems
120 Ansley Way
Roswell, GA 30075
1-888-326-2020
info@ecologixsystems.com
www.ecologixsystems.com

Siemens Corporation (Owners of PACT®)
Information Desk
Water Technologies
1-800-525-0658
information.water@siemens.com

AEROBIC, SUBMERGED GROWTH REACTORS

AWT Environmental, Inc (Aquapoint® product line)
241 Duchaine Boulevard
New Bedford MA 02745-1209
(505) 998-7577

Best Industries†
Sold through Environmental Waste Management Systems
PO Box 980,
Waialua, HI 96791

Bio-Microbics, Inc*†
8450 Cole Parkway
Shawnee, KS 66227
1-800-753-FAST

Bord Na Mona Environmental Products US Inc*
4106 Bernau Avenue
Greensboro, NC 27407
1-800-787-2356

Consolidated Treatment Systems Inc.(Contact Yoshi Tanabe at (808) 637-5537)* †
1501 Commerce Center Drive
Franklin, OH 45005
(937) 746-2727

Delta Environmental Products*†
8275 Florida Boulevard, East
PO Box 969
Denham Springs, LA 70726
(225) 665-1666

Jet Inc.*
750 Alpha Drive
Cleveland, OH 44143
(440) 461-2000

Microseptic*
23362 Madero Suite C
Mission Viejo, CA 92691
(949) 297-4590

Quanics*
6244 Old LaGrange Road
Crestwood, KY 40014
1-877-782-6427
www.quanics.net

AEROBIC, SUSPENDED GROWTH REACTORS

Aeration Systems
155 Grey Road
Falmouth, ME 04105
(207) 797-7351

† Denotes systems sold through vendors or manufacturers in Hawaii

* Denotes systems with National Sanitation Foundation Standard 40 certification. Go to http://www.nsf.org/Certified/Wastewater/Listing.asp?Standard=040& for a complete and up-to-date list of certified systems.

American Wastewater Systems, Inc.*
1307 South Fieldspan
Duson, LA 70529
1-800-960-3997
www.best1systems.com

Bionest Technologies Inc*
55 12th Street
PO Box 697
Grand-Mere, Quebec G9T 5L4
Canada
866-538-5662

Cajunaire LLC*
PO Box 1351
Denham Springs, LA 70727
1-800-996-9107
www.cajunaire.com

Ecological Tanks, Inc*†
2247 Highway 151 North
Downsville, LA 71234
1-800-277-8179
Email: aquasafe@bayou.com
www.etiaquasafe.com

Hydro-Action*
8645 Bourssard Road
Beaumont, TX 77713
(409) 892-3600

Norweco, Inc.
Firelands Industrial Park
220 Republic Street
Norwalk, OH 44857
(419) 668-4471
www.norweco.com

Quanics*
6244 Old LaGrange Road
Crestwood, KY 40014
1-877-782-6427
www.quanics.net

CHLORINE DISINFECTION UNITS

Hammonds
15760 West Hardy Road, Suite 400
Houston, TX 77060
(281) 999-2900
Fax (281) 847-1857
www.hammondscos.com

JET, Inc.
750 Alpha Dr.
Cleveland OH 44143
(440) 461-2000
Fax (440) 442-9008
www.jetincorp.com

Miox Corporation
5601 Balloon Fiesta Parkway NE
Albuquerque, NM 87113
(505) 343-0090
1-800-646-9426
E-mail: info@miox.com
www.miox.com

Norwalk Wastewater Equipment Company, Inc.
220 Republic Street
Norwalk OH 44857-1196
(419) 668-4471
Fax (419) 663-5440
www.norweco.com

Severn Trent De Nora
1110 Industrial Blvd
Sugar Land, TX 77478
(281) 240-6770
Fax (281) 670-6762
Email:
customer_service@severntrentdenora.com
www.severntrentdenora.com

COMPOSTING TOILETS

Advanced Composting Systems, LLC
195 Meadows Road
Whitefish, MT 59937
(406) 862-3854

Composting Toilet Systems, Inc.
Post Office Box 1928
Newport, WA 99156
1-888-7-TOILET (1-888-786-4538)
(509) 447-3708

Clivus Multrum, Inc.
15 Union Street
Lawrence, MA 01840
800-425-4887
forinfo@clivusmultrum.com

EcoJohn
P.O. Box 3752
Costa Mesa, CA 92628
1-866-ECOJOHN
(714) 568-1077

Ecological Engineering Group
508 Boston Post Road
PO Box 415
Weston, Massachusetts 02493-0003
1- 866-4-ECOENG
Email: eeginfo@ecological-engineering.com

Envirolet by Sancor
1-800-387-5126
Email: info@envirolet.com

Sun Mar
600 Main St.
Tonawanda, NY 14150
1-888-341-0782
Email: compost@sun-mar.com

CONSTRUCTED WETLANDS

Quanics
6244 Old LaGrange Road
Crestwood, KY 40014
1-877-782-6427
www.quanics.net/index.htm

DRAINFIELD SUPPLIERS

Advanced Drainage Systems, Inc.
460 Trueman Boulevard
Hillard, OH 43026
1-800-821-6710

American Onsite Manufacturing Company, Inc
1-800-345-3132
Email: info@americanonsite.com

Plastic Tubing, Inc.
ptipipe@ptifla.com

Presby Environmental Inc.
143 Airport Road
Whitefield, NH 03598
1-800-473-5298
info@presbyeco.com

Ring Industrial Group (EZ Flow® product line)
1-800-649-0253
Email: inforequest@ringindustrial.com

EXCAVATION AND INSTALLATION

Gecko Enterprises†
68-364 Kikou Street
Waialua, HI 96791
(808) 637-3240

Big Island Excavating†
16-209 Mikahla Street
Keaau, HI 06749

HOLDING TANKS

Jensen Pre-cast Products†
1255 Nuuanu Ave Suite C104D
Honolulu, HI
(808) 528-1175

INCINERATING TOILETS

EcoJohn
P.O. Box 3752
Costa Mesa, CA 92628
1-866-ECOJOHN
(714) 568-1077

Incinolet by Research Products/Blankenship
2639 Andjon
Dallas, TX 75220
1-800-527-5551
Email: Sales@Incinolet.com

MEMBRANE BIOREACTORS

Enviroquip, Inc
2404 Rutland Dr.
Austin, TX 78758
(512) 834-6000

GE Water & Process Technologies
ZENON Membrane Solutions
Corporate Headquarters
3239 Dundas Street West
Oakville, Ontario L6M 4B2
Canada

Koch Membrane Systems, Inc.
10054 Old Grove Road
San Diego, California 92131
USA
1-800-525-4369

Rodi Systems
236 Highway 516
Aztec, NM 87410
(505) 334-5865

Siemens Water Technologies
Information Desk
Water Technologies
1-800-525-0658
Email: information.water@siemens.com

NITROGEN REMOVAL SYSTEMS

AWT Environmental, Inc (Aquapoint® product line)
241 Duchaine Boulevard
New Bedford MA 02745-1209
(508) 998-7577

Spec Industries
550 Parkson Road
Hendersen, NV 89015
(702) 558-4444

PACKED BED FILTERS

American Onsite Manufacturing Company, Inc
1-800-345-3132
Email: info@americanonsite.com

AWT Environmental, Inc (Aquapoint Product line)
241 Duchaine Boulevard
New Bedford, MA 02745-1209
(508) 998-7577

Eljen Corporation
125A McKee Street
East Hartford, CT 06108
1-800-444-1359
info@eljen.com

Quanics
6244 Old LaGrange Road
Crestwood, KY 40014
1-877-782-6427
www.quanics.net

PUMPING AND MAINTENANCE SERVICES

Aqua Pumping LLC†
PO Box 247
Kahuku, HI 96731
(808) 232-0202

Gecko Enterprises†
68-364 Kikou Street
Waialua, HI 96791
(808) 637-3240

J&C Sanitation†
6837 Olohena Road
Kappa, HI 96746
(808) 822-4738

Kobayashi Trucking and Equipment†
5-5435 Kuhio Highway #C
Hanalei, HI 96714
(808) 232-0202

The Plumbing Contractors†
PO Box 167
Kaneohe, HI 86744

Roto-Rooter Plumbing and Drain†
240-K Puuhale Road
Honolulu, HI 96819
1-877-747-7686

Suck 'em Up Pumping†
PO Box 880510
Pukalani, HI 96788
(808) 877-3934 (Maui)
(808) 246-6664 (Kauai)

SEPTIC TANKS

Chem-tainer Industries of Hawaii, Inc. †
16-118 Li'ili'i Street
Shipman Industrial Park
Keaau, Hawaii 96749
1-800-870-5494

Fralo Plastech
PO Box 245
Syracuse, NY 13211
(866) 943-7256

Jensen Pre-cast Products†
1255 Nuuanu Ave Suite C104D
Honolulu, HI
(808) 528-1175

Orenco †
814 Airway Avenue
Sutherlin, OR 97479
(800) 853-9307

Plas-Tech Ltd†
317 Kilua Place
(808) 847-2339

Quality Precasts Products Inc.
33 South King Street, Suite 517
Honolulu, HI 96813
(808) 599-7700
Email: jimcornick@yahoo.com

SEQUENCED BATCH REACTORS

Aquarobics Miniplant*
206 Wyck Street, Suite 100
Winchester, VA 22601
1-800-927-8304
www.aquarobicinternational.com

International Wastewater Technologies (contact Glen Linbo)* †
2632-B Kilihau Street
Honolulu, HI 96819-2020
(808) 833-2298

TRICKLING BIOFILTERS

Waterloo Biofilter Systems Inc.
P.O. Box 400
143 Dennis Street
Rockwood, ON
N0B 2K0
(519) 856-0757
E-mail: wbs@waterloo-biofilter.com

ULTRAVIOLET LIGHT DISINFECTION UNITS

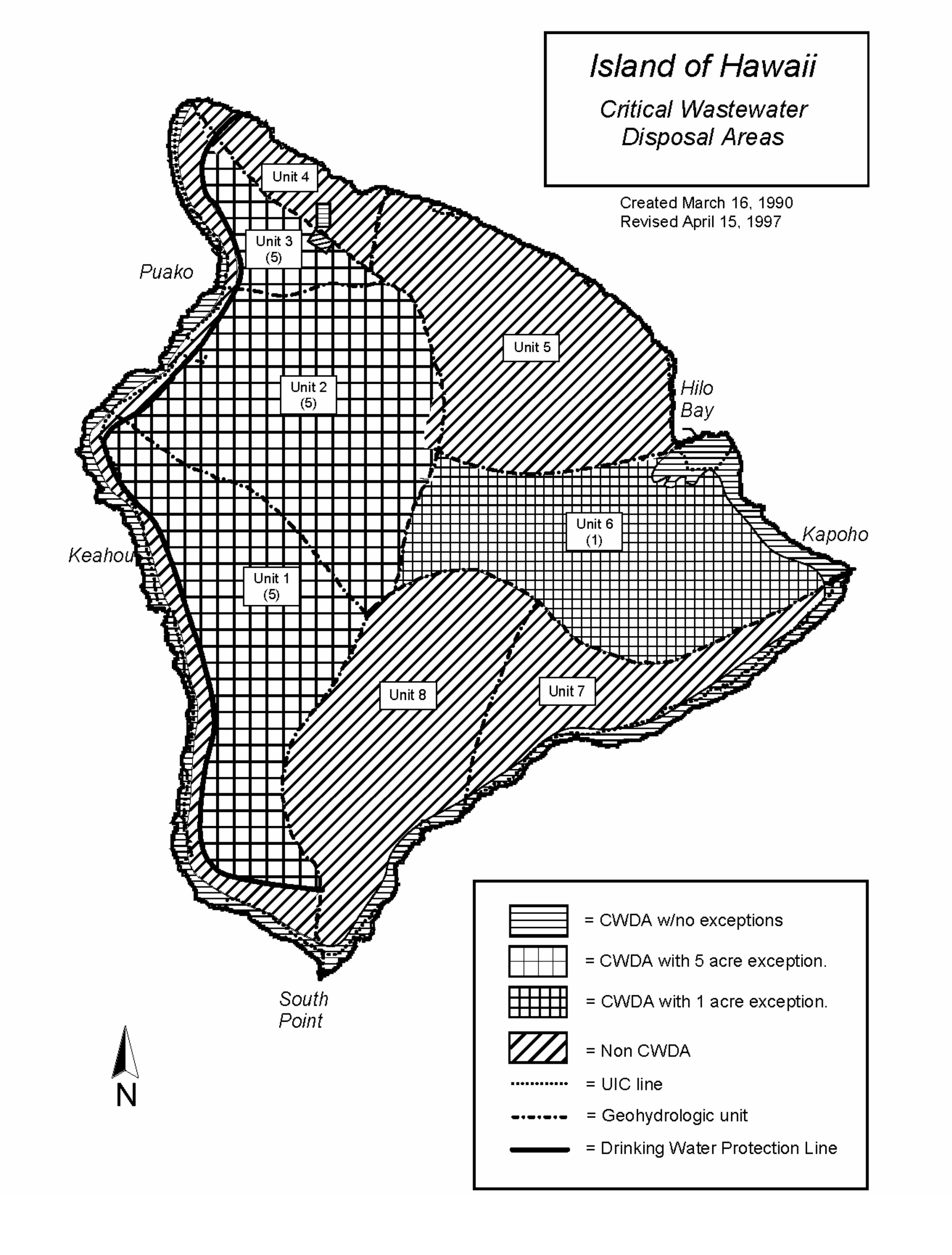
International Water-Guard Industries Inc.
3133 Sumner Ave.
Burnaby, BC, Canada, V5G 3E3
Phone (604) 255-5555
Fax (604) 255-5685
www.waterknowledge.com

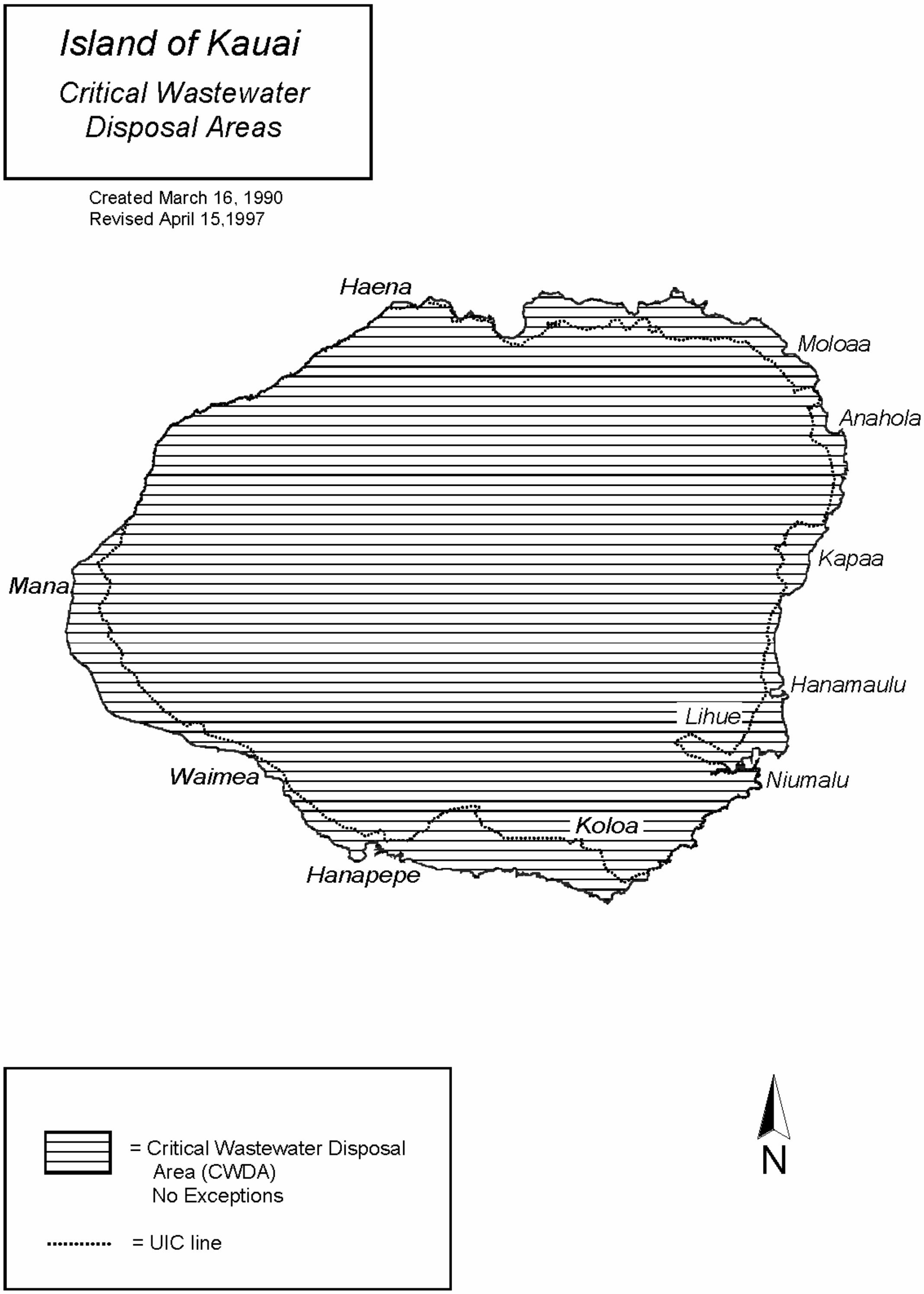
Ozonia
P.O. Box 455
491 Edward H. Ross Drive
Elmwood Park, NJ 07407
(201) 794-3100
Fax (201) 794-3358
www.ozonia.com

Salcor Engineering
P.O. Box 1090
Fallbrook, CA 92088-1090
(760) 731-0745
Fax (760) 731-2405
scruver@aol.com

Trojan Technologies, Inc. *
1380 East Vocell Blvd., Suite B
Davis, CA 95616
(530) 759-7600
Fax (530) 759-7620
Email: trojanca@trojanuv.com
www.trojanuv.com

Appendix C - Critical Wastewater Disposal Areas


Island of Hawaii
Critical Wastewater Disposal Areas
Created March 16, 1990
Revised April 15, 1997
Unit 4
Unit 3 (5)
Puako
Unit 5
Unit 2 (5)
Hilo Bay
Unit 6 (1)
Kapoho
Keahou
Unit 1 (5)
Unit 8
Unit 7
South Point
N
= CWDA w/no exceptions
= CWDA with 5 acre exception.
= CWDA with 1 acre exception.
= Non CWDA
= UIC line
= Geohydrologic unit
= Drinking Water Protection Line


Island of Kauai
Critical Wastewater
Disposal Areas
Created March 16, 1990
Revised April 15,1997
Haena
Moloaa
Anahola
Kapaa
Mana
Hanamaulu
Lihue
Niumalu
Waimea
Koloa
Hanapepe
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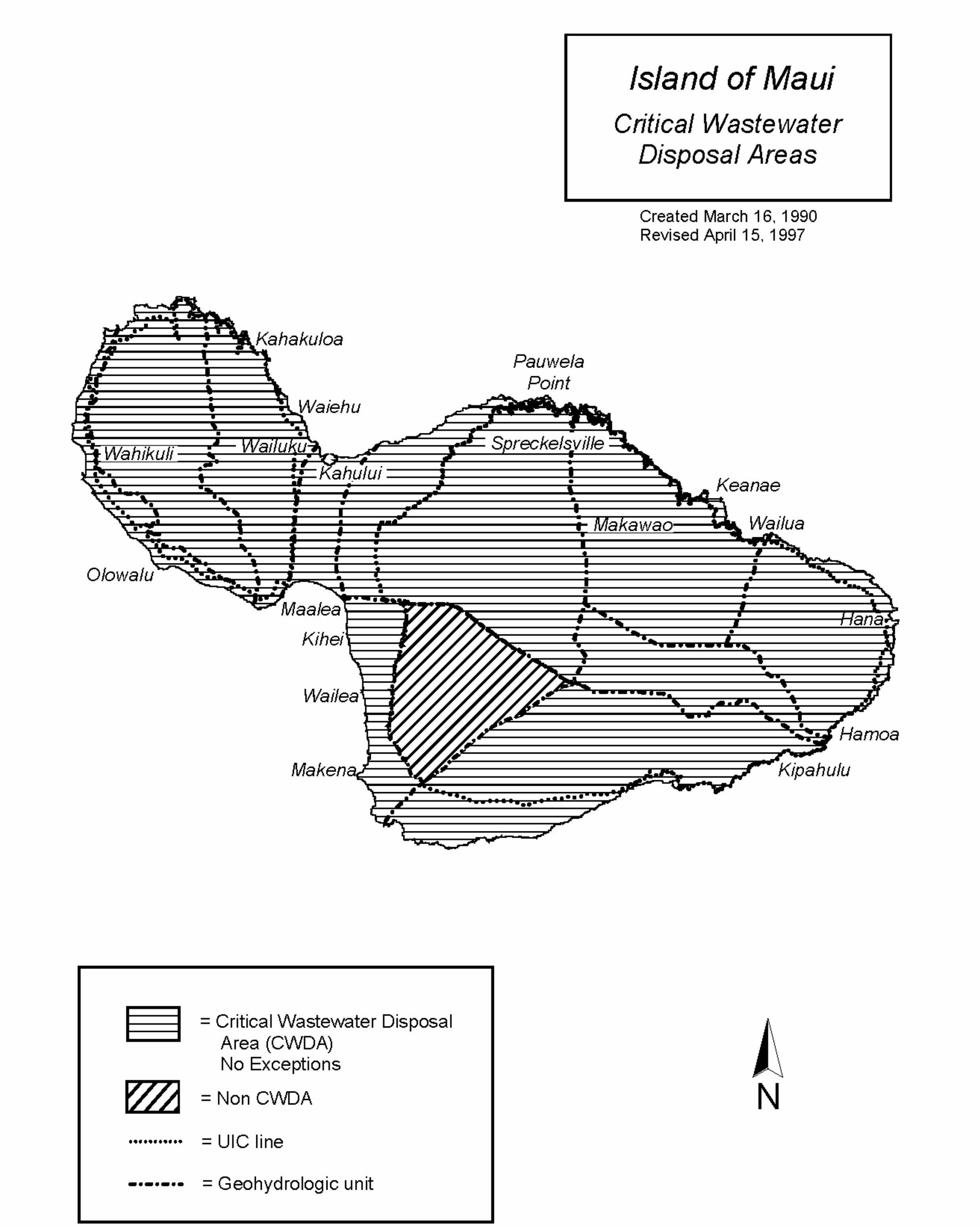
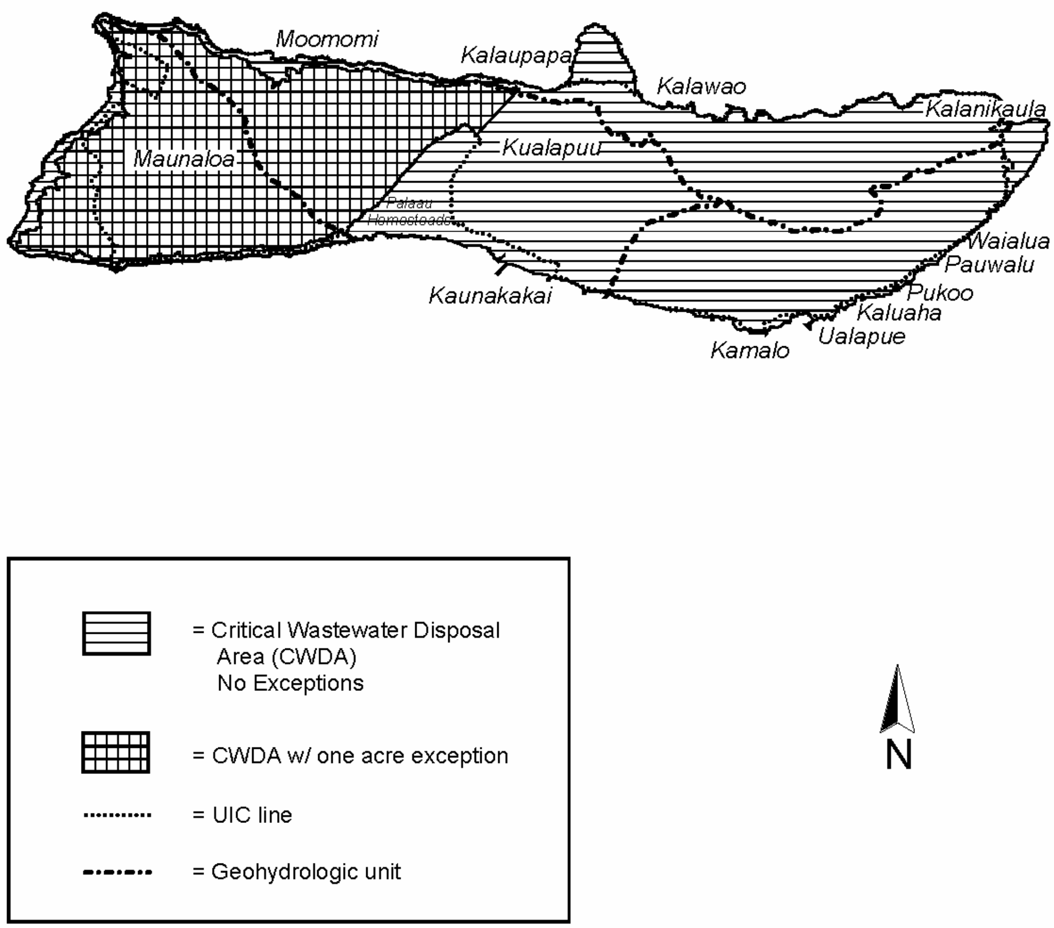
Area (CWDA)
No Exceptions
= UIC line
N

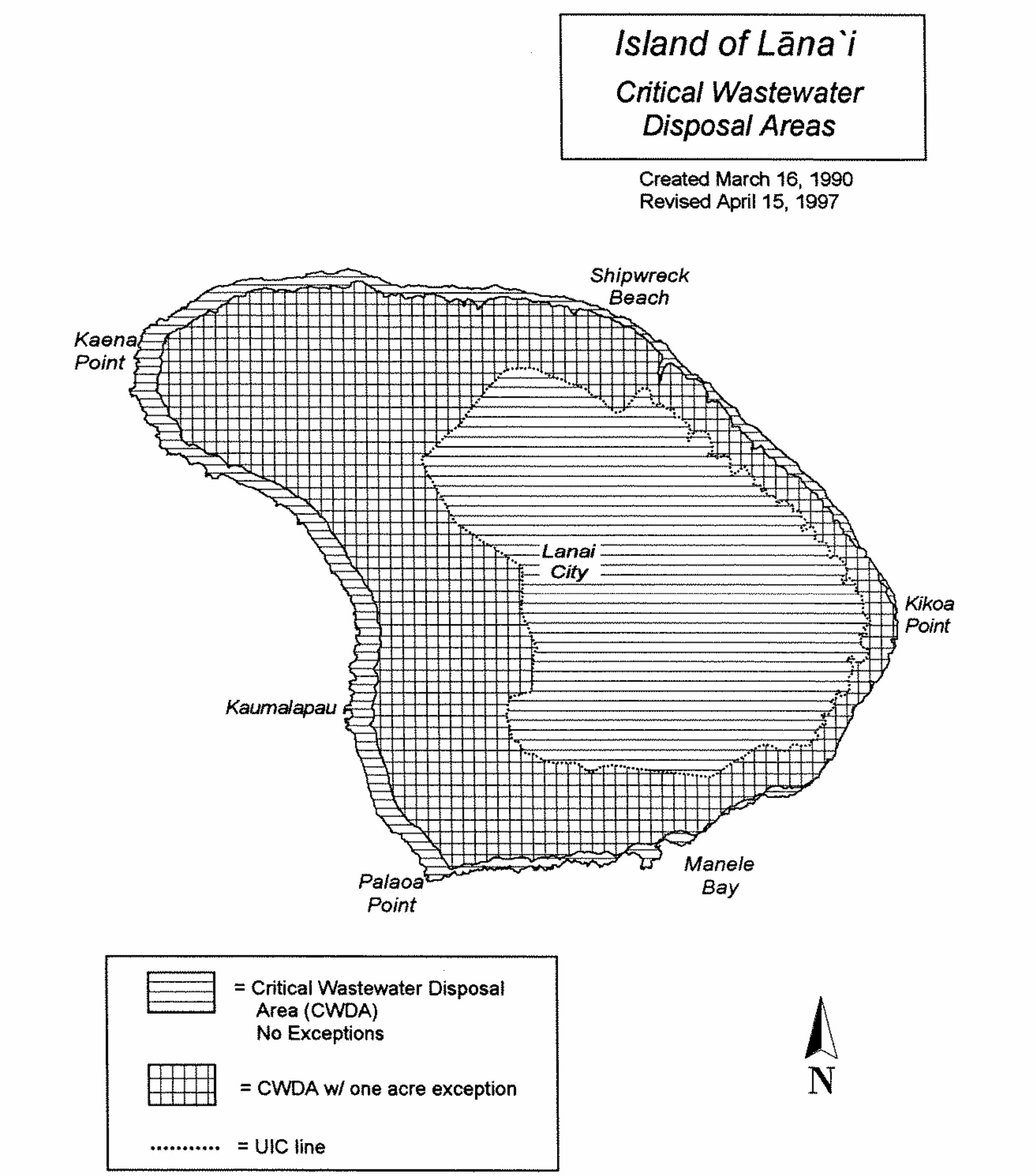

Island of Maui
Critical Wastewater Disposal Areas
Created March 16, 1990
Revised April 15, 1997
Kahakuloa
Pauwela Point
Waiehu
Wahikuli
Wailuku
Sprekelsville
Kahului
Keanae
Makawao
Wailua
Olowalu
Maalea
Hana
Kihei
Wailea
Hamoa
Makena
Kipahulu
= Critical Wastewater Disposal Area (CWDA) No Exceptions
= Non CWDA
= UIC line
= Geohydrologic unit
N

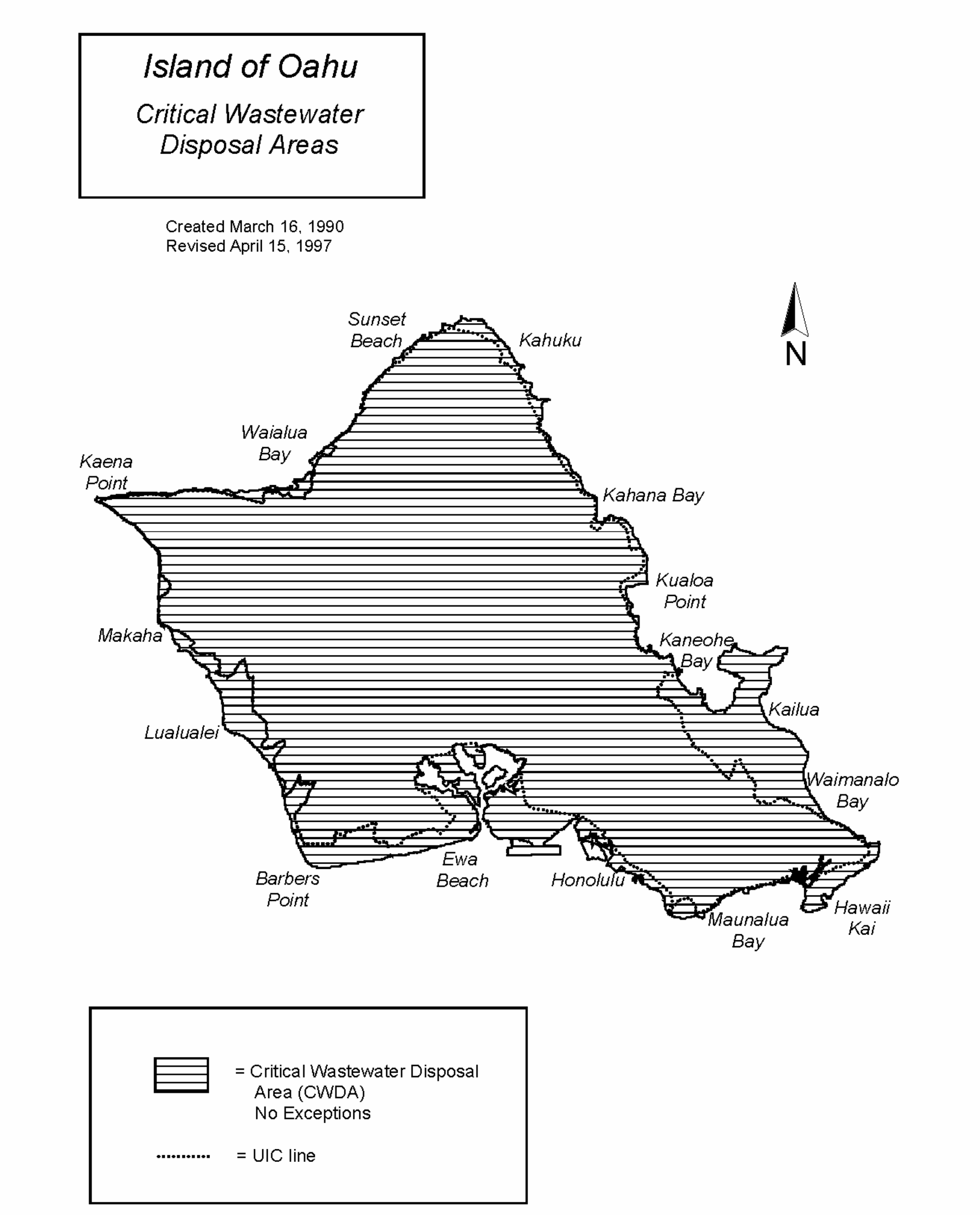
Island of Molokai

Critical Wastewater Disposal Areas

Created March 16, 1990
Revised April 15, 1997




Island of Lāna`i
Critical Wastewater Disposal Areas
Created March 16, 1990
Revised April 15, 1997
Shipwreck Beach
Kaena Point
Lanai City
Kikoa Point
Kaumalapau
Palaoa Point
Manele Bay
= Critical Wastewater Disposal Area (CWDA) No Exceptions
= CWDA w/ one acre exception
= UIC line
N


Island of Oahu
Critical Wastewater
Disposal Areas
Created March 16, 1990
Revised April 15, 1997
Sunset
Beach
Kahuku
N
Waialua
Bay
Kaena
Point
Kahana Bay
Kualoa
Point
Makaha
Kaneohe
Bay
Kailua
Lualualei
Waimanalo
Bay
Ewa
Beach
Barbers
Point
Honolulu
Hawaii
Kai
Maunalua
Bay
= Critical Wastewater Disposal
Area (CWDA)
No Exceptions
= UIC line

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