Low-Cost Treatment Technologies for Small-Scale Water Reclamation Plants

WateReuse Research Foundation

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About the WateReuse Research Foundation

The mission of the WateReuse Research Foundation is to conduct and promote applied research on the reclamation, recycling, reuse, and desalination of water. The Foundation's research advances the science of water reuse and supports communities across the United States and abroad in their efforts to create new sources of high quality water through reclamation, recycling, reuse, and desalination while protecting public health and the environment.

The Foundation sponsors research on all aspects of water reuse, including emerging chemical contaminants, microbiological agents, treatment technologies, salinity management and desalination, public perception and acceptance, economics, and marketing. The Foundation's research informs the public of the safety of reclaimed water and provides water professionals with the tools and knowledge to meet their commitment of increasing reliability and quality.

The Foundation's funding partners include the Bureau of Reclamation, the California State Water Resources Control Board, the California Energy Commission, and the California Department of Water Resources. Funding is also provided by the Foundation's Subscribers, water and wastewater agencies, and other interested organizations.

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ACRONYMS

A/O	Anaerobic/aerobic
A2/O	Anaerobic/anoxic/aerobic
AS	Activated sludge
BNR	Biological nutrient removal
BOD	Biochemical oxygen demand
CCI	Construction cost index
COD	Chemical oxygen demand
ENR	Engineering News Record
HAAs	Heterocyclic aromatic amines
ICEAS	Intermittent cycle extended aeration system
HRT	Hydraulic retention time
IFAS	Integrated fixed film activated sludge
LM	Living Machine®
MBBR	Moving bed biological reactor
MBR	Membrane bioreactor
MF	Microfiltration
mgd	Millions of gallons per day
MLE	Modified Ludzack-Ettinger
MPN	Most probable number
Schreiber N&D	Schreiber nitrification and denitrification system
NPDES	National Pollutant Discharge Elimination System
NTU	Nephelometric turbidity unit
O&M	Operation and maintenance
OD	Oxidation ditch
RBC	Rotating biological contactor
RO	Reverse osmosis
SBR	Sequencing batch reactor
TDS	Total dissolved solids
SRT	Solid retention time
THMs	Trihalomethanes
TMDL	Total maximum daily loads
TN	Total nitrogen
TOC	Total organic carbon
TOX	Total organic halogen
TP	Total phosphorus
TSS	Total suspended solids
UF	Ultrafiltration
USAID	U.S. Agency for International Development
USEPA	U.S. Environmental Protection Agency
UV	Ultraviolet
WAWTTAR	Water and Wastewater Treatment Technologies Appropriate for Reuse
WHO	World Health Organization

FOREWORD

The WateReuse Research Foundation, a nonprofit corporation, sponsors research that advances the science of water reclamation, recycling, reuse, and desalination. The Foundation funds projects that meet the water reuse and desalination research needs of water and wastewater agencies and the public. The goal of the Foundation's research is to ensure that water reuse and desalination projects provide high-quality water, protect public health, and improve the environment.

An Operating Plan guides the Foundation's research program. Under the plan, a research agenda of high-priority topics is maintained. The agenda is developed in cooperation with the water reuse and desalination communities including water professionals, academics, and Foundation Subscribers. The Foundation's research focuses on a broad range of water reuse research topics including:

- Defining and addressing emerging contaminants;
- Public perceptions of the benefits and risks of water reuse;
- Management practices related to indirect potable reuse;
- Groundwater recharge and aquifer storage and recovery;
- Evaluation and methods for managing salinity and desalination; and
- Economics and marketing of water reuse.

The Operating Plan outlines the role of the Foundation's Research Advisory Committee (RAC), Project Advisory Committees (PACs), and Foundation staff. The RAC sets priorities, recommends projects for funding, and provides advice and recommendations on the Foundation's research agenda and other related efforts. PACs are convened for each project and provide technical review and oversight. The Foundation's RAC and PACs consist of experts in their fields and provide the Foundation with an independent review, which ensures the credibility of the Foundation's research results. The Foundation's Project Managers facilitate the efforts of the RAC and PACs and provide overall management of projects.

The Foundation's primary funding partners include the Bureau of Reclamation, California State Water Resources Control Board, the California Energy Commission, Foundation Subscribers, water and wastewater agencies, and other interested organizations. The Foundation leverages its financial and intellectual capital through these partnerships and funding relationships.

This study identifies and evaluates established and innovative technologies that provide treatment of flows of less than 1 million gal per day. A range of conventional treatment processes, innovative treatment processes, and package systems were evaluated as part of this project. The primary value of this work is the extensive cost database, where the cost and operation data from existing small-scale wastewater treatment and water reuse facilities have been gathered and synthesized.

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EXECUTIVE SUMMARY

The shortage of freshwater is a severe problem for many areas of the world. Water reclamation and reuse provide promising opportunities to ease freshwater shortage problems. However, data and technical information for low-cost treatment technologies for small-scale water reuse projects are often unavailable, especially to communities with limited financial and technical resources in rural areas and in developing countries.

In response to this need, this study identifies and evaluates established and innovative technologies that provide treatment of flows of less than 1 million gal per day. A range of conventional treatment processes, innovative treatment processes, and package systems were evaluated as part of this project. The primary value of this work is the extensive cost database, where the cost and operation data from existing small-scale wastewater treatment and water reuse facilities have been gathered and synthesized. From these data, the costs and maintenance issues for the various types of treatment technology are compared and contrasted.

The selection of small-scale reclamation systems will depend on many factors, such as regulations, availability of land, the budget, and trained staff. Based on the results of this project, natural systems (ponds plus wetlands) are the best economic alternative for small communities if inexpensive land is available and if effluent water quality can satisfy the local regulations. If high water quality is desired and a budget is available, nonmembrane systems can be used. Membrane-based systems can be used if even higher water quality is needed and if the budget allows.

The results from this project have been incorporated into the Water and Wastewater Treatment Technologies Appropriate for Reuse (WAWTTAR) model for dissemination to rural communities and developing countries. The WAWTTAR model is available on the Internet for download at no cost and can be found at http://firehole.humboldt.edu/wawttar/.

Please note that this is not a comprehensive list of treatment technologies or systems that could be used for treatment of wastewater to reclaimed standards, as it represents the data that could be gathered within the time frame and budget of this project.

CHAPTER 1

INTRODUCTION

The shortage of freshwater is a severe problem for many areas of the world. Water reclamation and reuse provide promising opportunities to ease freshwater shortages. Satellite and small-scale reclamation has become synonymous with membrane bioreactors (MBRs). While MBRs produce a high-quality effluent, they also come at a high capital cost. Rural communities often don't have engineering or operation staff experienced in advanced membrane treatment. Further, the high quality of MBR effluent is not required for most applications. Many utilities are now looking for the optimal balance between effluent quality and cost to maximize reclamation efforts. However, data and technical information for treatment technologies for small-scale water reuse projects are often unavailable, especially to communities with limited financial and technical resources in rural areas and in developing countries.

In response to this need, the WateReuse Research Foundation (WRF) contracted Carollo Engineers and Humboldt State University to lead "Low-Cost Treatment Technologies for Small-Scale Water Reclamation Plants", WRF-06-008. The main goal of this study is to identify and evaluate established and innovative technologies that provide economical treatment for flows of fewer than 1 million gal per day (mgd). A range of conventional treatment processes, innovative unit treatment processes, and package systems were evaluated. The cost and operability data from existing small-scale water reuse facilities have been gathered and synthesized. From this analysis, the costs and maintenance issues for the various types of treatment technologies are compared and contrasted.

Specific objectives of this project included the following:

- Identify a range of conventional and innovative unit treatment processes and package systems to be evaluated.
- Gather and synthesize cost and operability data from existing small-scale (<1 mgd) wastewater treatment and water reuse facilities.
- Incorporate the results into the Water and Wastewater Treatment Technologies Appropriate for Reuse (WAWTTAR) model for dissemination to rural and developing countries. The WAWTTAR model (http://firehole.humboldt.edu/wawttar/) is available on the Internet for download at no cost.

The results can help identify treatment trains suitable for small-scale operation that will minimize capital, operating, and maintenance costs; minimize staffing requirements through automation and simplicity of operation; minimize waste streams while maintaining high product water quality; and be utilized by communities with limited financial and technical resources in rural areas and developing countries.

CHAPTER 2

RECLAIMED WATER REGULATIONS AND USES

The reclaimed water regulations and uses have been summarized at the state level, national level, and international level. These regulations and uses, included in Appendices A to F and in the WAWTTAR model, are the baseline of what level of treatment is required for a particular application. There is no need, for example, to go to the expense of an MBR when a particular application does not require filtration and may require only 23 MPN of coliform per 100 mL of effluent. Thus, the reader is encouraged to use the regulatory summaries in this document to define the minimum acceptable water quality criteria and then to review the data from this report with those criteria in mind when selecting potential treatment systems.

At the state level, the guidelines and regulations for reclaimed water in 34 states in the United States are summarized in Appendix A. A summary of the most stringent regulations for reclaimed water in each surveyed state is shown in Table 2.1, which is sorted by the stringency of disinfection requirements and treatment requirements. Details can be found in Appendix A. The guidelines and regulations for reclaimed water of the other 16 states in the United States are not available as of December 2008. The titles and websites for the guidelines and regulations and related environmental protection departments in other states are listed in Appendix B. The uses of reclaimed water in 12 states in the United States are summarized in Appendix C. All of the information presented is considered current as of December 2008. The uses of reclaimed water govern the effluent quality, with some states such as California having an extensive list of uses, water quality standards, and treatment technologies that are proven to meet the effluent quality standards.

At the national level, the U.S. Environmental Protection Agency (USEPA) and U.S. Agency for International Development (USAID) published a report, EPA/625/R-04/108 (Guidelines, 2004), that summarized reclaimed water regulations and uses through 2002. This information is listed in Appendix D and Appendix E.

At the international level, the World Health Organization (WHO) guidelines of microbial performance targets for wastewater and excreta use in agriculture and aquaculture are shown in Appendix F.

While this project does not evaluate the relative public health impacts of using the different indicator organisms and disinfection targets, it is worth noting that there are substantial differences among some states. Many states have limited regulations or guidelines with limited categories of water reuse, such as crop and turf irrigation. Some states use fecal coliform as an indicator organism, and other states (such as California) use a more inclusive indicator: total coliform, which is about 10 times more sensitive than fecal coliform. In some cases, a subset of fecal coliform, *Escherichia coli*, is used as an indicator organism.

One further regulatory item must be considered for reclaimed water treatment: the training and certification requirements of operations staff. Should a utility, for example, convert from a natural system to an MBR, such a facility may be required to find or train staff to the appropriate level prior to operation. The example of operator regulations in California is included as Appendix G.

Table 2.1. Summary of Most Stringent Regulations for Reclaimed Water in Each Surveyed State[a]

State	Indicator Organism(s)	Disinfection Requirements (per 100 mL)	Turbidity (NTU)	Nitrogen (mg/L)	TSS (mg/L)	BOD_5 (mg/L)
Utah	*E. coli*	ND (daily), < 9	< 2		< 5	< 10
Massachusetts	fecal coliform	ND (7 days), < 14	<= 2	< 10	< 5	<= 10
Indiana	fecal coliform	ND, < 14			< 5	< 10
Florida	fecal coliform	ND		< 10	< 5	< 20
Colorado	*E. coli*	ND in 75% of samples	<= 3		< 30	
Arizona	fecal coliform	ND in 4 of last 7 samples	<= 2	< 10		
Alabama	total coliform	< 1		< 10		
Nevada	total coliform	< 2.2				
New Jersey	fecal coliform	< 2.2	< 2	< 10	< 5	
Vermont	*E. coli*	< 2.2	< 2	< 5	< 5	< 10
California	total coliform	< 2.2	< 2 or < 0.2			
Washington	total coliform	< 2.2	<= 2		< 30	< 30
Wyoming	fecal coliform	< 2.2				
Oregon	total coliform	< 2.2	< 2			
Idaho	total coliform	< 2.2				
Hawaii	fecal coliform	< 2.2				
Maryland	fecal coliform	< 3			< 10	< 10
New Mexico	fecal coliform	< 5	< 3			< 10
Virginia	fecal coliform, *E. coli*, enterococci	<= 14; <= 11; <= 11	< 2			<= 10
N. Carolina	fecal coliform	<= 14	< 10	<= 4	<= 5	<= 10
Texas	fecal coliform	< 20	< 3			< 5
Delaware	fecal coliform	< 20	< 5		< 10	< 10
Georgia	fecal coliform	< 23	<= 3		< 5	< 5
Montana	fecal coliform	< 23			< 10	< 10
Ohio	fecal coliform	< 23				
South Carolina	fecal coliform	< 200			< 5	< 5
North Dakota	fecal coliform	< 200			< 30	< 25
Tennessee	fecal coliform	< 200			<= 30	
Nebraska	fecal coliform	< 200				
Missouri	fecal coliform	< 200				
South Dakota	total coliform	< 200				
Alaska					< 30	< 30
Wisconsin				< 10		< 50

[a]ND: not detected. TSS: total suspended solids. BOD_5: 5-day biochemical oxygen demand.

CHAPTER 3

TREATMENT PROCESS OVERVIEW

3.1. IDENTIFICATION OF TREATMENT PROCESSES AND PACKAGE SYSTEMS

The treatment trains reviewed for this project include a range of conventional, advanced, and alternative technologies. Two types of engineering approaches are included in this analysis, one being the use of pre-engineered "package" plants and the other being that of nonpackage "customized" plants. As shown in Table 3.1, there are five subcategories of treatment plants evaluated as part of this project: A) conventional (nonmembrane) customized plants, B) conventional package plants, C) membrane customized plants, D) natural systems, and E) alternative treatment systems. Some limited descriptions of the predominant treatment processes compiled for this project are also included here. The lack of inclusion of specific technologies within this report is based upon a lack of collected information on such technologies by the project team and does not reflect a negative judgment on those technologies.

Table 3.1. Categories of Treatment Trains and Processes

Treatment Trains	Processes
A) Conventional Customized Plants	A.1) conventional activated sludge (AS)
	A.2) extended aeration
	A.3) intermittent aeration
	A.4) anaerobic/aerobic (A/O)
	A.5) anaerobic/anoxic/aerobic (A2/O)
	A.6) Bardenpho
	A.7) biological nutrient removal (BNR)
	A.8) modified Ludzack-Ettinger (MLE)
	A.9) Schreiber nitrification and denitrification (Schreiber N&D)
	A.10) in-channel denitrification
	A.11) intermittent cycle extended aeration system (ICEAS)
	A.12) trickling filter
	A.13) rotating biological contactor (RBC)
B) Conventional Package Plants	B.1) activated sludge package plants
	B.2) sequencing batch reactor (SBR)
	B.3) oxidation ditches (ODs)
	B.4) biological filtration
C) Membrane Customized Plants	C.1) MBR
D) Natural Systems	D.1) pond
	D.2) lagoon
	D.3) constructed wetland
E) Alternative Treatment Systems	E.1) living machines (LMs)

3.2. CONVENTIONAL CUSTOMIZED PLANTS

Most conventional customized processes are developed based on the conventional activated sludge process and modified for specific purposes such as nutrient removal. Details of subcategories of conventional customized plants are discussed in the following section.

3.2.1 Activated Sludge

The flow diagram of a typical activated sludge system is shown in Figure 3.1. Figure 3.2 is a picture of an aeration tank in an activated sludge system.

The activated sludge process was first discovered in 1914 (Ritmann and McCarty, 2001). The activated sludge process is a biological wastewater treatment method in which the organic matter in raw wastewater is degraded by dispersed microorganisms. The microorganisms and flocs are called activated sludge. Usually a primary settling process separates solids from raw wastewater before the secondary activated sludge treatment. In the secondary activated sludge treatment process, activated sludge recycles between the aeration tank and the secondary clarifier to control the solid retention time (SRT) in the aeration tank. After sedimentation, the clear effluent is discharged from the top of the secondary clarifier. The activated sludge process is widely used for the treatment of municipal and industrial wastewater (Ritmann and McCarty, 2001).

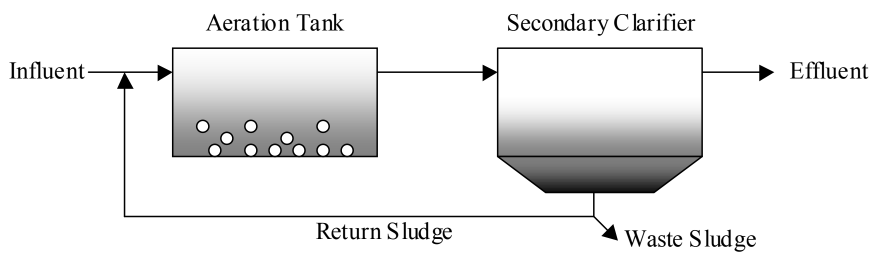

Figure 3.1. Flow diagram of conventional activated sludge system.

Figure 3.2. Sample picture of an aeration tank in an activated sludge system.

3.2.2 Extended Aeration

An extended aeration process is a modification of activated sludge process without primary settling and longer aeration time. Compared to a conventional activated sludge process, an extended aeration process has a higher biochemical oxygen demand removal efficiency and generates less sludge. However, the long aeration time means larger basins due to a long hydraulic residence time (HRT).

3.2.3 Biological Nutrient Reduction (BNR) Processes

Nutrient removal processes such as nitrogen removal and phosphorus removal can be added to the conventional activated sludge process. Nitrogen removal includes nitrification and denitrification. The nitrification process converts ammonia to nitrite and finally to nitrate. Nitrification lowers concentrations of ammonia in wastewater, a substance toxic to aquatic organisms, and controls eutrophication as well (Tchobanoglous et al., 2003). Denitrification includes the reduction of nitrate to nitric oxide, nitrous oxide, and nitrogen gas. Nitrogen removal is important for the protection of surface discharge and groundwater recharge (Tchobanoglous et al., 2003).

Various processes have been developed for BNR, such as intermittent aeration, anaerobic/aerobic (A/O), Bardenpho, modified Ludzack-Ettinger (MLE), Schreiber nitrification and denitrification (N&D), in-channel denitrification, and intermittent cycle extended aeration systems (ICEASs).

3.2.4 Trickling Filter and RBCs

Both rotating biological contractors (RBCs) and trickling filters develop a large biofilm surface and rely on mass transfer of oxygen from bulk liquids to the biofilm (Tchobanoglous et al., 2003).

An RBC consists of a series of closely spaced circular disks that are submerged in wastewater and rotating through it. These disks support the growth of microorganisms for biological degradation of wastewater. The advantages of RBCs are short contact time and short retention time due to a large active surface, low power requirement, and low sludge production. The disadvantage is that shafts within the mechanical process need regular maintenance.

A trickling filter is a nonsubmerged fixed-film biological reactor using rocks or plastic packing to support the growth of biofilms for biodegradation. Wastewater is distributed from the top of the filter beds by a rotary distributor. The advantage of a trickling filter is the high oxygen transfer efficiency due to the large contact area between air and liquids. However, energy costs are also high for trickling filters because wastewater needs to be pumped to the top of the filter.

3.3. CONVENTIONAL PACKAGE PLANTS

3.3.1 Activated Sludge Package Plant

Activated sludge package plants are prepackaged plants utilizing the activated sludge process for small-flow applications. Because such systems are prepackaged, they usually have smaller footprints than conventional activated sludge plants.

3.3.2 SBR

A sequencing batch reactor (SBR) is an activated sludge reactor composed of one or more periodically operated fill-and-draw reactors (Herzbnin et al., 1985).

A typical SBR system has five stages for each cycle: fill, react, settle, draw, and idle. During the anoxic fill stage, microorganisms utilize biochemical oxygen demand (BOD) and remove NO_3^- in influent wastewater. During the aerobic react stage, waste degradation and nitrification are enhanced with the aeration in the reactor. During the settle stage, mixed liquor suspended solids (MLSS) settle in the reactor. The relatively clean supernatant is then removed in the draw stage, and the remaining wastewater settles in the idle stage (Davis and Masten, 2004). SBRs are similar to the five-stage Barnard process, and the only difference is that the SBR process uses carryover NO_3^- from the settle and draw stages to drive predenitrification (Ritmann and McCarty, 2001). SBRs can achieve 90% total nitrogen removal. The disadvantage of SBRs is that they need many tanks and relatively long HRTs.

The flow diagram of a typical SBR system is shown in Figure 3.3 (Tchobanoglous et al., 2003). Figure 3.4 is a sample picture of an installed SBR system manufactured by Siemens.

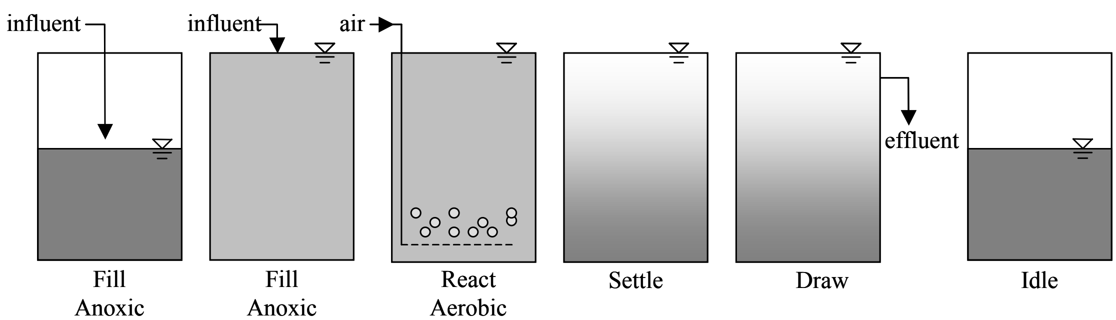

Figure 3.3. Flow diagram of SBR system.

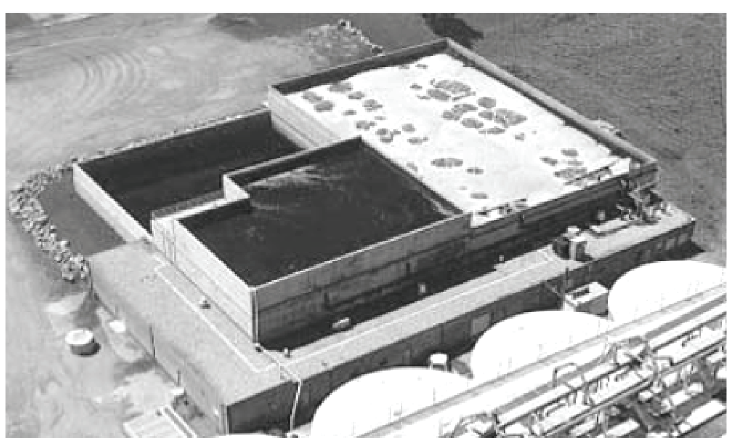

Figure 3.4. SBR system by Siemens (OMNIFLO).

3.3.3 OD

An oxidation ditch (OD) is a modified extended aeration activated sludge treatment process used for long-term aeration and high SRTs. An OD usually has elliptical or circular channels and utilizes aeration rotors to circulate wastewater in the channel to supply oxygen to facilitate biodegradation in channels. ODs are easily maintained, relatively unaffected by load fluctuations, and form relatively less sludge than do conventional activated sludge systems. They are easily controlled by changing the rotation of the rotor and the dipping depth, and such changes require relatively little energy. Furthermore, ODs can perform both N&D in the same structure to save energy. Mixing in ODs is improved compared to results in conventional aeration tanks. However, ODs require a relatively large area.

The flow diagram of a typical OD is shown in Figure 3.5. Figure 3.6 is a sample picture of a modified OD with multiple channels by U.S. Filter (Siemens).

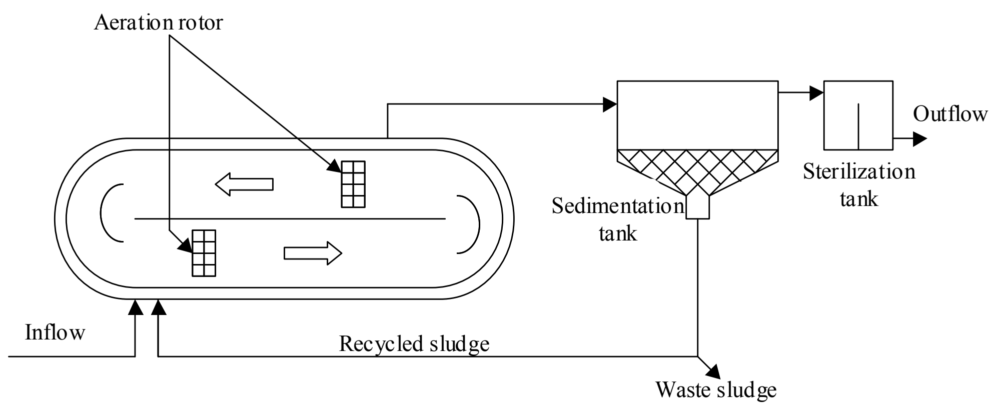

Figure 3.5. Process flow diagram of OD.

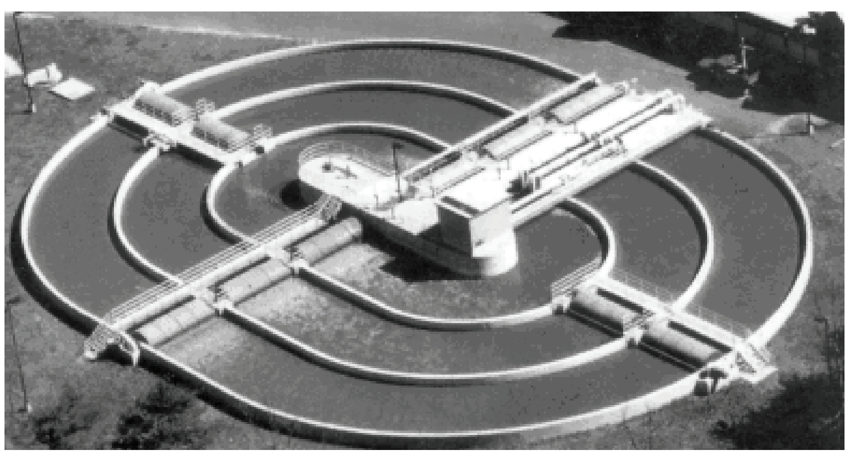

Figure 3.6. Multichannel OD by U.S. Filter (Siemens).

3.3.4 Biological Filtration

A biological filtration system utilizes particulate media or disks to host biological substrate that then treat wastewater, as opposed to seeding wastewater with inoculated return sludge. The media used in biological filtration have large surface areas on the surface of filtration media to support the microbial growth and form biofilms, which are used for the nitrification process. Without utilizing a recirculating activated sludge process, biological filtration systems eliminate secondary clarifiers and associated costs and space requirements. Figure 3.7 shows an installed package biological filtration system manufactured by Orenco Systems, Inc. In Figure 3.7, the treatment system includes an underground recirculation tank and several pods that contain the textile filter media. Primary tanks are located at each home that feeds the treatment system, and most systems also include a dosing tank for the effluent dispersal field.

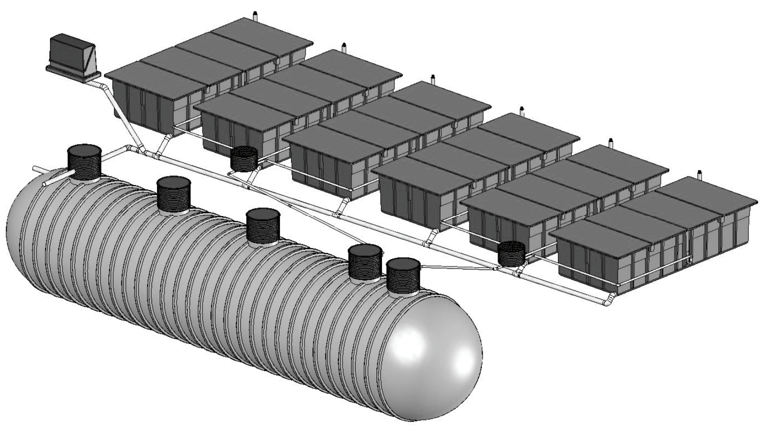

Figure 3.7. AdvanTex system by Orenco Systems, Inc.

3.4. MEMBRANE CUSTOMIZED PLANTS

MBRs integrate membranes (microfiltration [MF] or ultrafiltration [UF]) into activated sludge systems. MBRs use membrane filtration instead of sedimentation, which is used in conventional activated sludge systems, to separate biomass from effluent in secondary clarifiers.

The MLSS concentration in MBRs can reach 10,000 to 15,000 mg/L, which is much higher than MLSS values in conventional activated sludge systems (~3000 to 5000 mg/L). The pores of MBR membranes are smaller than some pathogens such as protozoa, allowing for the effective removal of some pathogens. MBRs have a reduced treatment system footprint due to the lack of clarifiers.

The flow diagram of a typical MBR system is shown in Figure 3.8. Figure 3.9 shows two sample pictures of MBRs manufactured by Zenon (Z-MOD) and Siemens Water Technologies (Xpress).

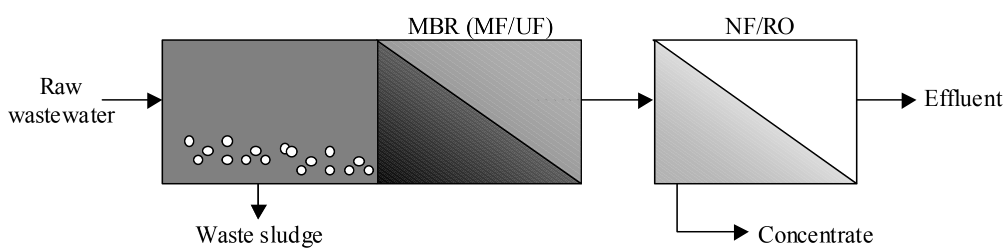

Figure 3.8. Process flow diagram of MBR.

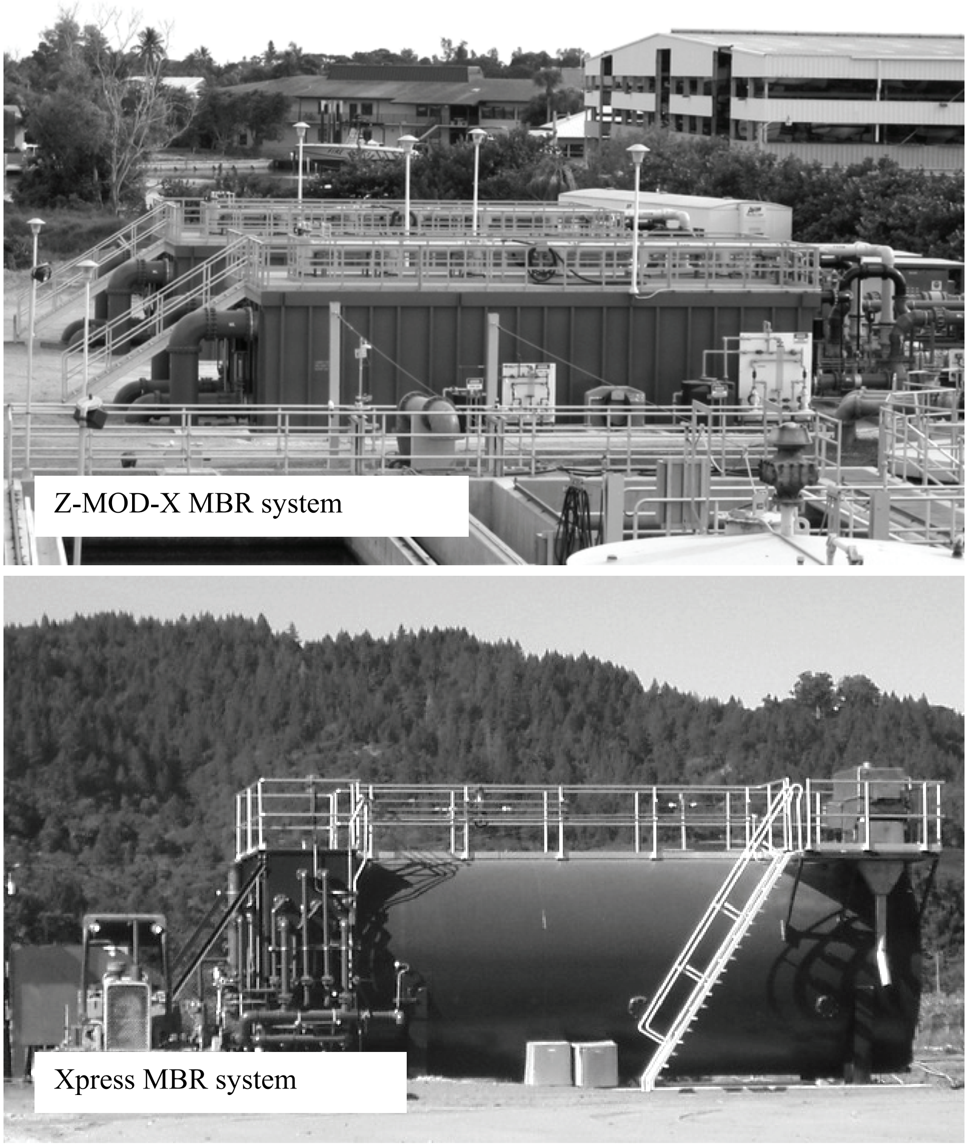

Figure 3.9. Sample pictures of MBR systems.

3.5. NATURAL SYSTEMS

Natural systems rely upon natural microbial, biological, physical, and chemical processes in lagoons, ponds, and wetlands to treat wastewater (Constructed Wetlands, 2000). As there is no need to construct major facilities for natural systems, they are generally cost-effective. The operation and maintenance (O&M) costs are also relatively low. Such systems can provide adequate treatment of organic pollutants (5-day BOD [BOD_5] and total suspended solids [TSS]), nitrogen, and phosphorus. The performance is relatively consistent because of the large area, which acts as a natural filter, and the long retention time. Treatment efficiency of these systems is seasonal, highest in summer or in warm climates. Treatment efficiency is lower in winter and in cold climates. Additionally, natural systems require relative large areas and may produce nuisance insects. Figure 3.10 is a sample picture of a constructed wetland.

Figure 3.10. Constructed wetland system for Arcata, CA.

3.6. ALTERNATIVE TREATMENT SYSTEMS

As the costs detailed further in this report illustrate, larger-flow treatment plants realize economies of scale relative to construction costs. Stated another way, the costs to construct small-scale treatment plants can be prohibitive, limiting the ability to efficiently tap into wastewater supplies for decentralized reuse. This section examines several alternative treatment technologies that may provide lower-cost or lower-maintenance treatment that may be cost-effectively employed.

One such system, the Living Machine® (LM), was evaluated. The LM was developed by Dr. John Todd. It mimics the cleaning functions of wetlands and uses a series of tanks to support vegetation and organisms for wastewater treatment (Wastewater, 2002). The flow diagram of an LM is shown in Figure 3.15 (Wastewater, 2002).

There are advantages to LMs. They can be chemical-, odor-, and noise-free. They can effectively remove BOD, TSS, and total nitrogen (TN) while keeping a small ecological footprint and have reduced maintenance costs. Also, LM systems are aesthetically pleasing and have been incorporated into environmentally friendly locations, such as the Audubon Society's Corkscrew Swamp Nature Reserve in South Florida. However, LM systems are highly tailored to each specific site and thus result in relatively high costs for installation compared to other treatment systems.

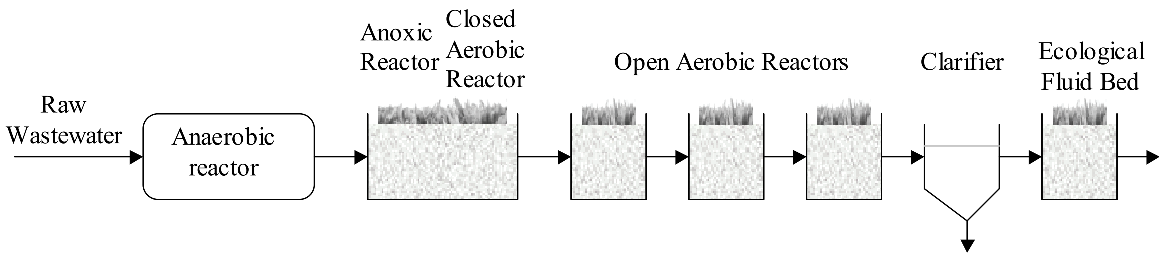

Figure 3.11. Flow chart of a sample LM.

As part of this project, the team reviewed two nonbiological treatment systems, the point-of-need water recycling system (PONWRS) and the Integrated Membrane System (IMANS®). These two systems are relatively unproven. However, they both focus on the same innovative basic premise, leaving the nutrients in and taking the pathogens out. More details for these systems are included in Appendix H.

CHAPTER 4

COST ANALYSIS

This section summarizes the data-gathering and -processing methods for this project. The cost and operation data from over 234 small-scale wastewater treatment and water reuse facilities have been gathered and synthesized.

4.1. DATA GATHERING AND PROCESSING

4.1.1. Data Sources

This project includes four different searches for cost and performance data on wastewater treatment and water reuse treatment technologies. The first search worked directly with equipment manufacturers and targeted various general treatment types. Utilities that own the various types of technologies were then contacted for cost information. A utility survey (Appendix I) was developed and sent out to utilities for information collection. The second search approach used information from USDA Rural Development state office dockets for loans and grants on wastewater projects. This information was requested through the Freedom of Information Act. The third search used a cost database developed by Camp Dresser & McKee Inc. The fourth search used water reuse cost information from Carollo projects.

The treatment trains evaluated for this project include a range of conventional, advanced, and alternative technologies. A total of 234 plants and systems have been surveyed. The locations of these plants and systems in the United States are shown in Figure 4.1. Information collected outside the United States was not used for the data analysis in this report.

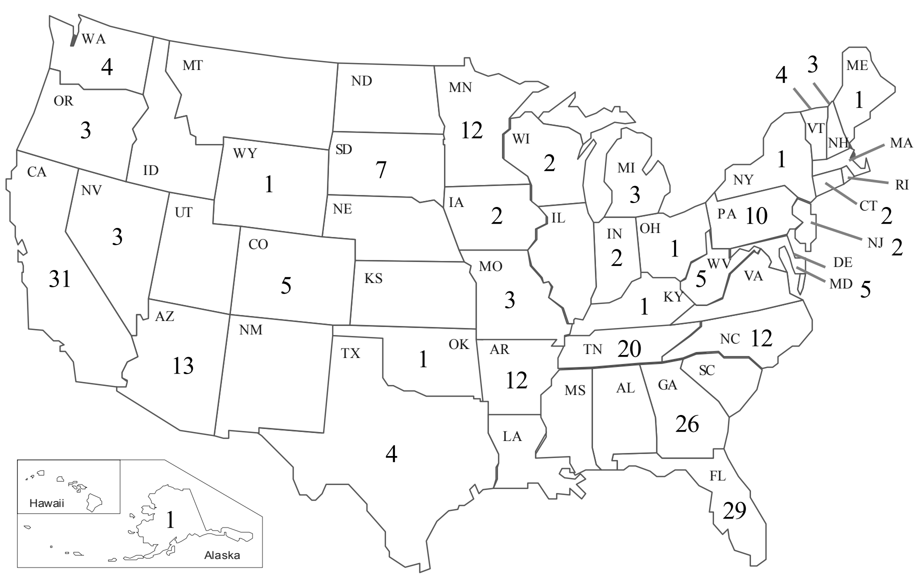

Figure 4.1. Locations of surveyed plants and systems in the U.S.

These plants and systems are divided into five categories:

A) conventional customized plants (83 plants),

B) conventional package plants (63 plants),

C) membrane customized plants (24 plants),

D) natural systems (58 plants), and

E) alternative treatment systems (6 plants).

The capacities (flow) of the 234 plants are shown in Figure 4.2. Eighteen percent of the plants were less than 0.1 mgd, 53% between 0.1 and 1 mgd, 11% between 1 and 2 mgd, 9% between 2 and 3 mgd, 6% between 3 and 4 mgd, and 3% between 4 and 5 mgd. The goal of this project was to compile data in the flow range of 0.1 to 1.0 mgd. However, the plants with flows below 5 mgd were included for the value of reference. Plants with flows above 5 mgd were excluded from the following analysis.

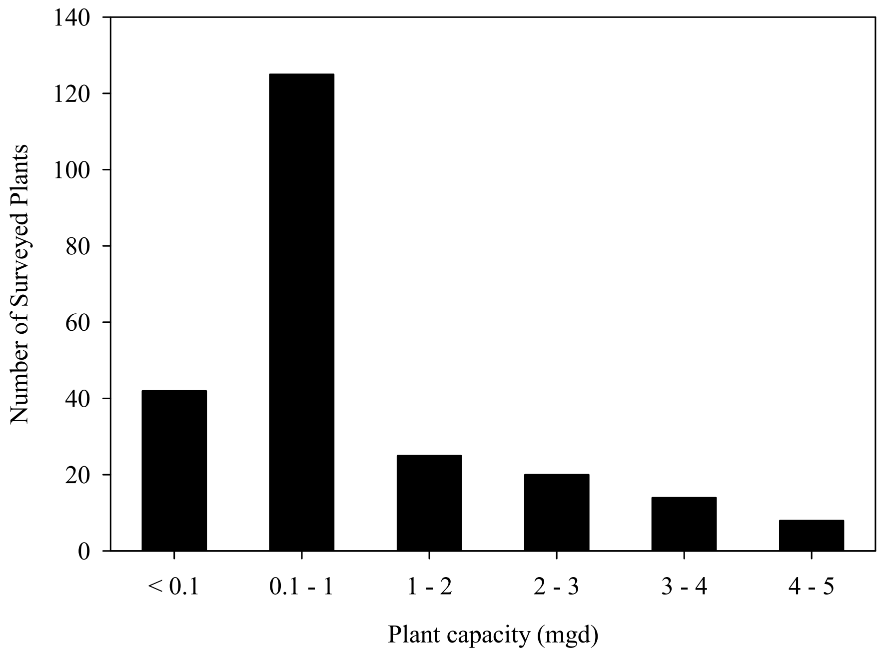

Figure 4.2. Capacities of surveyed plants.

Not all construction costs and O&M costs could be collected in every plant evaluated in this study. Only construction costs were gathered on 93 plants, only O&M costs were collected on 17 plants, and both construction and O&M costs were collected on 124 plants, as shown in Figure 4.3. Plants with only equipment costs are excluded from the analysis in this report.

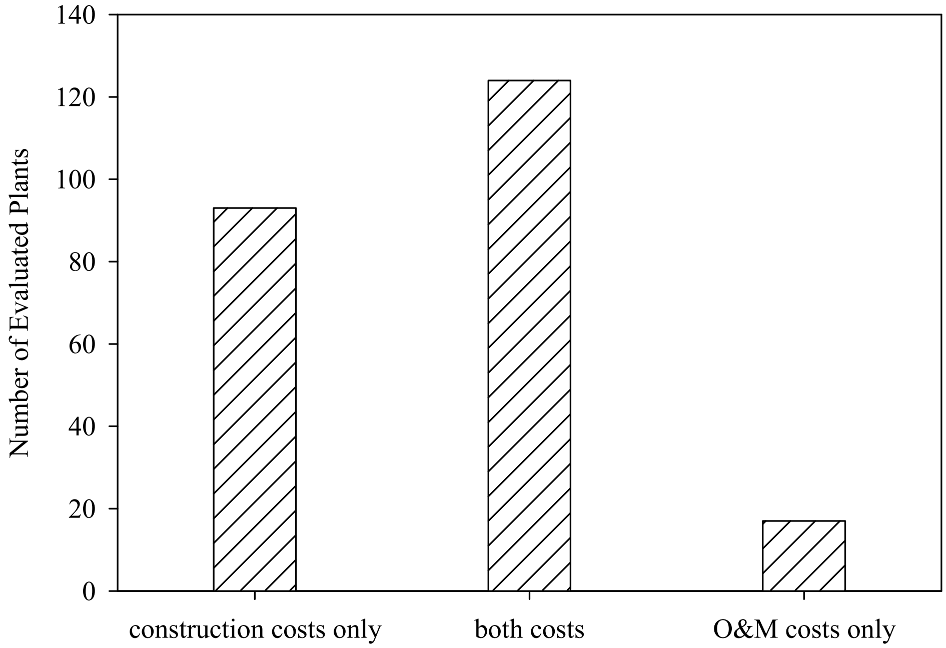

Figure 4.3. Data type of surveyed plants.

The distribution construction dates of evaluated plants are shown in Figure 4.4. Fifty-two percent of the evaluated plants were built or bid after 2000, 28% from 1990 to 1999, 18% from 1980 to 1989, and 2% between 1970 and 1979.

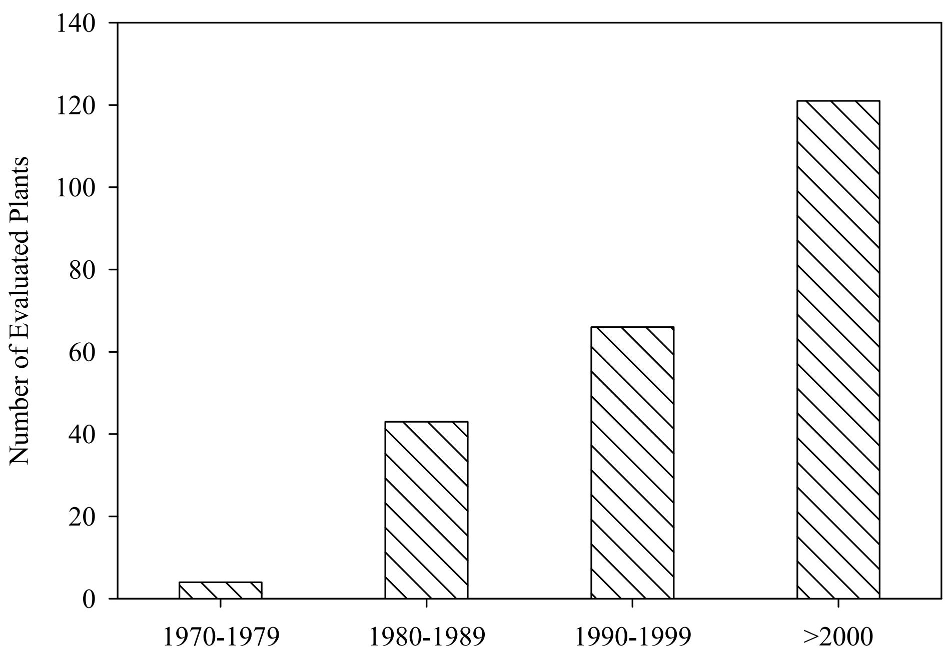

Figure 4.4. Construction dates of surveyed plants.

4.1.2. Cost Factors

There are a number of technology and process decisions that impact cost and add variability to the cost data set, discussed here as “hard” and “soft” costs. Hard costs include the expected equipment and construction costs (engineering and permitting costs are not included in this analysis). These hard costs can be impacted by the current competition for labor and services (available skilled labor, material supplies, and the abundance or absence of projects), which impacts the low bid for these projects. The hard cost will be impacted by the type of use of the reclaimed water and the regulations associated with that use. For example, regulations for certain types of reclaimed water use require higher levels of filtration or disinfection then would be required for other reclaimed water uses. This phenomenon also can be seen with nutrient removal (or lack thereof), which can impact the bottom-line hard cost. If a utility decides to reclaim water as an alternative to discharge to a nutrient-limited waterway, there are avoided costs for not having to reduce nutrients in the treatment train. If a utility decides to provide highly treated, low-nutrient water to supplement a water body (beneficial reuse), then there is an added cost for the nutrient removal. Other items that impact the hard costs include the inclusion of treatment process redundancy and various reliability requirements, as are required particularly in California and Washington for “tertiary recycled water.”

Other issues that may introduce scatter in the cost data are referred to here as “soft” cost components. These soft components include implementation problems such as permitting, lawsuits, funding, user contracts, public perception, and antigrowth efforts that may slow down or halt a project, substantially increasing the project cost. For large projects, these costs may have only a minimal impact on the net budget. For the relatively small projects examined in this project, these added soft costs could extend the total cost well past reasonable levels.

Additional “value” available from reclamation as “soft” costs include reduced potable water infrastructure for new construction, reduced potable water supply management based on smaller distribution and storage requirements for potable water, reduced source capacity requirements to be explored in addition to avoiding investment in water rights purchase, and costs of buying into total-maximum-daily-load trade markets necessary for a new National Pollutant Discharge Elimination System (NPDES) permit. However, the collection or estimation of these costs is beyond the project scope and is not covered in this analysis.

It is important to note the level of engineering accuracy in construction costs that was applied to this project. Currently the American Association of Cost Engineers provides five classes of cost estimation accuracy, as shown in Table 4.1.

Table 4.1. Levels of Engineering Accuracy for Cost Estimation

Class	Expected Accuracy Range for Cost Estimation	
	Low End	High End
5	-20% to -50%	+30% to +100%
4	-15% to -30%	+20% to +50%
3	-10% to 20%	+10% to +30%
2	-5% to -15%	+5% to +20%
1	-3% to -10%	+3% to +15%

While the costs used in this report are real costs encountered by the various utilities, we recommend treating these costs as Class 5 estimates. Further, some of the treatment facilities surveyed as part of this project did not have filtration or disinfection. As part of this project, our team provided construction cost estimations of UV disinfection and filtration. Typically, cost estimation in Class 5 is used for strategic business planning purposes, such as but not limited to market studies, assessment of initial viability, evaluation of alternate schemes, project screening, project location studies, evaluation of resource needs and budgeting, long-range capital planning, etc. The expectations for the accuracy of the costs found within this report must match the reality of the challenge of providing those estimates based on data from a diverse collection of facilities with various conditions that impact the cost.

4.1.3. Filtration and Disinfection

For all of the treatment trains, the required level of disinfection is dependent upon the reclaimed water use. For some uses, filtration is not required and only minimal disinfection is needed. For other uses, filtration to a high water quality and high-level disinfection is required.

For each treatment plant reviewed under this project, the existence of filtration and disinfection was determined. If there was no noted filtration or disinfection, or if there was no filtration and only minimal disinfection, costs for filtration (using continuous backwash sand filtration) and high-level disinfection (using UV disinfection at 65% UV transmittance) were added to better normalize the cost database. The design of these additional treatment processes is conservatively based upon meeting the turbidity and disinfection criteria required for “tertiary recycled water” under Title 22 of the California Code of Regulations. Again, there are occasions where filtration is not required and disinfection to “tertiary recycled water” standards is not required, and thus treatment costs could be reduced in many circumstances. The full-cost data set in Appendix J includes the added cost columns for filtration and disinfection, if utilized. The user of this report could modify the costs to subtract out filtration and/or high-level disinfection if needed.

The continuous backwash filter was used as the basis for the cost estimation of filtration technologies if the surveyed treatment plant did not include filtration. Parkson's DynaSand® Filter is a continuous backwash, upflow, deep bed, granular medium filter commonly used for reuse applications. The internal washing system cleans filter media and requires no backwash pumps or storage tanks.

If a surveyed utility did not include disinfection, the Trojan UV3000 UV disinfection system costs were included. This low-pressure UV disinfection system is shown in Figure 4.5.

Figure 4.5. Open-channel UV disinfection system by Trojan Technologies.

4.1.4. Normalization of Data

Three types of cost data are calculated or estimated: construction costs, O&M costs, and present value costs. Both construction costs and O&M costs are normalized to December 2008. Present value costs are also based on December 2008.

Construction costs are the costs associated with constructions of the treatment systems. They do not include costs for engineering, permitting, legal services, and general contingency. Land costs and collection system costs, if known, were subtracted from the gathered costs. Construction costs of filtration and disinfection systems are included if no filtration or disinfection systems existed in each treatment plant.

To compare the construction costs of facilities built at different dates and different locations, original costs were normalized to a national average level with the Engineering New Record (ENR) 20-city construction cost indexes (CCIs) and R.S. Means location factors, as shown in Equation 1.

$$\text{Total construction cost}_{\text{normalized}} = \text{Original construction cost} * \frac{\text{CCI}_{\text{current date}}}{\text{CCI}_{\text{built date}}} * \frac{1}{\text{location factor}_{\text{R.S. Means}}}$$

Equation 1

Unit construction costs ($million/mgd) are calculated as the total construction costs normalized by the treatment flow capacities of their corresponding systems, as shown in Equation 2.

$$\text{Unit construction cost} = \frac{\text{Total construction Costs}_{\text{normalized}}}{\text{Capacity}}$$ Equation 2

O&M costs are the costs associated with O&M. O&M costs at different dates and different locations were normalized to national average levels as well. These costs were broken down into energy, materials, and labor, as shown in Equation 3. The energy costs were normalized with average retail prices of electricity published by the Energy Information Administration at the U.S. Department of Energy, as shown in Equation 4. Material and manpower costs were normalized to ENR material price indexes (Equation 5) and ENR skilled labor indexes (Equation 6). Both ENR material price indexes and skilled labor indexes can be accessed through ENR's website: http://enr.construction.com/. Each category of O&M costs was then also normalized to R.S. Means location factors.

$$\text{Annual O \& M cost}_{\text{nomalized}} = \text{Annual energy cost}_{\text{nomalized}} + \text{Annual material cost}_{\text{normalized}} + \text{Annual labor cost}_{\text{nomalized}}$$ Equation 3

$$\text{Annual energy cost}_{\text{normalized}} = \text{original energy cost} * \frac{\text{retail price of electricity}_{\text{current date}}}{\text{retail price of electricity}_{\text{built date}}} * \frac{1}{\text{location factor}_{\text{R.S. Means}}}$$

Equation 4

$$\text{Annual material cost}_{\text{normalized}} = \text{original material cost} * \frac{\text{ENR material price index}_{\text{current date}}}{\text{ENR material price index}_{\text{built date}}} * \frac{1}{\text{location factor}_{\text{R.S. Means}}}$$

Equation 5

$$\text{Annual labor cost}_{\text{normalized}} = \text{original labor cost} * \frac{\text{ENR skilled labor index}_{\text{current date}}}{\text{ENR skilled labor index}_{\text{built date}}} * \frac{1}{\text{location factor}_{\text{R.S. Means}}}$$

Equation 6

Unit O&M costs ($/1000 gal) are calculated as the annual O&M costs normalized by the treatment flow capacities of their corresponding systems and then normalized to 1000 gal, as shown in Equation 7.

$$\text{Unit O \& M cost} = \frac{\text{Annual O \& M cost}}{\text{Capacity (mgd)} * \text{(365 days/1000 gallons)}}$$ Equation 7

Present value costs are the costs in currently valued dollars to be expended over a period of time less the net of any funds to be repaid. In the context of cost analysis of wastewater treatment facilities, present value costs are the total cost of owning and operating a wastewater treatment facility for the life of the system in current dollars. The construction costs are one-time costs at the base year if no payment plans are considered. O&M costs are a series of annually recurring costs that need to be converted to present value costs. For this analysis, engineering and permitting costs are not included in the present value costs. Equation 8 shows the equation for such conversion.

$$\text{Present Value of O \& M Cost} = \text{Annual O \& M cost}_{\text{normalized}} * \sum_{t=1}^{n} \frac{1}{(1+d)^n} = \text{Annual O \& M cost}_{\text{normalized}} * \frac{(1+d)^n - 1}{d(1+d)^n}$$

Equation 8

In Equation 8, *d* is the discount rate and *n* is the number of years. If we assume the water reuse systems can last for 20 years ($n = 20$) and a discount rate of 5% ($d = 0.05$), the present value cost can be estimated using Equation 9 and unit present value costs can be calculated using Equation 10.

$$\text{Present Value Cost} = \text{Construction Costs} + \text{Annual O \& M cost}_{\text{normalized}} * \frac{(1+d)^n - 1}{d(1+d)^n}$$

Equation 9

$$\text{Unit present value cost} = \frac{\text{Present value cost}_{\text{normalized}}}{\text{Capacity}}$$

Equation 10

4.2. COMPARISONS OF TREATMENT PROCESSES AND PACKAGE SYSTEMS

4.2.1. General Trend of Construction Costs and Capacities

The data plots or cost curves of total construction costs and unit construction costs versus capacities are shown in Figures 4.6 and 4.7. Costs and capacities are plotted on log-log graphs. Regression lines, 95% confidence intervals, and 95% prediction intervals are also shown in these figures. The general trend is that small flow systems have higher unit construction costs, possibly due to economies of scale for construction and/or possibly due to “soft” cost issues.

The scaling effect is further shown in the plot of unit construction costs and capacities without log transformation (Figure 4.8). A regression line is also developed. The figure shows that unit construction costs are much higher at small flows (<1 mgd) and relatively low and consistent at large flows (>1 mgd). To conduct the comparisons of treatment processes and systems with different flows, log-transformation and cost-capacity curves are used for all the following analyses.

Please note that the regression lines are developed only to show the general trend of construction costs and capacities for all evaluated technologies in this report. The best value of these data is the database itself, which can be mined for the most relevant data for a particular project. The authors of this report recommend site-specific analysis for the basis for engineering costing of new water reuse facilities.

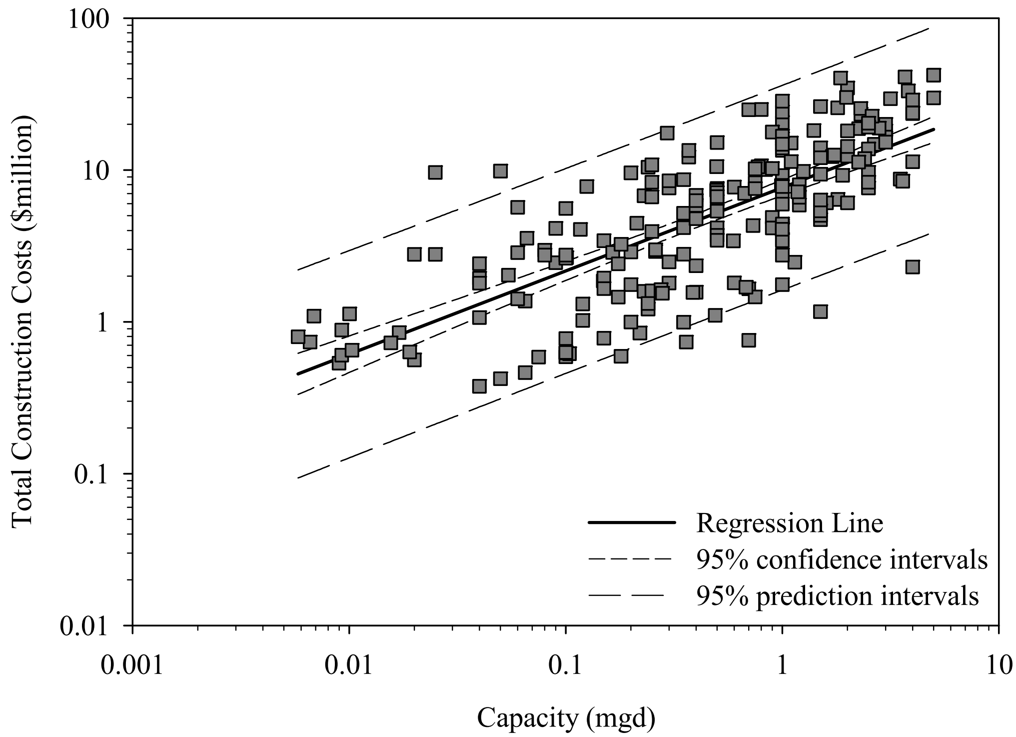

Figure 4.6. Total construction costs.

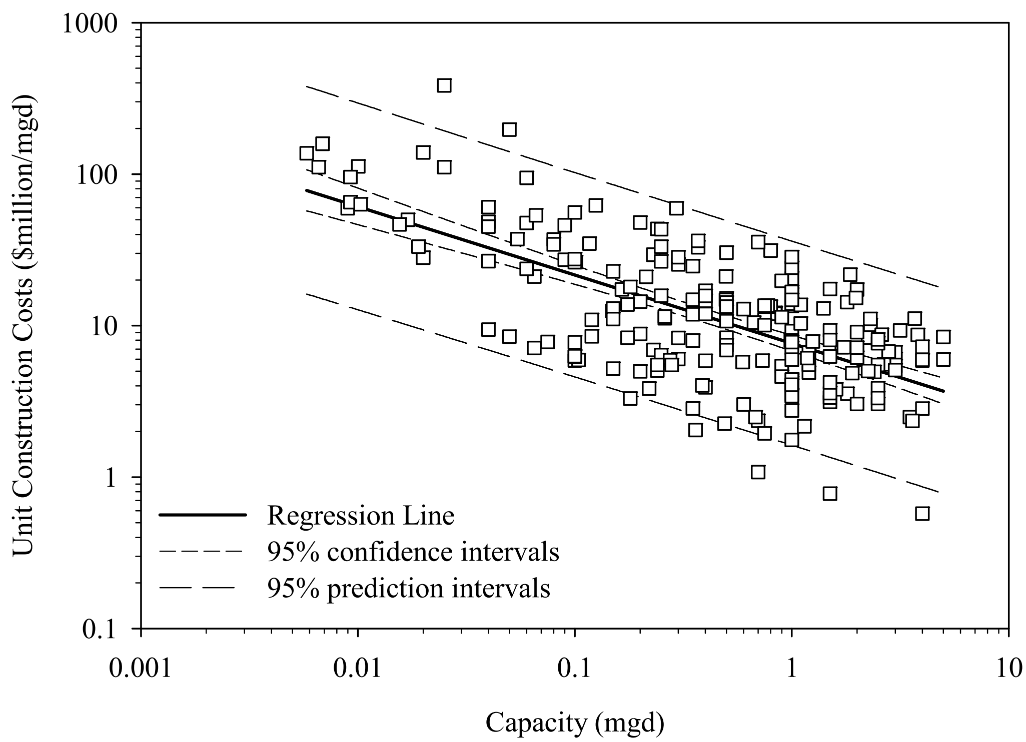

Figure 4.7. Unit construction costs.

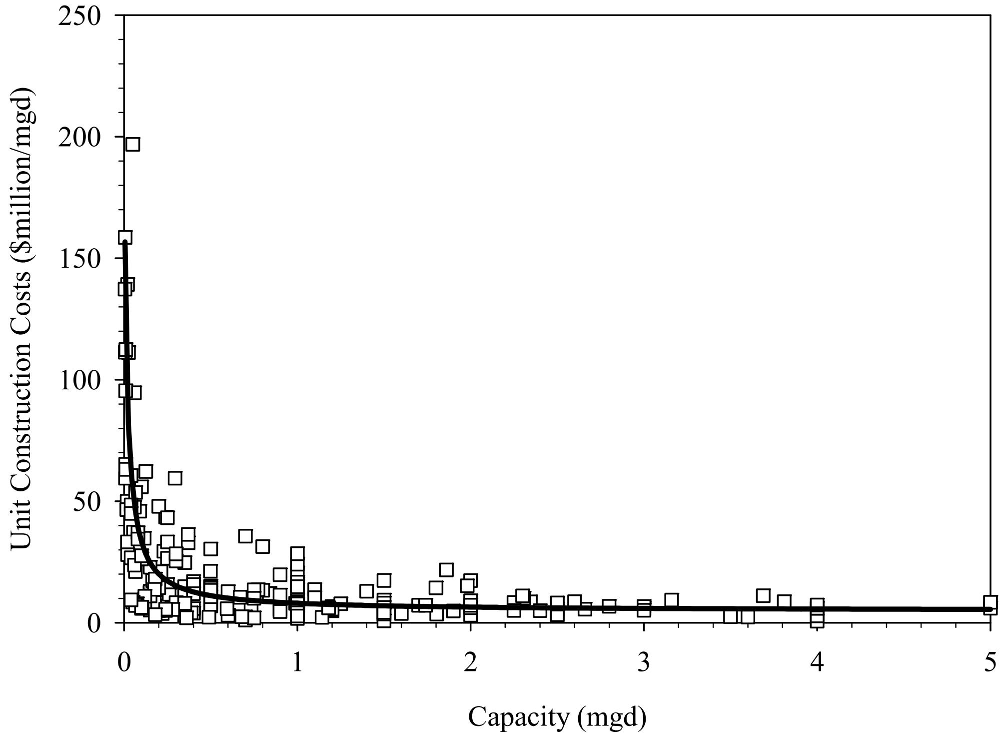

Figure 4.8. Raw data of unit construction costs. Solid line, regression line.

4.2.2. Unit Construction Cost-Capacity Curves of Selected Processes

Unit construction cost-capacity curves were plotted for selected processes.

- Figure 4.9 shows the construction costs of activated sludge plants.
- Figure 4.10 shows the construction costs of extended aeration plants.
- Figure 4.11 shows the construction costs of Bardenpho plants.
- Figure 4.12 shows the construction costs of MLE plants.
- Figure 4.13 shows the construction costs of ICEAS plants.
- Figure 4.14 shows the construction costs of package plants.
- Figure 4.15 shows the construction costs of SBR plants.
- Figure 4.16 shows the construction costs of ODs.
- Figure 4.17 shows the construction costs of MBR plants.
- Figure 4.18 shows the construction costs of ponds.
- Figure 4.19 shows the construction costs of lagoons.
- Figure 4.20 shows the construction costs of wetlands.
- Figure 4.21 shows the construction costs of LMs.

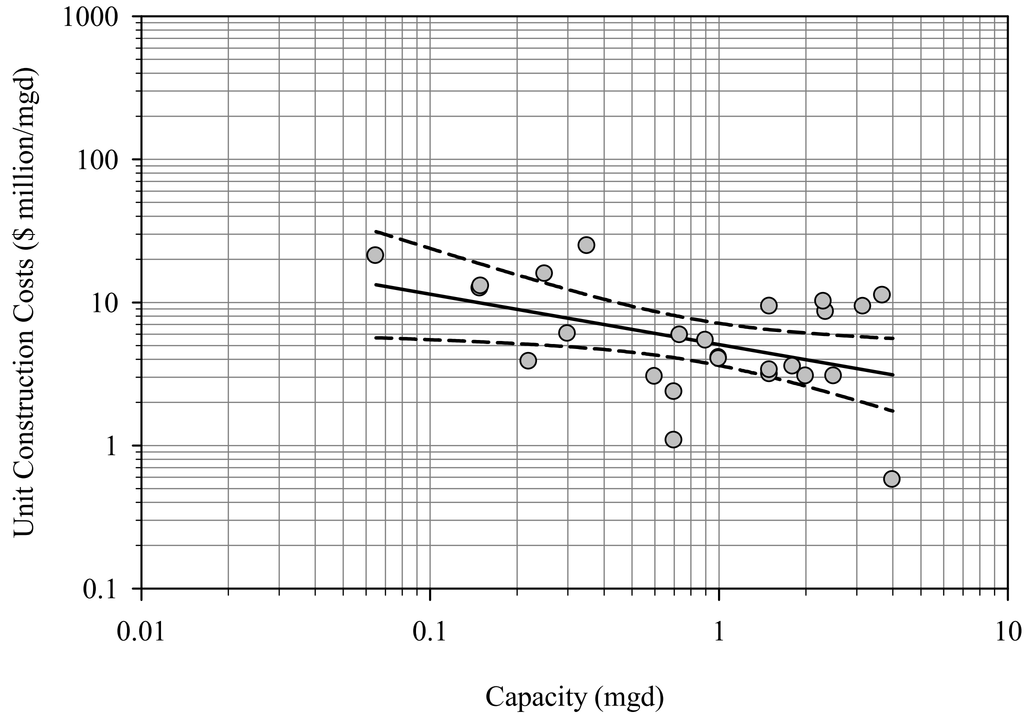

Figure 4.9. Unit construction costs of activated sludge plants.
Solid line. regression line; dash lines, 95% confidence intervals.

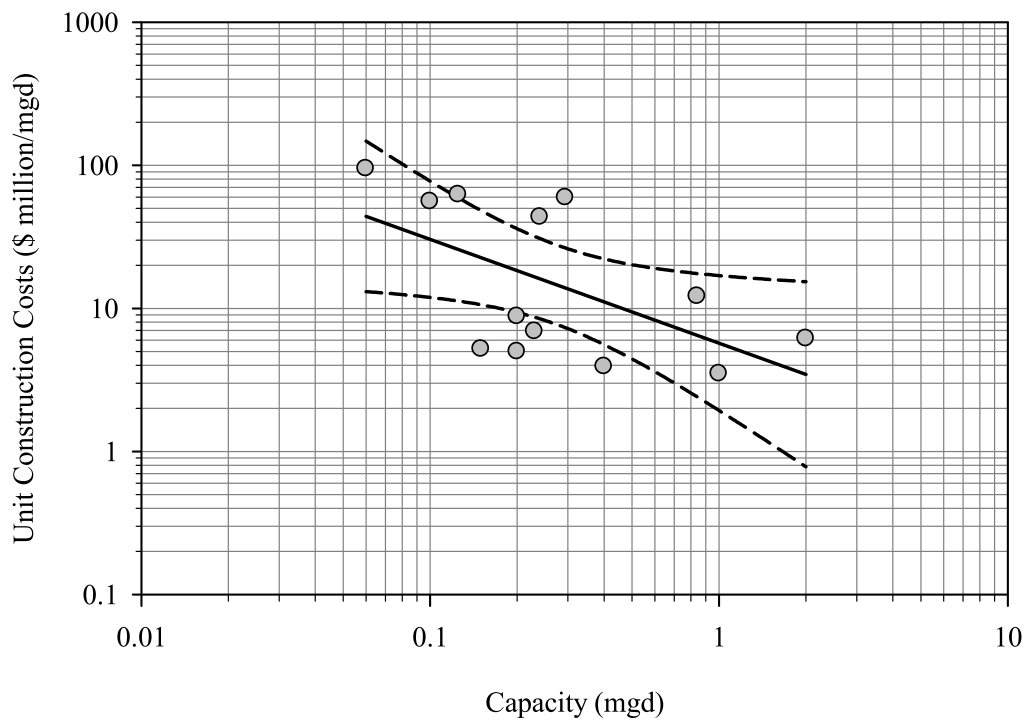

Figure 4.10. Unit construction costs of extended aeration plants.
Solid line, regression line; dash lines, 95% confidence intervals.

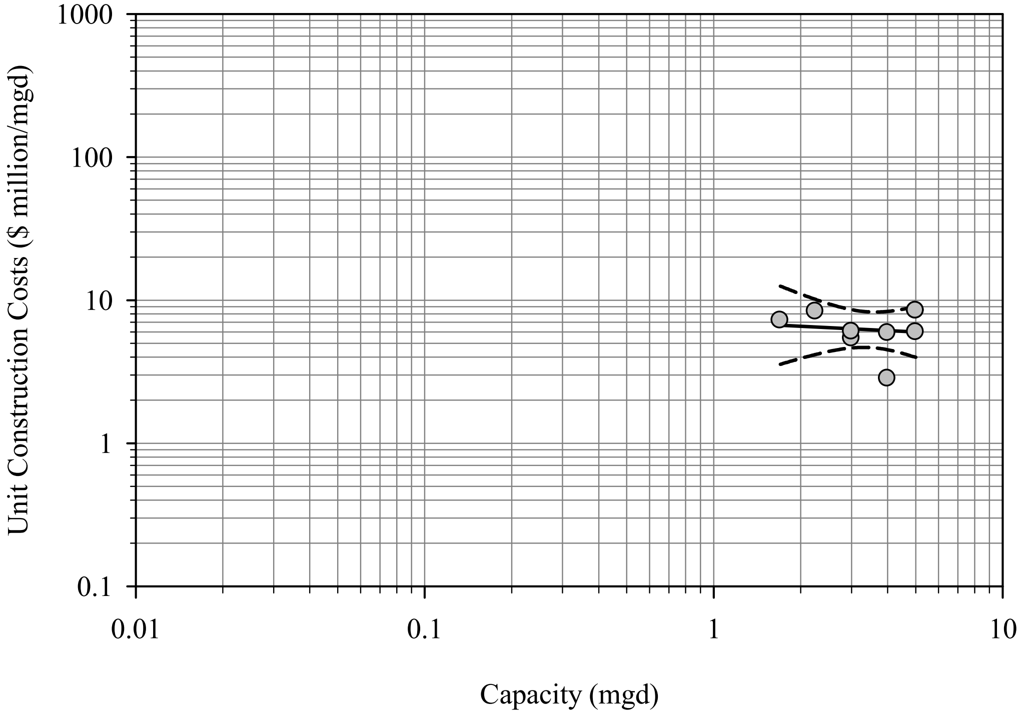

Figure 4.11. Unit construction costs of Bardenpho plants.
Solid line, regression line; dash lines, 95% confidence intervals.

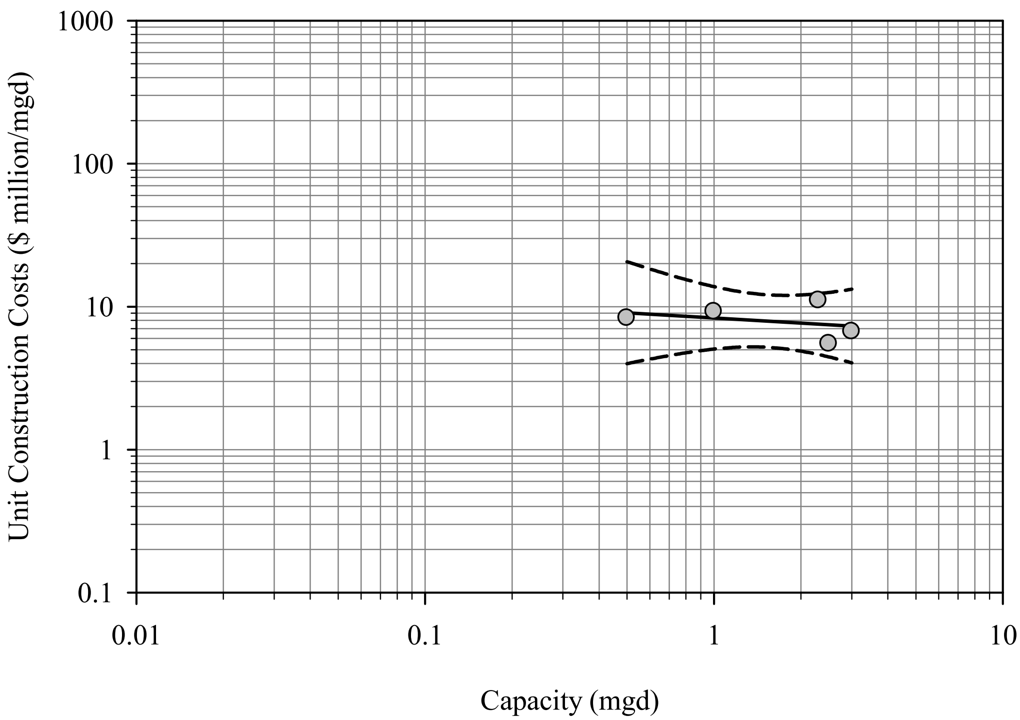

Figure 4.12. Unit construction costs of MLE plants.
Solid line, regression line; dash lines, 95% confidence intervals.

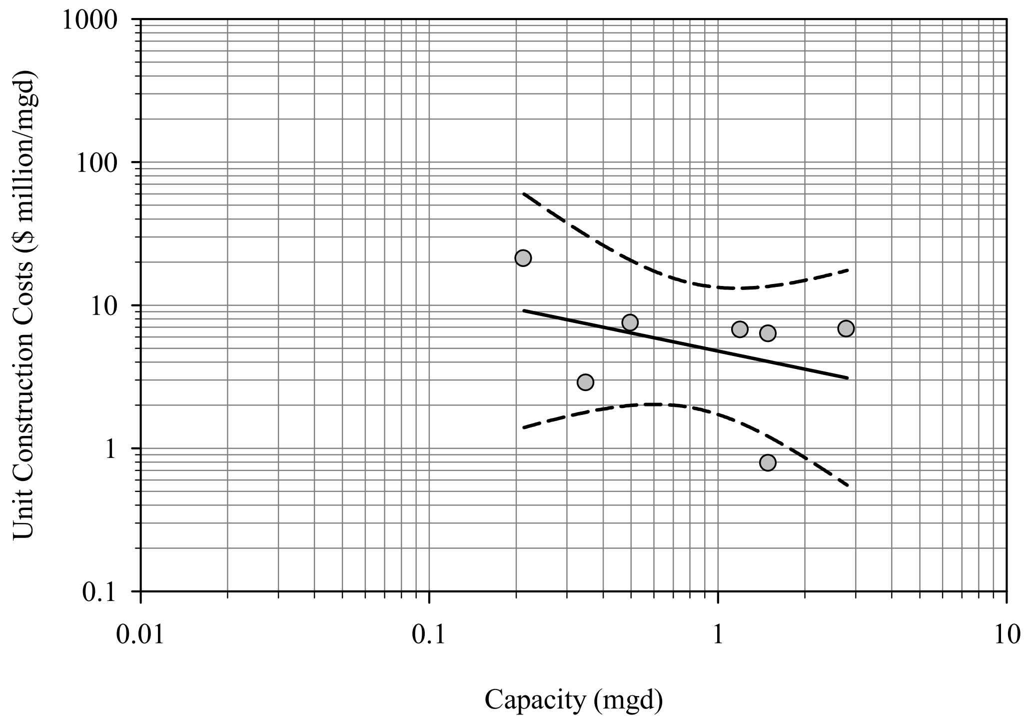

Figure 4.13. Unit construction costs of ICEAS plants.
Solid line, regression line; dash lines, 95% confidence intervals.

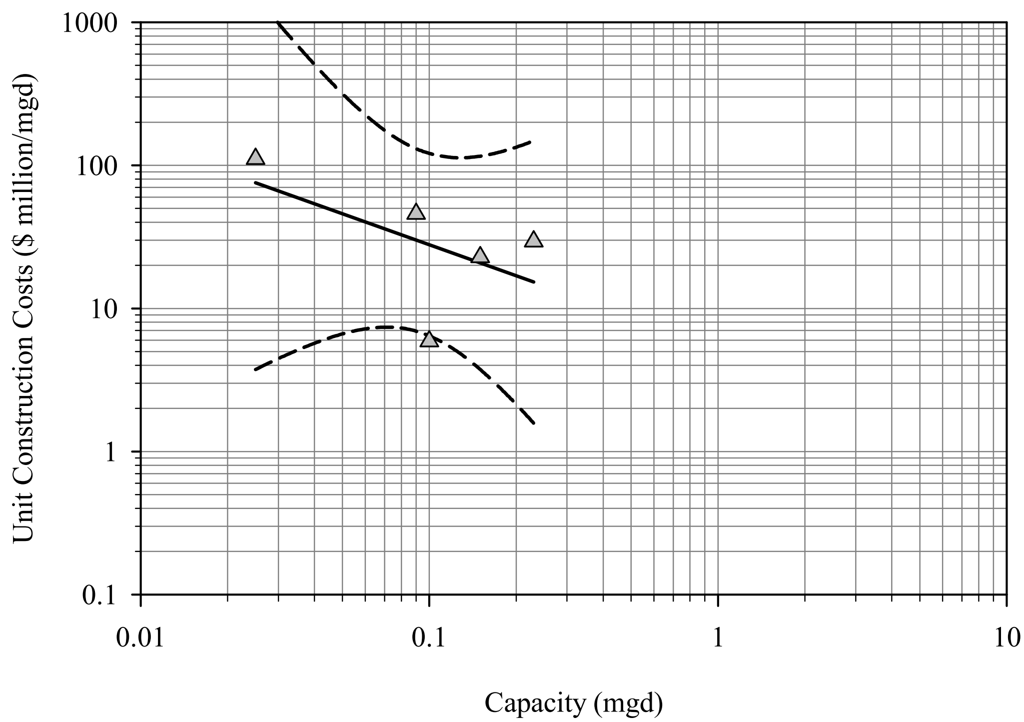

Figure 4.14. Unit construction costs of package plants.
Solid line, regression line; dash lines, 95% confidence intervals.

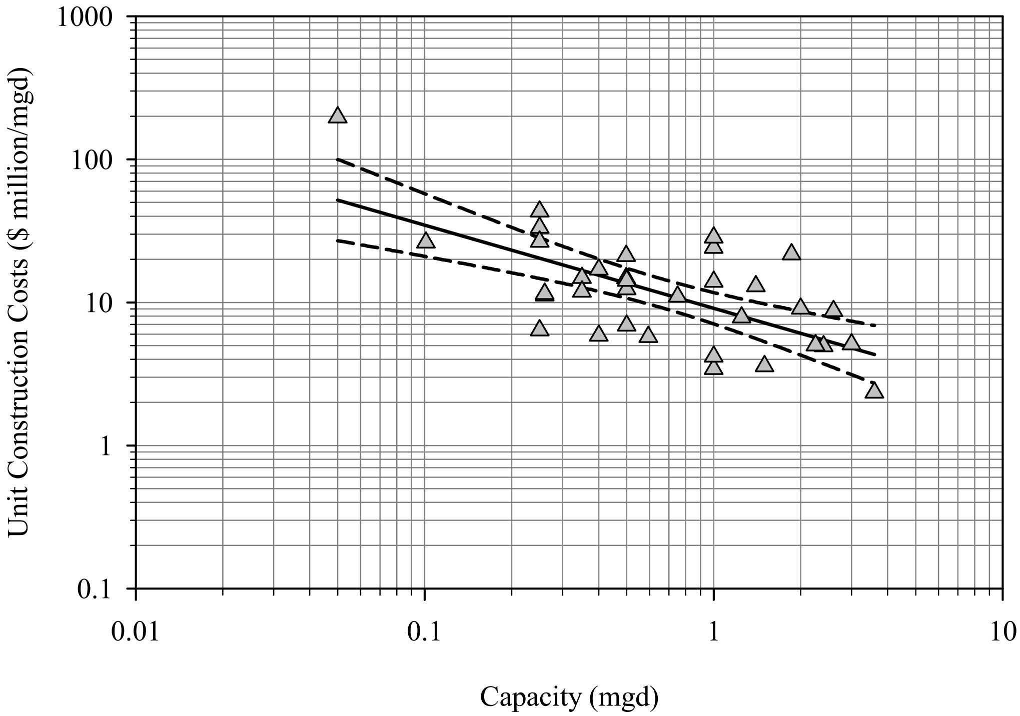

Figure 4.15. Unit construction costs of SBR plants.
Solid line, regression line; dash lines, 95% confidence intervals.

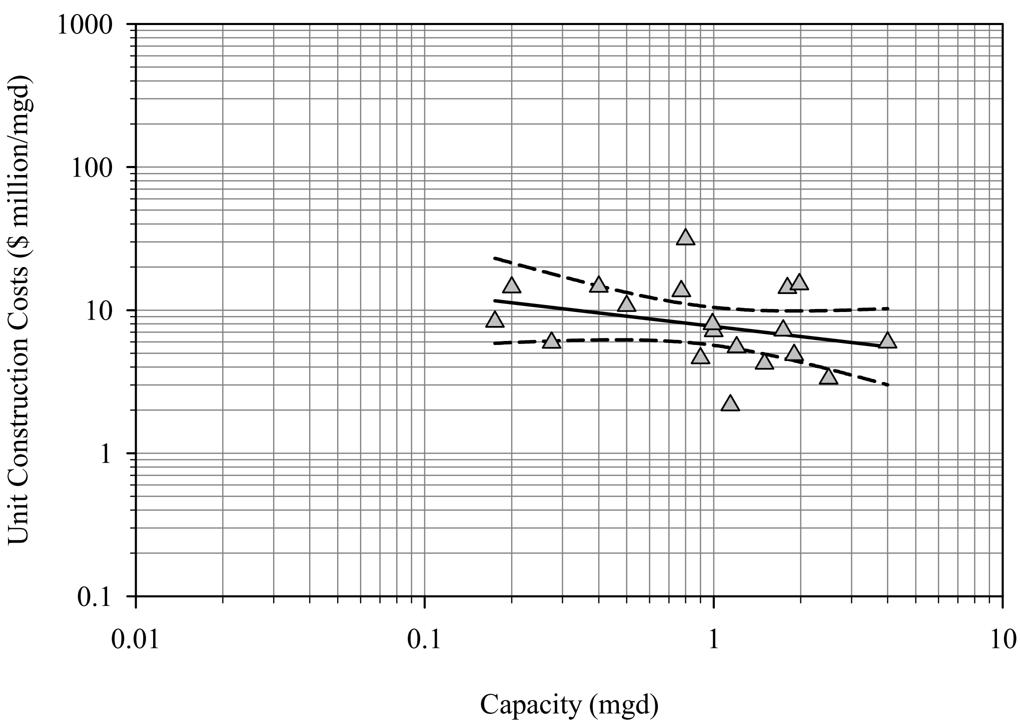

Figure 4.16. Unit construction costs of ODs.
Solid line, regression line: dash lines, 95% confidence intervals.

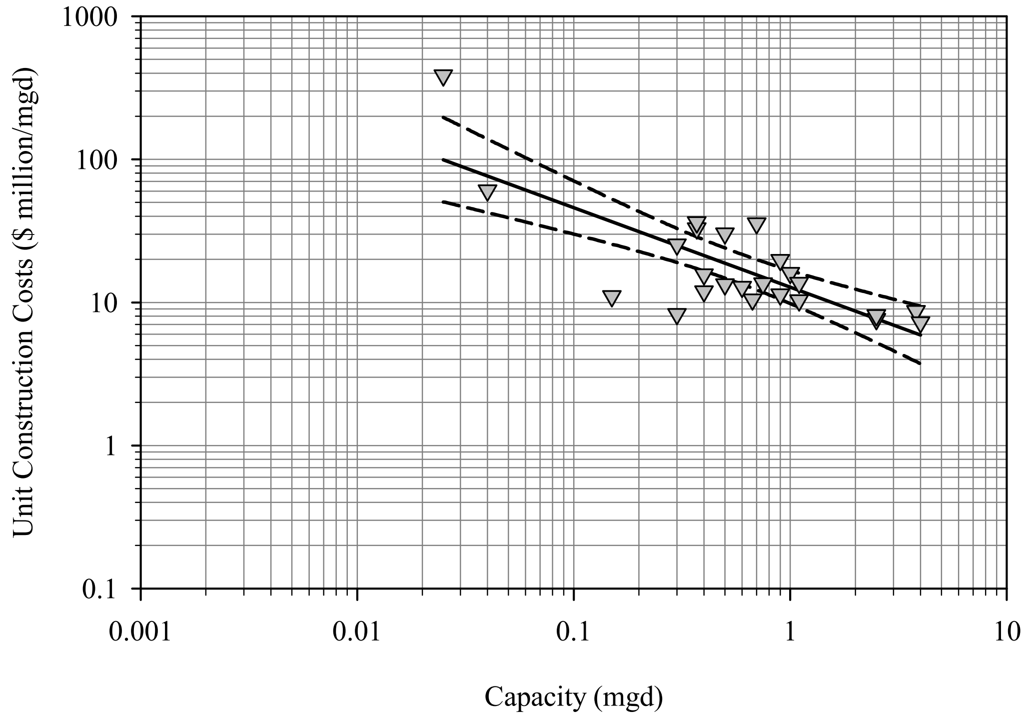

Figure 4.17. Unit construction costs of MBRs.
Solid line, regression line; dash lines, 95% confidence intervals.

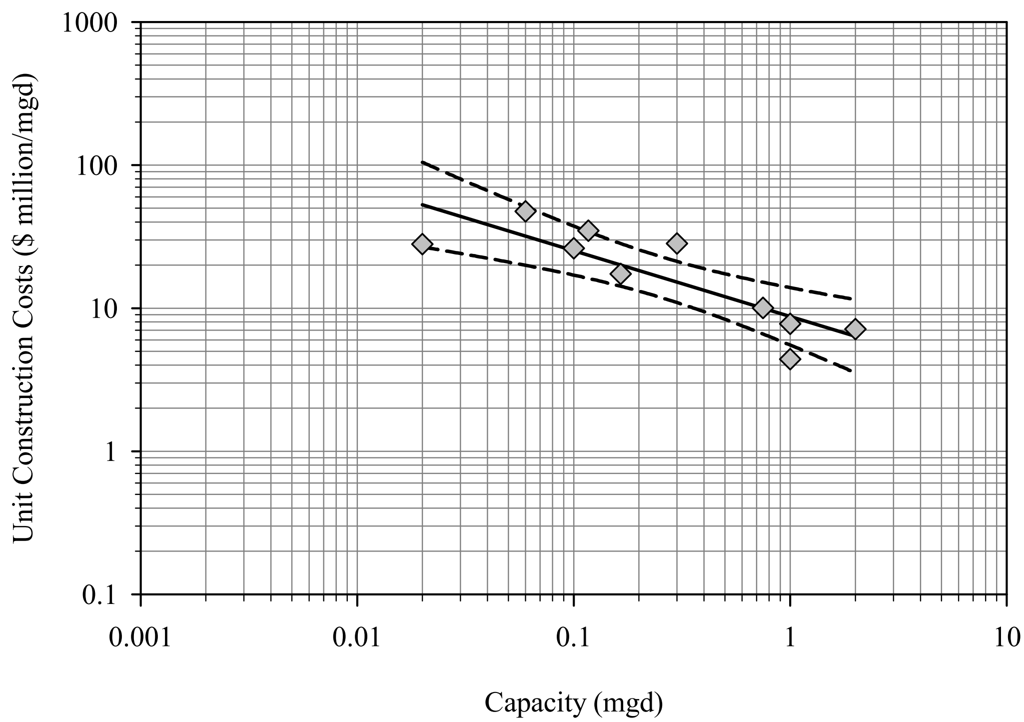

Figure 4.18. Unit construction costs of ponds.
Solid line, regression line; dash lines, 95% confidence intervals.

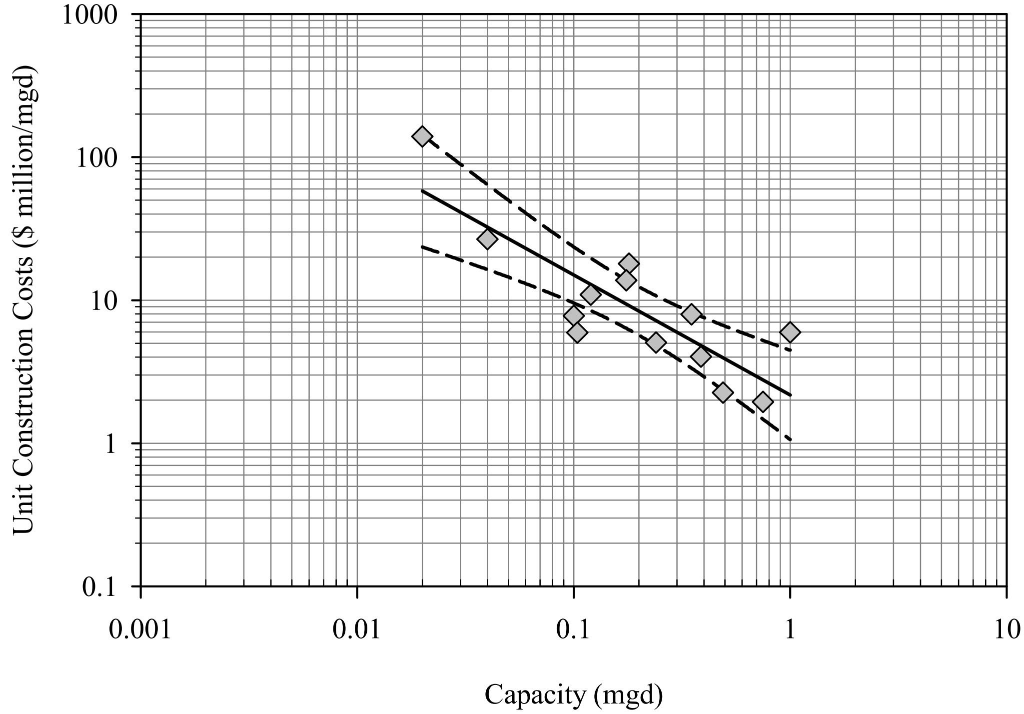

Figure 4.19. Unit construction costs of lagoons.
Solid line, regression line; dash lines, 95% confidence intervals.

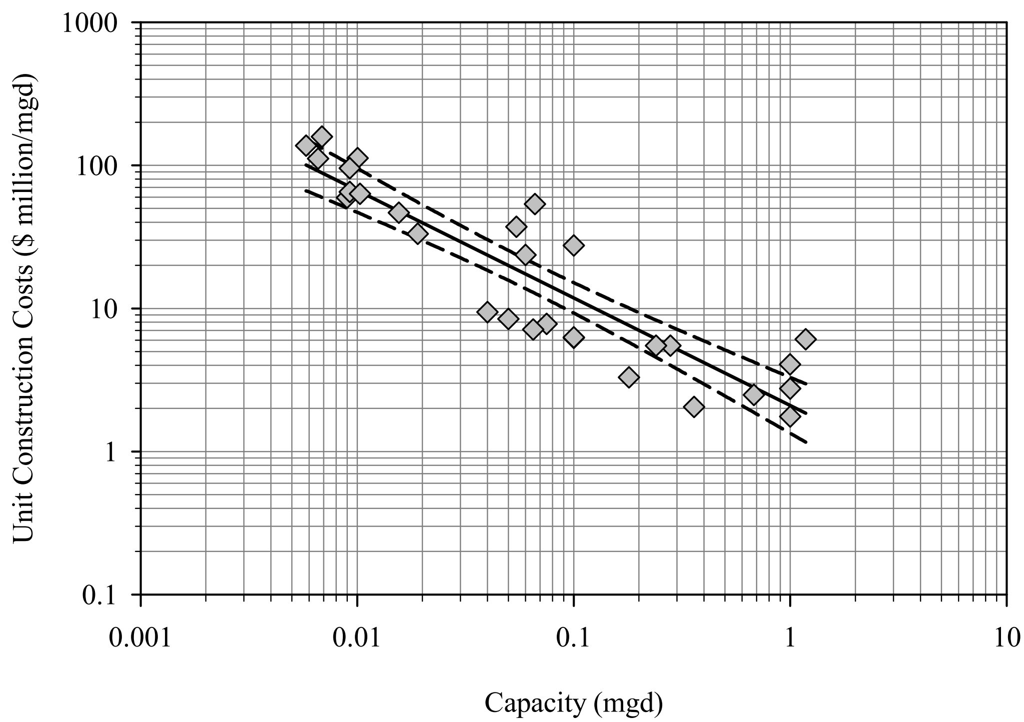

Figure 4.20. Unit construction costs of wetlands.
Solid line, regression line; dash lines, 95% confidence intervals.

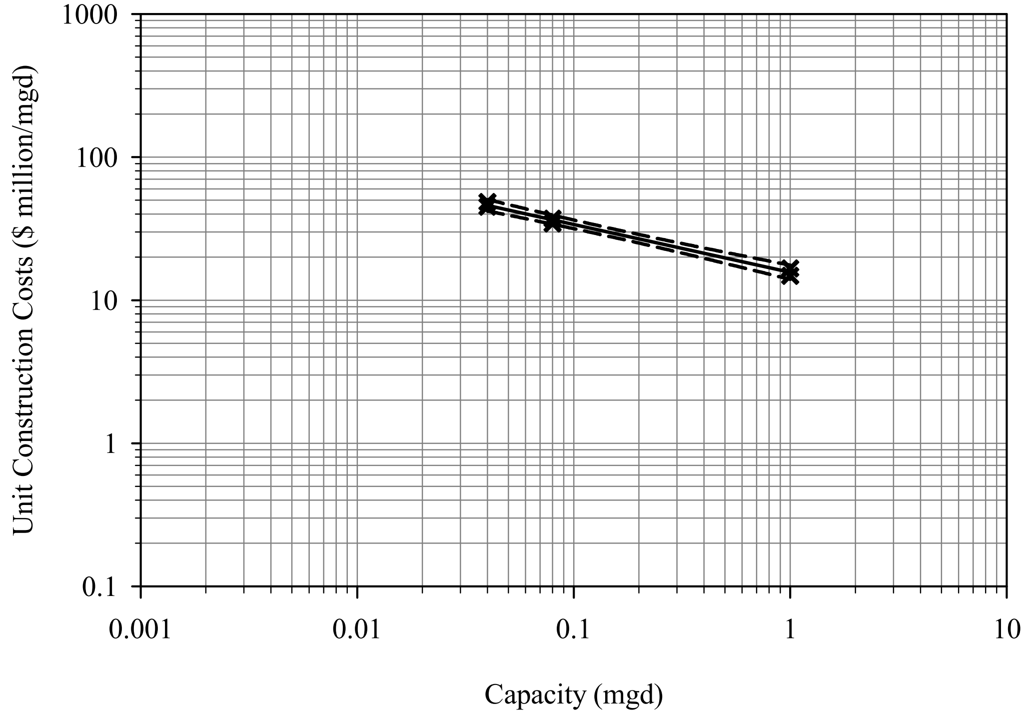

Figure 4.21. Unit construction costs of LMs.
Solid line, regression line; dash lines, 95% confidence intervals.

4.2.3. Comparison of Unit Construction Costs

The cost curves were segregated based upon treatment technology. Unit construction costs were compared for each category.

- Figure 4.22 indicates that conventional customized plants and conventional package plants have similar unit construction costs.
- Figure 4.23 shows that membrane customized plants are more expensive than conventional customized plants.
- Figure 4.24 indicates that natural systems are less expensive than are conventional customized plants.
- Figure 4.25 shows that alternative treatment systems (in this case the LM natural system) are more expensive than conventional customized plants.
- Figure 4.26 indicates that membrane customized plants and alternative treatment systems (in this case, the LM natural system) have similar unit construction costs.

In summary, the unit construction costs of natural systems were the least expensive, followed by similar costs for conventional package plants and conventional customized plants, while alternative treatment systems and membrane customized plants were the most expensive.

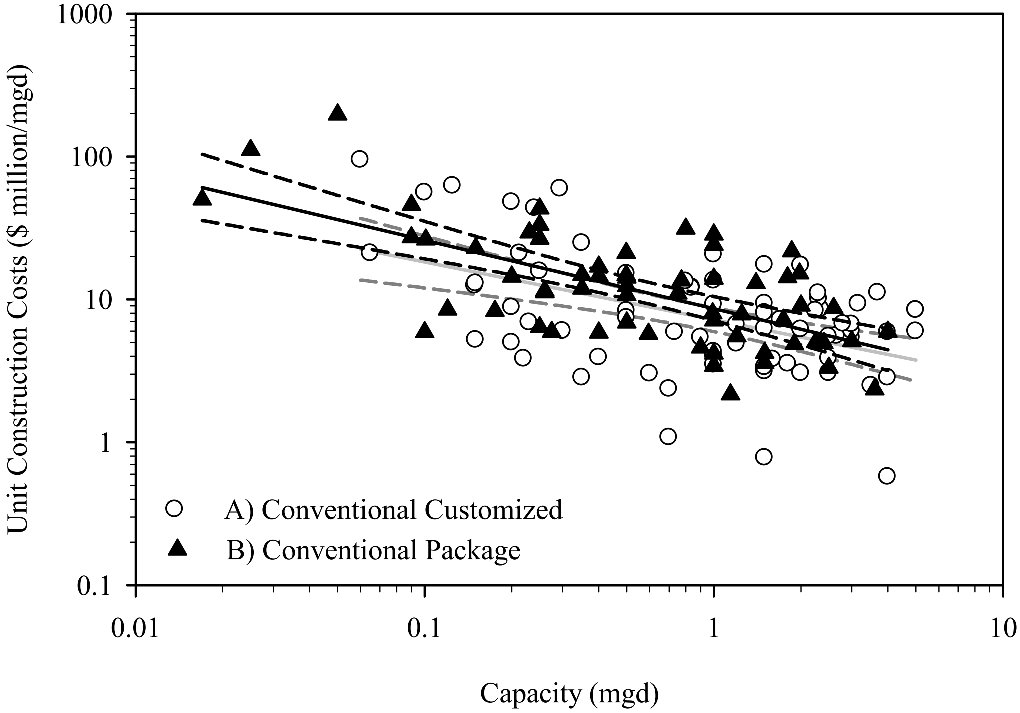

Figure 4.22. Comparison of unit construction costs of conventional customized plants and conventional package plants.
Solid lines, regression lines; dash lines, 95% confidence intervals.

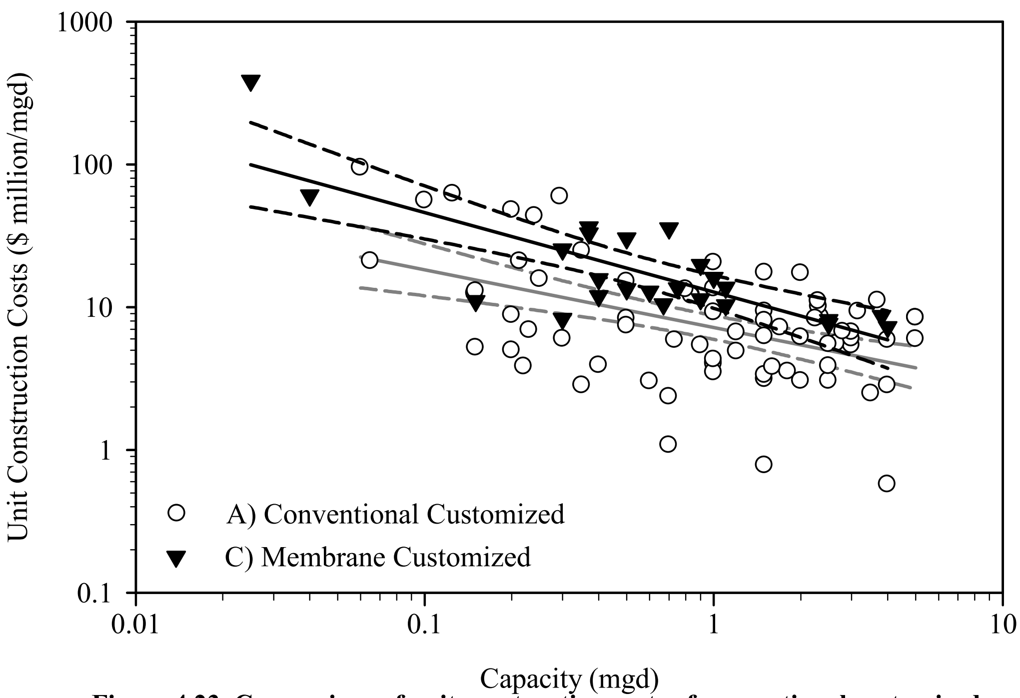

Figure 4.23. Comparison of unit construction costs of conventional customized plants and membrane customized plants.
Solid lines, regression lines; dash lines, 95% confidence intervals.

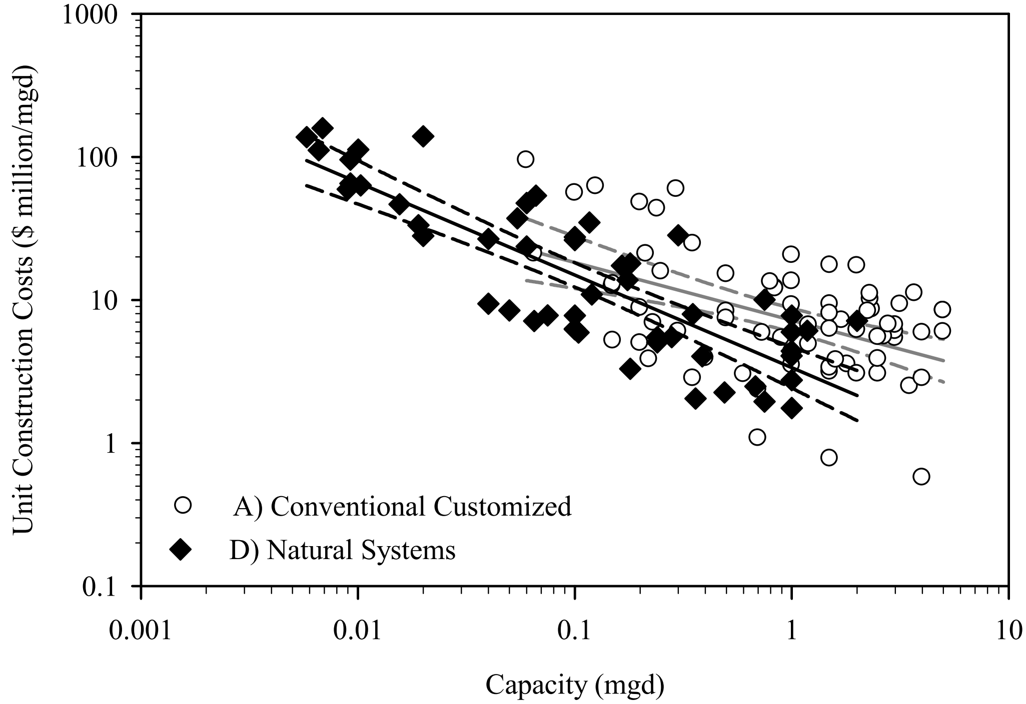

Figure 4.24. Comparison of unit construction costs of conventional customized plants and natural systems.
Solid lines, regression lines; dash lines, 95% confidence intervals.

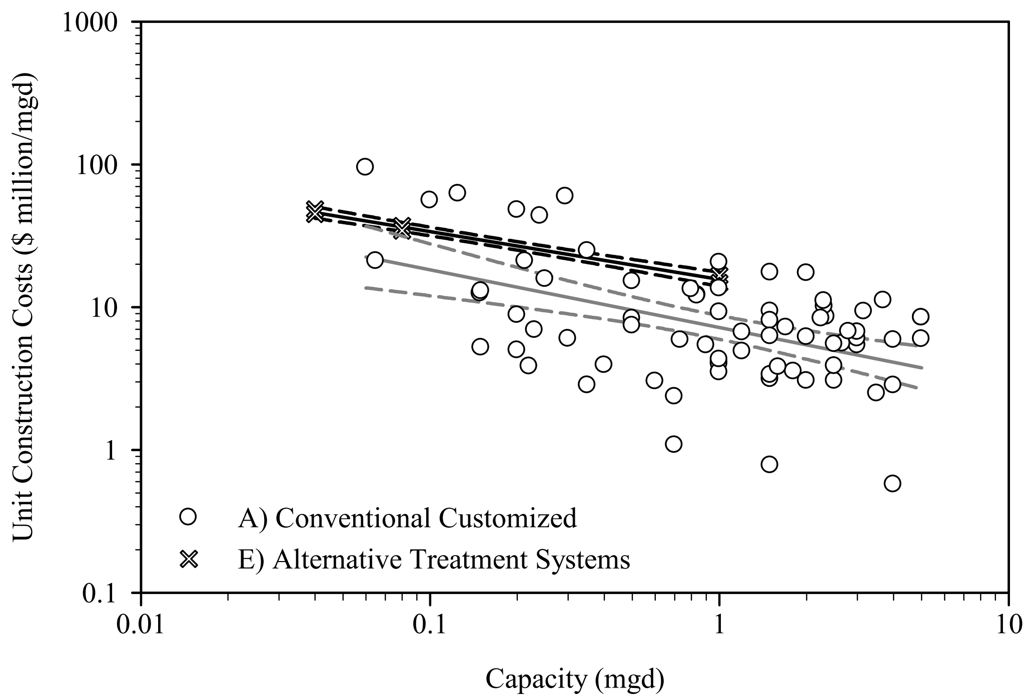

Figure 4.25. Comparison of unit construction costs of conventional customized plants and alternative treatment systems.
Solid lines, regression lines; dash lines, 95% confidence intervals.

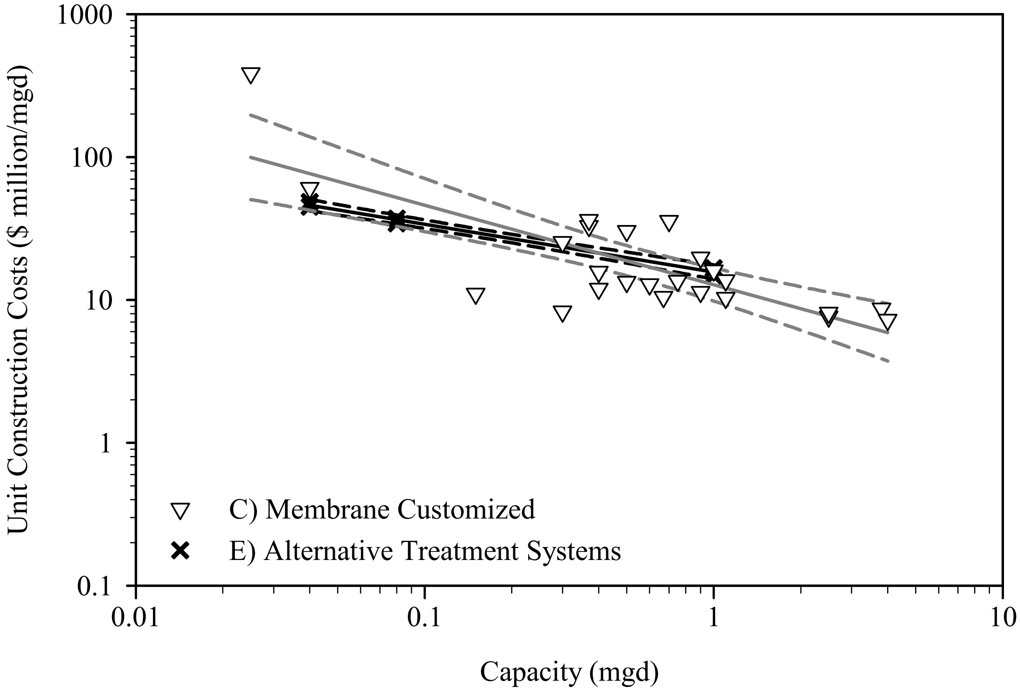

Figure 4.26. Comparison of unit construction costs of membrane customized plants and alternative treatment systems.
Solid lines, regression lines; dash lines, 95% confidence intervals.

4.2.4. General Trend of O&M Costs and Capacities

The data plots or cost curves of total O&M costs and unit O&M costs versus capacity are shown in Figures 4.27 and 4.28. Regression lines, 95% confidence intervals, and 95% prediction intervals are also shown in these figures. Please note that the regression lines are developed only to show the general trend of O&M costs and capacities for all evaluated technologies in this report. The authors of this report recommend site-specific analysis for the basis for engineering costing of new water reuse facilities.

The general trend is that lower-flow systems have a higher unit O&M cost, possibly because of economies of scale for O&M and/or possibly because of "soft" cost issues.

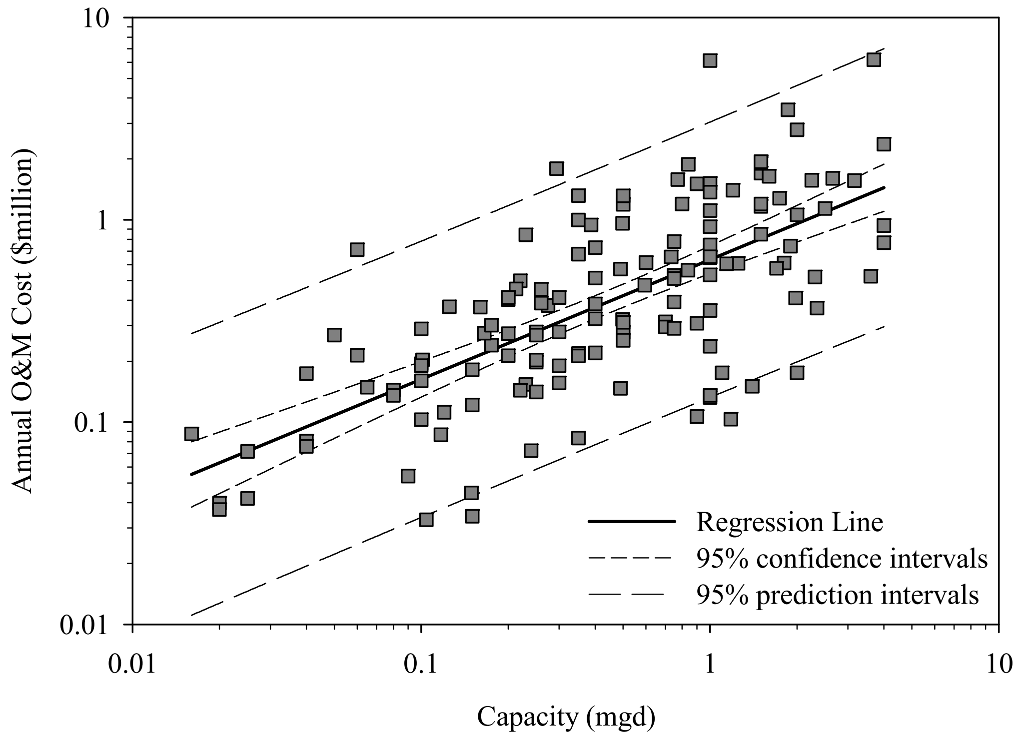

Figure 4.27. Total annual O&M costs.

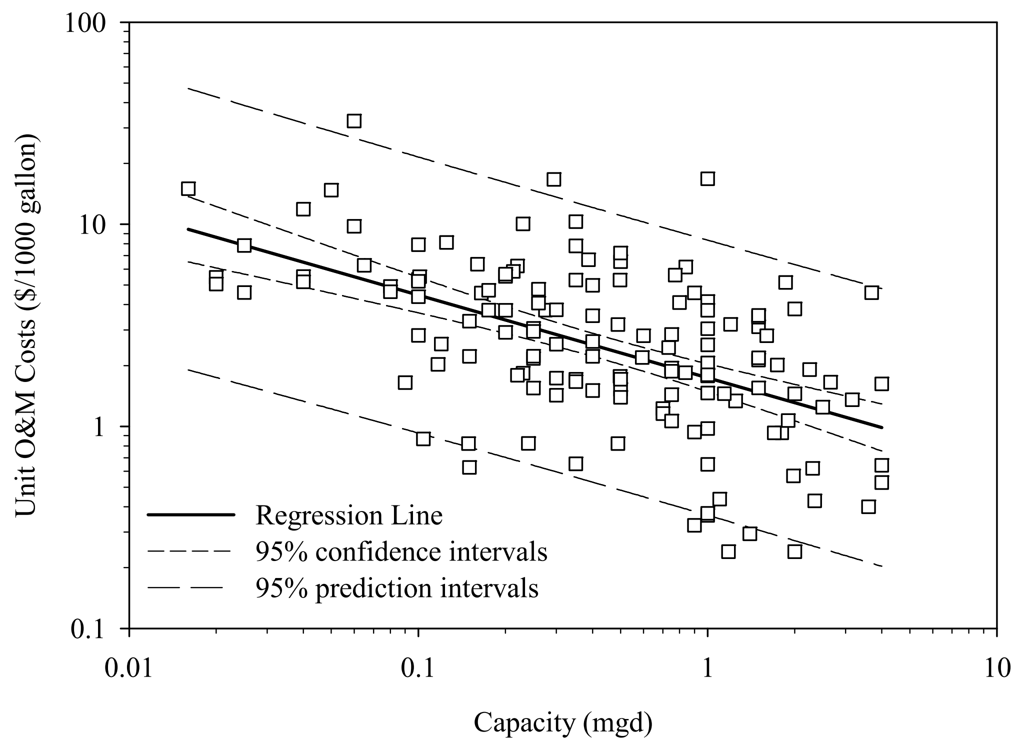

Figure 4.28. Unit O&M costs.

4.2.5. Comparison of Unit O&M Costs

The unit O&M costs are compared among the treatment plants.

- Figure 4.29 indicates that conventional customized plants and conventional package plants have similar unit O&M costs.
- Figure 4.30 shows that conventional customized plants and membrane customized plants also have similar unit O&M costs.
- Figure 4.31 suggests that natural systems and conventional customized plants have similar unit O&M costs.
- Figure 4.32 indicates that conventional customized plants and alternative treatment plants have similar unit O&M costs.

In total, these results show that all systems have similar unit O&M costs.

Please note that the O&M costs include only limited costs for energy consumption, materials, labor, testing, chemicals, and sludge handling. Other specific costs for membrane customized systems such as the costs for replacing membranes and oscillating valves are not available and therefore are not included in this analysis. These additional costs could increase the O&M costs of membrane customized systems significantly, so detailed analysis of these costs is necessary for a more accurate cost estimation.

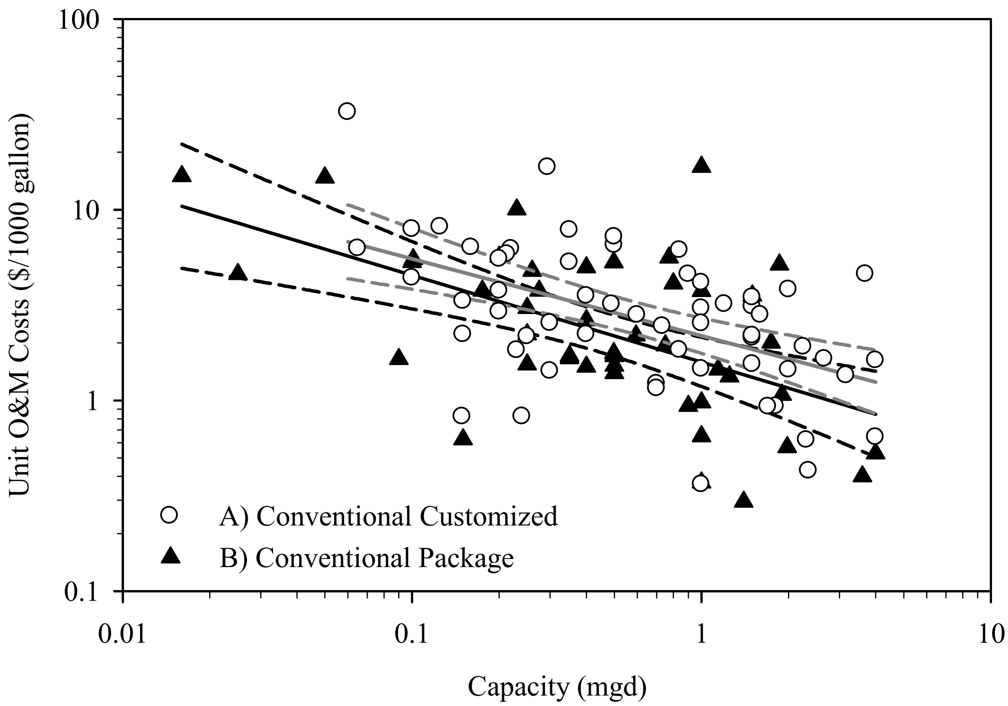

Figure 4.29. Comparison of unit O&M costs of conventional customized plants and conventional package plants.
Solid lines, regression lines; dash lines, 95% confidence intervals.

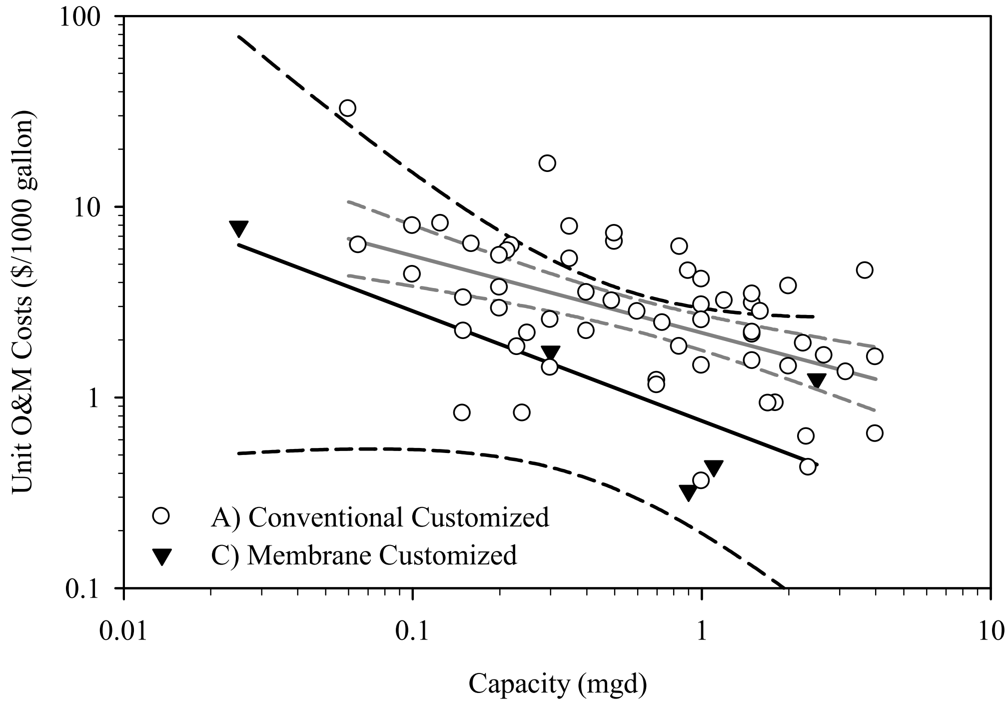

Figure 4.30. Comparison of unit O&M costs of conventional customized plants and membrane customized systems.
Solid lines, regression lines; dash lines, 95% confidence intervals.

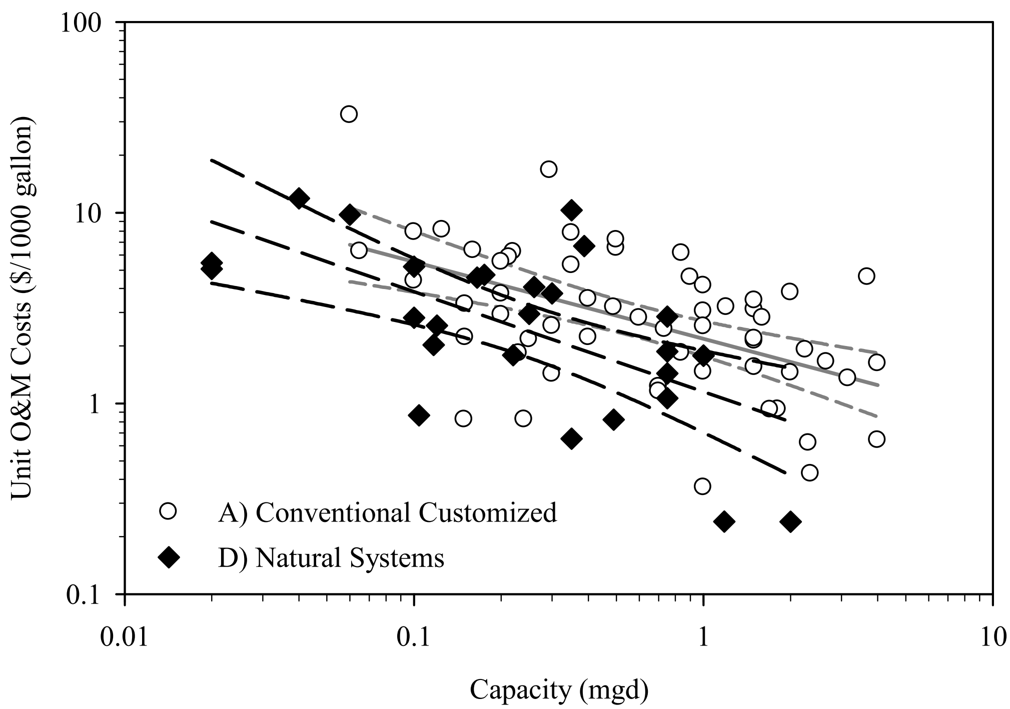

Figure 4.31. Comparison of unit O&M costs of conventional customized plants and natural systems.
Solid lines, regression lines; dash lines, 95% confidence intervals.

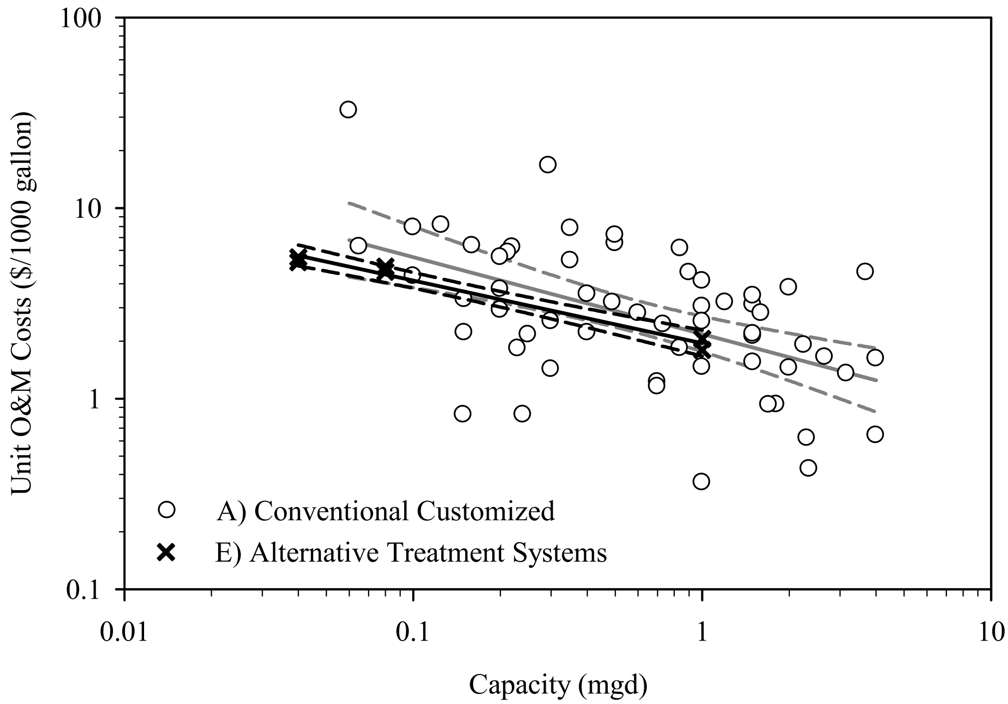

Figure 4.32. Comparison of unit O&M costs of conventional customized plants and alternative treatment systems.
Solid lines, regression lines; dash lines, 95% confidence intervals.

4.2.6. Comparison of Unit Present Value Costs

The unit present value costs of the different treatment systems are compared.

- Figure 4.33 indicates that conventional customized plants and conventional package plants have similar unit present value costs.

- Figure 4.34 shows that conventional customized plants and membrane customzied plants also have similar unit present value costs.

- Figure 4.35 indicates that natural systems are less expensive than conventional customized plants.

- Figure 4.36 suggests that conventional customized plants and alternative treatment plants have similar unit present value costs.

These results show that the unit present value costs of natural systems were the lowest, while all other systems have similar unit present value costs.

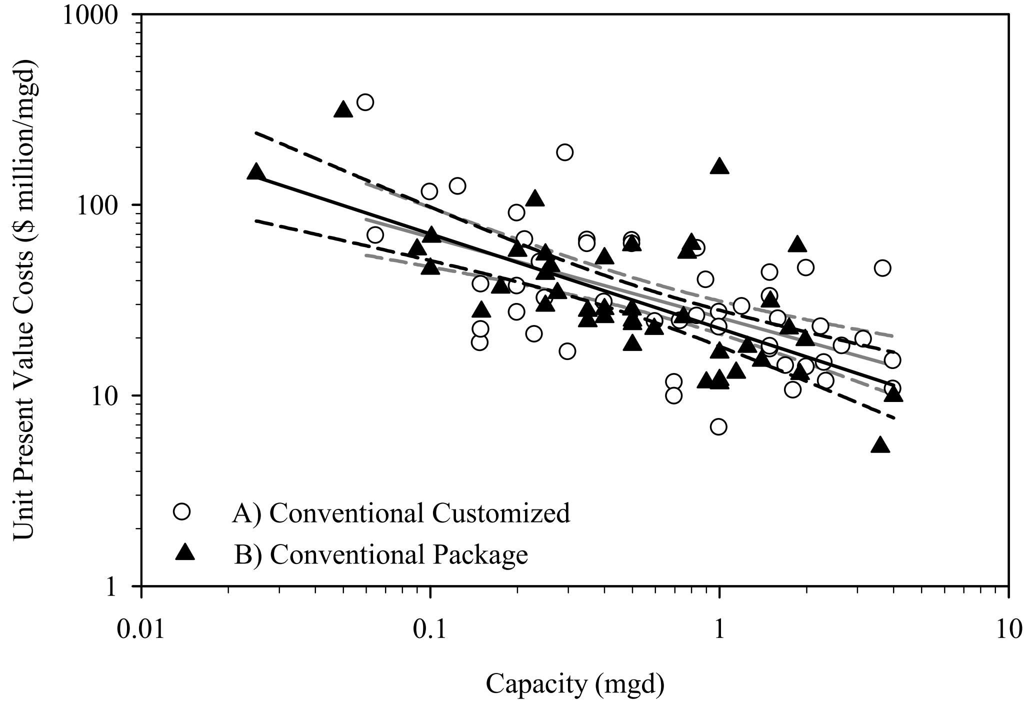

Figure 4.33. Comparison of unit present value costs of conventional customized plants and conventional package plants.
Solid lines, regression lines; dash lines, 95% confidence intervals.

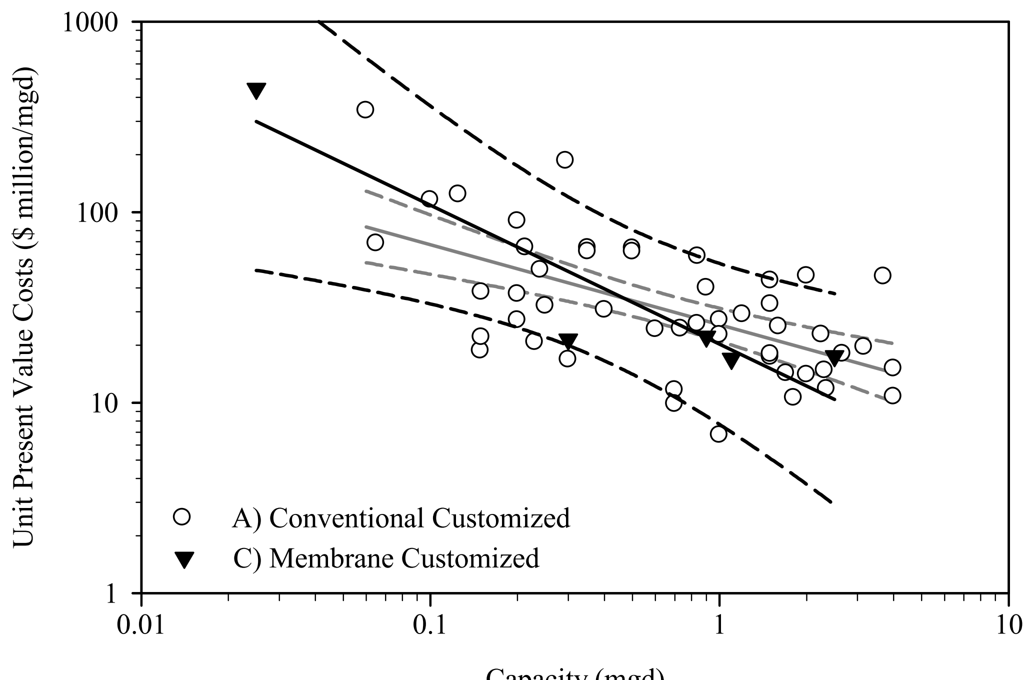

Figure 4.34. Comparison of unit present value costs of conventional customized plants and membrane customized plants.
Solid lines, regression lines; dash lines, 95% confidence intervals.

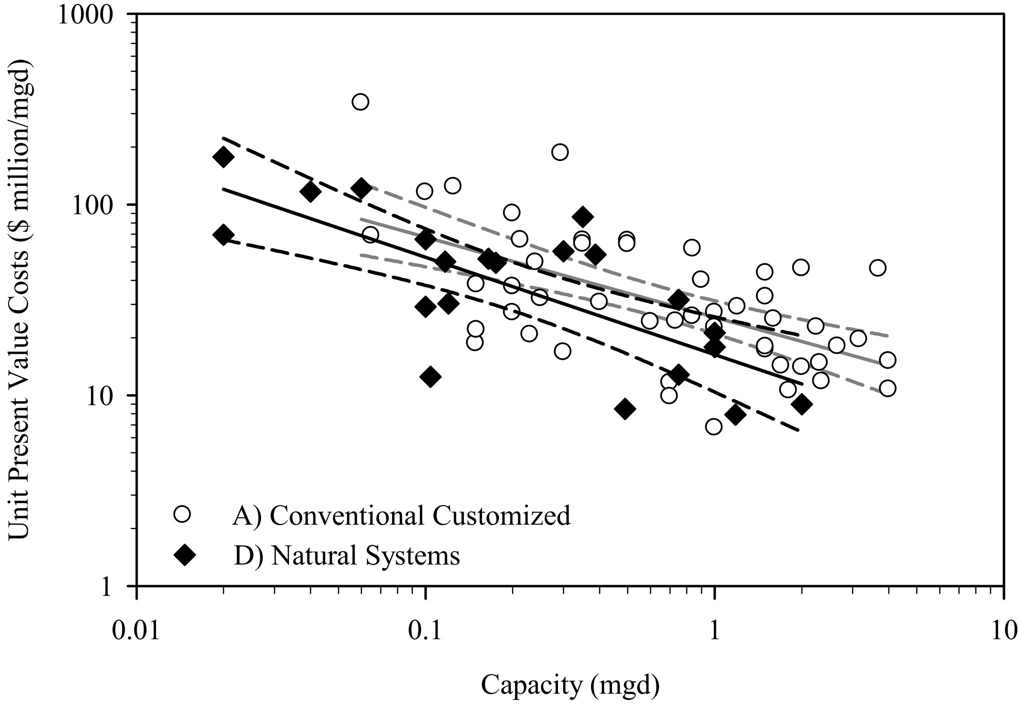

Figure 4.35. Comparison of unit present value costs of conventional customized plants and natural systems.
Solid lines, regression lines; dash lines, 95% confidence intervals.

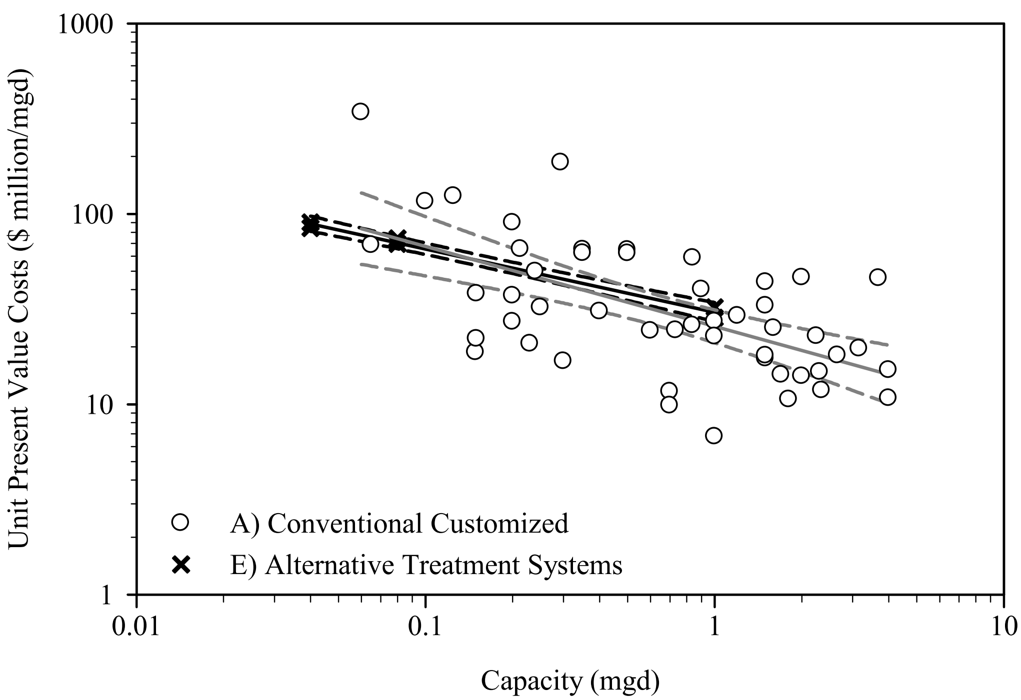

Figure 4.36. Comparison of unit present value costs of conventional customized plants and alternative treatment systems.
Solid lines, regression lines; dash lines, 95% confidence intervals.

4.2.7. Comparison of Effluent Water Quality

The effluent water quality (BOD_5), TSS, TN, and total phosphorus (TP) of natural systems were lower than those of other plants and systems (Figure 4.37). Other systems were similar in effluent water quality, while membrane customized plants were cleaner than conventional systems. A detailed comparison of each subcategory of the treatment processes shows a similar conclusion (Figure 4.38).

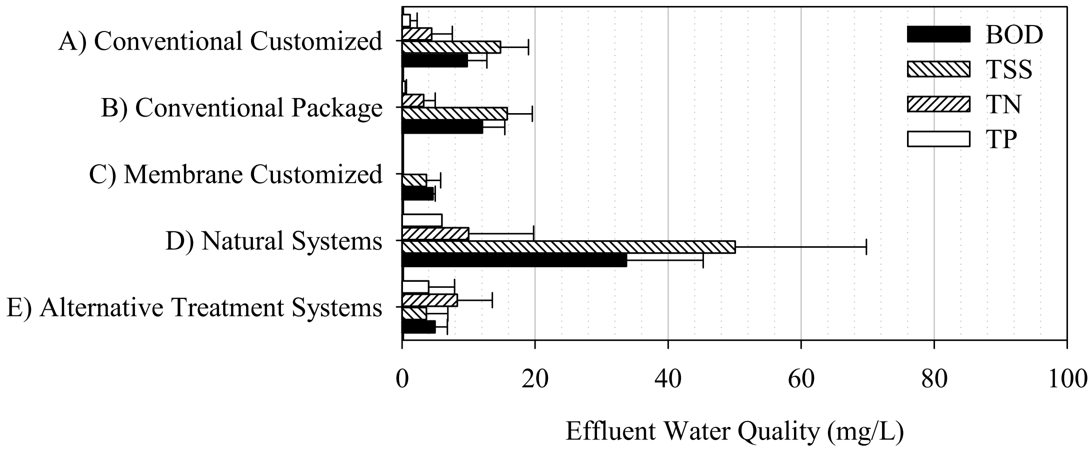

**Figure 4.37. Comparison of effluent water quality.
Error bars stand for 95% confidence intervals.**

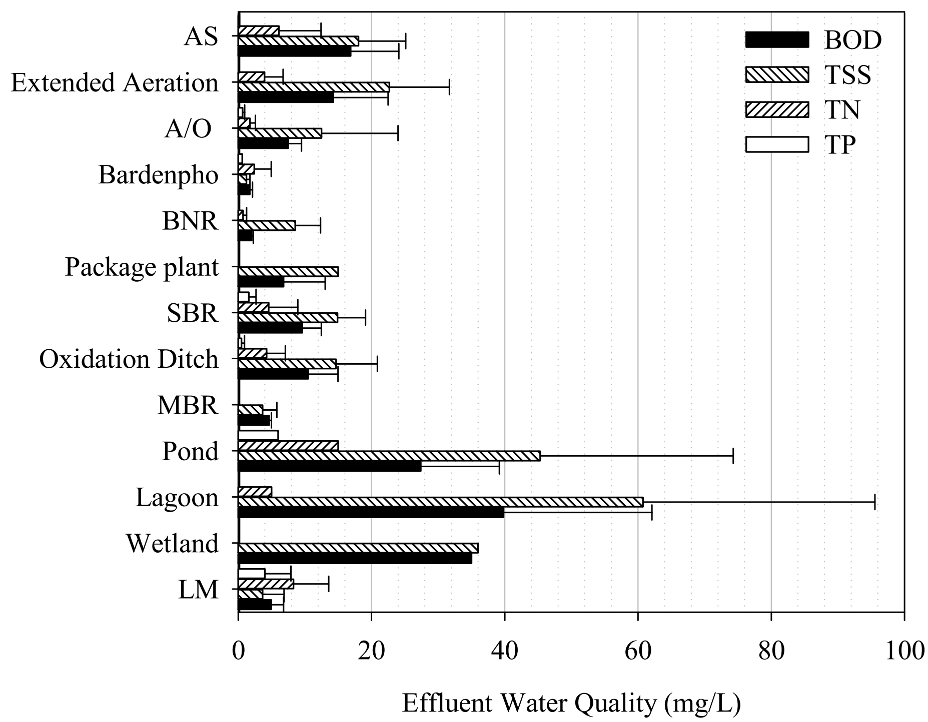

**Figure 4.38. Detailed comparison of effluent water quality of each subcategory.
Error bars stand for 95% confidence intervals.**

The removal efficiency of natural systems and alternative treatment systems was lower than those of other plants and systems (Figure 4.39). Other systems were similar in removal efficiency. A detailed comparison of each subcategory of the treatment processes shows a similar conclusion (Figure 4.40).

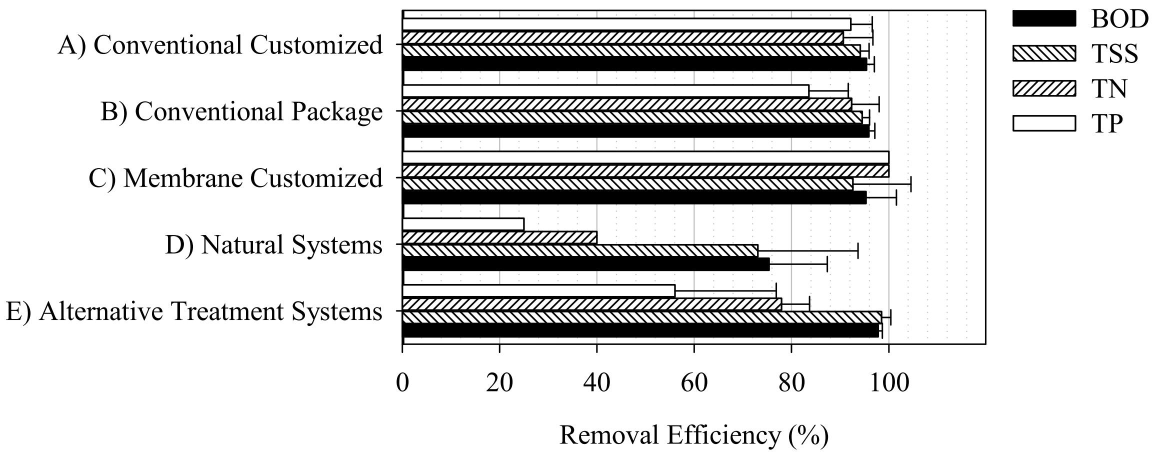

Figure 4.39. Comparison of removal efficiency.
Error bars stand for 95% confidence intervals.

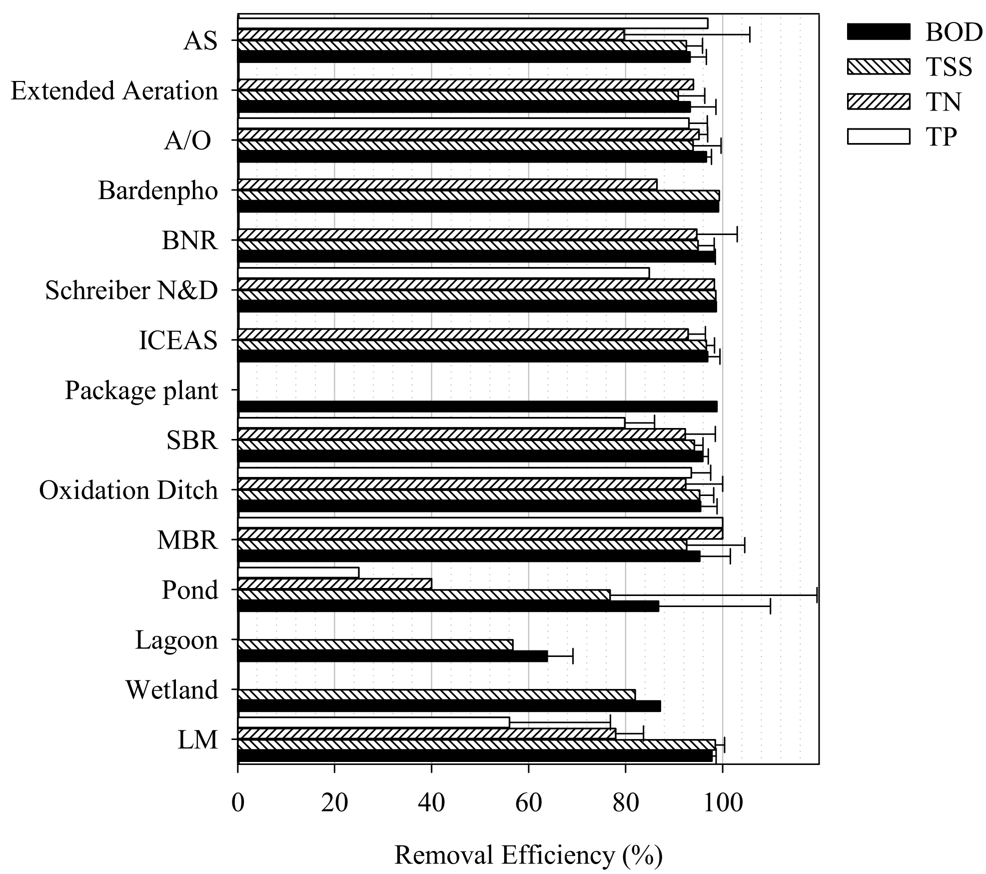

Figure 4.40. Detailed comparison of removal efficiency of each subcategory.
Error bars stand for 95% confidence intervals.

CHAPTER 5

THE WAWTTAR MODEL

The information on treatment processes and cost information results have been incorporated into the WAWTTAR model. The WAWTTAR model can be found at http://firehole.humboldt.edu/wawttar/. This website also contains a detailed user manual, some of which is repeated here.

5.1. INTRODUCTION TO WAWTTAR

WAWTTAR is a tool to assist in the planning and implementation of water and wastewater treatment systems, including treatment systems incorporating water reuse. The program was designed to be used at the pre-feasibility step in facility planning and/or infrastructure investment. The initial development goal was to develop a planning tool that could be used by both donors and beneficiaries of waste/wastewater infrastructure investments to maximize cultural acceptance of the facility and thereby minimize the risk of financial and technological failure. The program has an extensive database of water and wastewater treatment processes (over 200, all user expandable), on-site/decentralized waste and wastewater treatment processes, and a range of collection systems. The process database includes removal efficiencies, resource requirements, bases for design, color photographs, line drawings, and referenced text files. The process can be used to formulate a wide range of treatment systems (treatment trains).

WAWTTAR is a predictive model intended to assist planners in selecting suitable water and wastewater treatment options appropriate to the material and manpower resources available to particular communities throughout the world. The localized performance and cost of a large number of possible systems can be estimated with WAWTTAR for locations and conditions for which basic information on the problem to be solved is available. For example, decentralized on-site systems can be compared with centralized collection and treatment systems. WAWTTAR is designed to assist in alleviating the problem of overlooking good processes for water and wastewater treatment and also to help screen out treatment technologies which are inappropriate for given locales and situations. The selection of inappropriate technologies often results in facilities that perform poorly and fall into disrepair due to a lack of basic resources such as spare parts, O&M personnel, and technical expertise. It is hoped that design errors of this kind can be significantly reduced or eliminated via the use of WAWTTAR. WAWTTAR is designed to be used by those with some technical background in water and wastewater treatment.

WAWTTAR's main use is to screen and research possible water and wastewater treatment options, with emphasis placed on options that incorporate water reuse. (WAWTTAR does not exclude more conventional options and is of equal usefulness in the screening and research of such options.) It is intended to assist planners to improve their strategies for water and wastewater treatment in most locations and under local conditions. It will not choose the "best" possible option for a given situation, which can be done only by using solid engineering judgment. It can, however, be used to evaluate many more systems than would ordinarily be possible on the basis of performance and cost-effectiveness and therefore facilitate the selection of sensible options. WAWTTAR is not a dynamic program and does not analyze the response of a given system to changing influent conditions. Such issues must be explored by multiple trials of treatment systems with different influent quality.

5.2. WAWTTAR COMPONENTS

The program consists of four databases, an editor to create treatment trains, an editor to describe a community, and a calculator to sort the treatment processes through the community descriptors, receiving water standards, and reuse standards. The four databases are wastewater (including on-site) processes, water treatment processes, collection systems, and water quality standards. All databases can be edited to update and/or to add or delete information.

The water quality standard database contains a collection of U.S. and international potable and wastewater discharge and reuse standards. Each standard can specify a minimum and/or maximum concentration for any of nearly 100 water quality constituents. The user can enter new or modified standards in just a few moments if no existing standard in the database is appropriate for the problem under consideration.

The collection system database contains a number of conventional and alternative wastewater collection systems. Each collection system is characterized by text information describing the technology, pictures and line drawings of components of the collection system, and cost curves that relate the cost per capita to the population density of the community.

The water and wastewater treatment databases share a common structure. The main purpose of the process database is to provide information on the capabilities, physical and cultural limitations, costs, resource requirements, and possible environmental impacts of water and wastewater treatment and reuse processes. Cultural limitations and environmental impacts are also of prime importance and, unlike many facility planning efforts, are given attention equal to that of economic and performance factors. Cultural limitations are significant for the reasons discussed previously—a treatment technology which is in conflict with cultural norms of a given location is of little use. Environmental impacts are important since water and wastewater treatment systems have by-products and influence local conditions. It is important to avoid substituting one set of environmental problems for another, such as a wastewater treatment process that negatively impacts groundwater wells because of by-products and hydrological conditions. Alternatively, some processes such as constructed wetlands can have beneficial environmental impacts, and scenarios exist where such possible benefits should be taken into account in a positive sense.

While the editor for the process database is easy to use, detailed knowledge of a treatment process is required to enter a new process or edit an existing one. WAWTTAR uses a curve fit of land requirements, construction costs, and O&M costs and performance vs. process loading (hydraulic, organic, or solids) to perform calculations. Cost breakdowns are to localize construction and O&M costs for a particular community. The construction cost for each process is divided into categories of labor, earthwork, manufactured equipment, structures, concrete, steel, and pipes/valves/instruments. O&M cost categories are labor, chemicals, materials, and energy and land requirements. These must be included in any treatment process data file. Information on treatment processes can come from USEPA documents, technical reports, manufacturers, and practical experience as developed or reported by private and public agencies. In addition to the technical data described above, sufficient reference material (text, photos, and line drawings) is provided for each process so that WAWTTAR can serve as an educational tool for engineers and community planners.

The treatment processes are joined together into treatment trains representing logical assemblies of processes to treat water or wastewater. While a number of treatment trains are preassembled, a train editor is provided so that the user can easily construct new trains or modify existing trains that might be worthy of consideration for the problem under study. The treatment trains are assembled in a "point and click" fashion from the list of processes in the treatment process database.

An editor is also provided to enter the community under consideration into the community database. The community database contains previously analyzed problems and a comprehensive list of questions intended to describe the relevant characteristics of the community in question. These questions include water demand, wastewater production, resource cost and availability, the presence or absence of institutional support, population characteristics, and various cultural factors which could affect the handling of waste.

The availability and cost of resources can dramatically affect the feasibility of treatment and reuse options from construction to everyday O&M. Resources in this case include the type and reliability of power supply, manpower ranging from simple unskilled labor to technical and professional personnel, a list of treatment chemicals that are readily available, and any other type of human or physical capital that might be necessary.

5.3. WAWTTAR OPERATION

The basic operation of WAWTTAR is as follows: problem parameters such as performance standards, material costs, raw water or wastewater quality, community needs and capabilities, and planning horizon are entered by the user into the community database. The user can then proceed using the existing list of treatment trains, or the user can construct several additional treatment trains from a supplied, comprehensive list of available treatment processes. The user also specifies whether the calculation of treatment process performance should be based on the maximum efficiency, the minimum efficiency, or the mean efficiency. The user then instructs WAWTTAR to find feasible and infeasible treatment trains from the list of potential trains.

WAWTTAR first screens these potential trains based on community resource availability, followed by social and cultural considerations, treatment process limitations, reuse quality limitations (if reuse has been specified), and finally effluent disposal quality (water quality standards). This screening process for selecting feasible treatment trains is illustrated in Figure 5.1. Treatment trains that fail any of the screening criteria are classified as infeasible treatment trains and are eliminated from further consideration. WAWTTAR then calculates the performance, construction costs, and O&M costs of the remaining feasible treatment systems based on simple mathematical models of each of the treatment processes. Feasible treatment trains are sorted based on a user-specified criterion of minimum capital cost, minimum O&M cost, or minimum total cost.

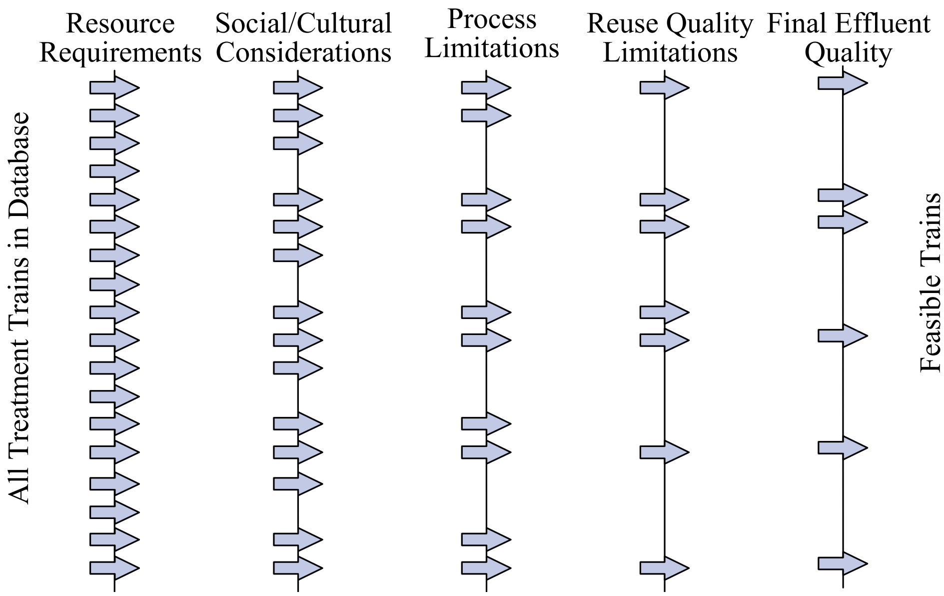

Figure 5.1. Screening process used to identify feasible treatment trains in WAWTTAR.

5.4. WAWTTAR OUTPUT

Any treatment train that fails the screening criteria established by the user is classified as infeasible, and entries are made in the "Infeasible Solution File." The Infeasible Solution File is an output text file that contains general design criteria for the community (planning period, design population, design flow, and effluent standard) and information on what screening criterion was not met by the treatment train. Frequently, review of why a train was classified as infeasible yields important insight into the current problem and design process. Therefore, the user is encouraged to examine and potentially re-evaluate problem specifications after consideration of the material available in the Infeasible Solution File.

Information detailing the cost and performance of feasible treatment trains is output to the Feasible Solution File. This text file again contains the general design criteria for the problem, followed by a detailed accounting of capital cost, O&M cost, land requirements, and land cost for each process in each feasible train. The total cost for the train, total per capita cost, and total cost per dwelling for each treatment train also are supplied. All costs are reported based on a user-specified choice of annual or total project costs. An adaptability index, ranging from 0 to 3, which rates the adaptability of each train to upgrading and which provides for variation in hydraulic loading and changes in influent quality, is also reported. Final effluent quality for each of up to 10 user-specified water quality constituents is reported for each train. Finally, potential social and environmental impacts for each feasible treatment train are reported as code numbers that are explained at the end of the file. After the listing of information on each feasible treatment train, the trains are presented in a table in ranked order. As noted earlier, the user can specify rank criteria of minimum capital cost, minimum O&M cost, or minimum total project cost.

5.5. WAWTTAR APPLICATION

WAWTTAR has been used in a wide range of communities including Jamaica (semirural setting), Bulgaria (municipal/industrial setting), the West Bank and Gaza (municipal and periurban setting), Koror (Palau), Brazil, two small communities in Hawaii, and a number of small to medium-sized communities in California, Oregon, Washington, Idaho, and Arizona. Validation exercises to date have shown that the program is sensitive to the range of environmental, economic, and social conditions considered in the program design. All applications have found WAWTTAR to be a useful tool for the pre-feasibility stage of the wastewater facility planning process. The program is also being used in a number of universities in the United States as part of the curriculum in water and wastewater engineering. WAWTTAR and associated documentation can be freely downloaded from the WAWTTAR website at http://firehole.humboldt.edu/wawttar.

5.6. INCORPORATING NEW TREATMENT PROCESS COST DATA INTO WAWTTAR

The building blocks of the treatment trains compared by WAWTTAR are individual treatment processes. Realistic construction and O&M costs for commonly used treatment processes are needed to allow a meaningful evaluation of the appropriateness and cost-effectiveness of a treatment train. The majority of cost data currently provided in WAWTTAR are from USEPA sources and generally are for facilities with a design flow rate greater than 1 mgd. In addition, many of the data are over 15 years old and do not include some of the new technologies in common use today. Cost information collected as part of this research activity fills a big gap in the existing database by providing a source of contemporary data for small treatment facilities. Data on the cost of individual treatment processes collected during this project have been evaluated for inclusion into the WAWTTAR construction and O&M cost curves. In some cases, the new data have filled in a missing region on an existing cost curve. In other cases, the new data have been averaged along with existing data to improve the reliability of the existing cost curve. In a couple of cases, the new data have completely replaced existing cost information since they were judged to be more representative of existing construction practices. While the process of incorporating new data into WAWTTAR is ongoing as new cost information continues to trickle in, a new version of the WAWTTAR database will be made available soon for download from the WAWTTAR website (http://firehole.humboldt.edu/wawttar/). The new version of the database will contain not only the new cost data collected as part of this project but also a number of treatment trains containing treatment processes appropriate for small communities which plan on reusing the effluent.

CHAPTER 6

CONCLUSIONS

The treatment trains reviewed for this project include a range of conventional, advanced, and alternative treatment plants and systems. The costs span a range of flows, allowing for water reuse treatment costs to be quickly estimated.

The primary value of this work is the extensive cost database, where the cost and operation data from existing small-scale wastewater treatment and water reuse facilities have been gathered and synthesized.

The selection of small-scale reclamation systems will depend on many factors, such as the type of reuse application, regulations, availability of land, the budget, and staffs. Based on the results of this project, natural systems may be the most cost-effective solution for small communities if inexpensive land is available and effluent water can fulfill the local regulations. If high water quality is desired and a budget is available, conventional customized systems can be used. Membrane customized systems can be used if even higher water quality is needed. For example, membrane systems can provide increased removal of trace organics (microconstituents) and provide a pathogen barrier that nonmembrane systems cannot attain.

The data within this project can be mined for specifically relevant applications, based upon the type of recycled water use and the guiding regulations at the point of use. For example, treatment plants not needing filtration and high levels of disinfection would reduce costs compared to the values shown here.

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APPENDIX A

SUMMARIZED STATE GUIDELINES AND REGULATIONS FOR RECLAIMED WATER

Table A. Summarized Guidelines and Regulations for Reclaimed Water

State	Treatment Standards, Disinfection Standards, and Design Requirements
Alabama	**Treatment Standards** nitrogen < 10 mg/L. **Disinfection Standards** coliform bacteria < 1/100 mL (maximum).
Alaska	**Treatment Standards** **from source other than stabilization pond**: TSS: arithmetic mean < 30 mg/L (30 days), < 45 mg/L (7 days), < 60 mg/L (1 day); **from source at a stabilization pond**: < 70 mg/L (30 days); **from source other than stabilization pond**: BOD: arithmetic mean < 30 mg/L (30 days), < 45 mg/L (7 days), < 60 mg/L (1 day); **from source at a stabilization pond**: < 45 mg/L (30 days) and > 65% removal by weight, < 65 mg/L (7 days); pH 6–9.
Arizona	**Treatment Standards** **Class A+**: turbidity: <= 2 NTU (24-h average), <= 5 NTU (maximum), nitrogen < 10 mg/L (5-sample geometric mean); **Class A**: turbidity: <= 2 NTU (24-h average), <= 5 NTU (maximum); **Class B+**: nitrogen < 10 mg/L (5-sample geometric mean); **Class C**: total retention time in wastewater stabilization ponds > 20 days. **Disinfection Standards** **Class A+, Class A**: fecal coliform not detectable in 4 of the last 7 samples (average), < 23/100 mL (maximum); if alternative treatment processes or alternative turbidity criteria are used or if reclaimed water is blended with other water, there is no detectable enteric virus in 4 of the last 7 monthly reclaimed water samples; **Class B+, Class B**: fecal coliform < 200/100 mL in 4 of the last 7 samples (average, < 800/100 mL); **Class C**: fecal coliform < 1000/100 mL in 4 of the last 7 samples (average), < 4000/100 mL (maximum). **Design Requirements** The minimum chlorine contact time is 15 min for wastewater at 70 °F and 30 min for wastewater at 50 °F, based on a flow equal to four times the daily design flow; required concentration of chlorine (TSS < 30 mg/L and BOD_5 < 30 mg/L): 15–30 (pH 6), 20–35 (pH 7), 30–45 (pH 8); required concentration of chlorine (TSS < 20 mg/L and BOD_5 < 20 mg/L): 6–10 (pH 6), 10–20 (pH 7), 20–35 (pH 8).

Table A. Summarized Guidelines and Regulations for Reclaimed Water

State	Treatment Standards, Disinfection Standards, and Design Requirements
California	**Treatment Standards** turbidity: <= 2 NTU (24-h average), <= 5 NTU (5% in 24 h), < 10 NTU (maximum) (coagulated and passed through natural undisturbed soils or a bed of filter media); or < 0.2 NTU (5% of 24 h) and < 0.5 NTU (maximum) (MF, UF, NF, or RO membrane). **Disinfection Standards** **Disinfected Tertiary Recycled Water**: total coliform < 2.2 MPN/100 mL in 7 days (median), only one sample > 23 MPN/100 mL in 30 days, none > 240 MPN/100 mL in 30 days; **Disinfected Secondary-2.2 Recycled Water**: total coliform < 2.2 MPN/100 mL in 7 days (median), only one sample > 23 MPN/100 mL in 30 days; **Disinfected Secondary-23 Recycled Water**: total coliform < 23 MPN/100 mL in 7 days (median), only one sample > 240 MPN/100 mL in 30 days. **Design Requirements** **Disinfected Tertiary Recycled Water**: (1) A chlorine disinfection process following filtration that provides a CT value >= 450 mg-min/L at all times with a modal contact time of at least 90 min, based on peak dry weather design flow; or (2) a disinfection process that, when combined with the filtration process, has been demonstrated to inactivate and/or remove 99.999% of the PFU of F-specific bacteriophage MS2 or poliovirus in the wastewater. A virus that is at least as resistant to disinfection as poliovirus is may be used for purposes of demonstration.
Colorado	**Treatment Standards** **Category 1**: TSS < 30 mg/L (daily maximum); **Category 2, Category 3**: turbidity: <= 3 NTU (monthly average), <= 5 NTU in more than 5% of the individual analytical results during any calendar month. **Disinfection Standards** **Category 1, Category 2**: *E. coli* < 126/100 mL (monthly geometric mean), < 235/100 mL (maximum); **Category 3**: *E. coli* below detection limit in at least 75% of samples in a calendar month, < 126/100 mL (maximum). **Design Requirements** Section 5.16.0 (Disinfection), 5.16.1 (Chlorination and Dechlorination), 5.16.2 (UV Disinfection), 5.16.3 (Ozone Disinfection) of Policy 96-1 - Design Criteria Considered in the Review of Wastewater Treatment Facilities.
Delaware	**Treatment Standards** **Restricted Public Access Sites**: TSS < 50 mg/L (mechanical systems), < 90 mg/L (ponds), BOD < 50 mg/L (average), < 75 mg/L under peak loads; **Limited Public Access Sites**: TSS < 30 mg/L, BOD < 30 mg/L; **Unlimited Public Access Sites**: turbidity < 5 NTU, TSS < 10 mg/L, BOD < 10 mg/L. **Disinfection Standards** **Restricted Public Access Sites**: fecal coliform < 200/100 mL (maximum), disinfection requirements may be waived when wastewater is irrigated in remote or restricted-use sites such as forests; **Limited Public Access Sites**: fecal coliform < 200/100 mL (maximum); **Unlimited Public Access Sites**: fecal coliform < 20/100 mL (maximum).

Table A. Summarized Guidelines and Regulations for Reclaimed Water

State	Treatment Standards, Disinfection Standards, and Design Requirements
Florida	<u>**Treatment Standards**</u> **Basic disinfection**: TSS < 10 mg/L, BOD < 20 mg/L (annual arithmetic mean), <30 mg /L (4 samples in a month), < 45 mg /L (7 samples in a month), < 60 mg /L (maximum); **High-level disinfection:** TSS < 5 mg/L, BOD < 20 mg/L (annual arithmetic mean), < 30 mg /L (4 samples in a month), < 45 mg /L (7 samples in a month), < 60 mg /L (maximum); **High-level disinfection (principal or full treatment and disinfection):** nitrogen < 10 mg/L (annual average), TSS < 5 mg/L, BOD < 20 mg/L (annual arithmetic mean), < 30 mg /L (4 samples in a month), < 45 mg /L (7 samples in a month), < 60 mg /L (maximum); **Intermediate-level disinfection:** nitrogen **<** 12 mg/L (annual average), TSS < 10 mg/L, BOD < 20 mg/L (annual arithmetic mean), < 30 mg /L (4 samples in a month), < 45 mg /L (7 samples in a month), < 60 mg /L (maximum); **Low-level disinfection:** TSS < 40–60 mg/L, BOD < 40–60 mg/L; **Industrial use**: TSS < 10 mg/L. <u>**Disinfection Standards**</u> **Basic disinfection**: pH 6–8.5, fecal coliform < 200/100 mL (annual arithmetic mean of monthly values and geometric mean of 10 separate samples in a month), and < 400/100 mL in 10% of the samples in a month, < 800/100 mL (maximum), chlorine (if used) residual > 0.5 mg/L for more than 15 min of contact time at the peak hourly flow; **High-level disinfection:** pH 6–8.5, fecal coliform < detection limits, a domestic wastewater facility: < detection limits in 75% of the samples, < 25/100 mL in 25% of the samples (maximum), chlorine (if used) residual > 1 mg/L for more than 15 min of contact time at the peak hourly flow. For new and expanded treatment facilities after 07/01/1991: > 25 mg/L (fecal coliforms < 1000/100 mL), > 40 mg/L (1000/100 mL < fecal coliforms < 10,000/100 mL), > 120 mg/L (fecal coliforms > 10,000/100 mL); **High-level disinfection (principal or full treatment and disinfection):** pH 6–8.5, total organic carbon: < 3 mg/L (monthly average), < 5 mg/L (maximum) (full), total organic halide: < 0.2 mg/L (monthly average), < 0.3 mg/L (maximum) (full), fecal coliform < detection limits, a domestic wastewater facility: < detection limits in 75% of the samples, < 25/100 mL in 25% of the samples (maximum), chlorine (if used) residual > 1 mg/L for more than 15 min of contact time at the peak hourly flow. For new and expanded treatment facilities after 07/01/1991, > 25 mg/L (fecal coliforms < 1000/100 mL), > 40 mg/L (1000/100 mL < fecal coliforms < 10,000/100 mL), > 120 mg/L (fecal coliforms > 10,000/100 mL); **Intermediate-level disinfection:** pH: 6–8.5, fecal coliform < 14/100 mL (annual arithmetic mean of monthly values and median of 10 separate samples in a month), and < 43/100 mL in 10% of the samples in a month, < 86/100 mL (maximum; chlorine [if used] residual > 1 mg/L for more than 15 min of contact time at the peak hourly flow); **Low-level disinfection:** pH: 6–8.5, fecal coliform < 2400/100 mL; **Industrial use**: pH: 6–8.5, case by case under A.A.C. chapter 9, article 7. <u>**Design Requirements**</u> **Basic disinfection**: The Department shall approve alternatives to the specified TSS limitation if the applicant provides reasonable assurances in the engineering report that the alternative control measures will ensure nonclogging of the system; **High-level disinfection:** Filtration shall be provided for TSS control. Chemical feed facilities for coagulant, coagulant aids, or polyelectrolytes shall

Table A. Summarized Guidelines and Regulations for Reclaimed Water

State	Treatment Standards, Disinfection Standards, and Design Requirements
	be provided. Such chemical feed facilities may be idle if the TSS limitation is being achieved without chemical addition. A pretreatment program shall be prepared and implemented; **High-level disinfection (principal or full treatment and disinfection):** Discharges to surface waters shall meet reclaimed water or effluent limits established by procedures contained in Chapter 62-650, F.A.C., and the requirements of the antidegradation policy contained in Rules 62-4.242 and 62-302.300, F.A.C. No mixing zones shall be allowed; control measures will ensure nonclogging of the system; **Intermediate-level disinfection:** Alternatives to the specified TSS limitation shall be approved by the Department if the applicant provides an affirmative demonstration that the alternative control measure will ensure nonclogging of the system.
Georgia	**Treatment Standards** turbidity <= 3 NTU, TSS < 5 mg/L, BOD < 5 mg/L, pH: 6–9. **Disinfection Standards** fecal coliform < 23/100 (monthly geometric mean), < 100/100 mL (maximum), detectable disinfectant residual at the delivery point (strongly recommended).
Hawaii	**Disinfection Standards** **R-1 (Significant reduction in viral and bacterial pathogens):** fecal coliform < 2.2/100 mL in 7 days (median), < 23/100 mL in more than one sample in any 30 days, < 200/100 mL (maximum), a disinfection process that, when combined with the filtration process, has been demonstrated to inactivate and/or remove 99.999% of the PFU of F-specific bacteriophage MS2 or poliovirus in the wastewater. A virus that is at least as resistant to disinfection as poliovirus is may be used for purposes of demonstration, a disinfection process that, when combined with the filtration process, has been demonstrated to inactivate and/or remove 99.999% of the PFU of F-specific bacteriophage MS2 or poliovirus in the wastewater. A virus that is at least resistant to disinfection as poliovirus is may be used for purposes of demonstration; **R-2 (Disinfected Secondary-23 Recycled Water):** fecal coliform < 23/100 in 7 days (median), < 200/100 mL in more than one sample in any 30 days; **R-2 (Undisinfected Secondary Recycled Water):** none.
Idaho	**Disinfection Standards** **A**: total coliform < 2.2/100 mL (average); **B**: total coliform < 2.2/100 mL (average); **C:** total coliform < 23/100 mL (average); **D:** total coliform < 230/100 mL (maximum); **E:** up to "too numerous to count".
Indiana	**Treatment Standards** **Pollutant-bearing water application on land with a high potential for public exposure:** TSS < 5 mg/L, BOD < 10 mg/L, pH 6–9; **Domestic wastewater application on land with a low potential for public exposure:** TSS < 30 mg/L, BOD < 30 mg/L, pH 6–9. **Disinfection Standards** **Pollutant-bearing water application on land with a high potential for public exposure:** fecal coliform not detectable (mean), < 14/100 mL

Table A. Summarized Guidelines and Regulations for Reclaimed Water

State	Treatment Standards, Disinfection Standards, and Design Requirements
	(maximum), chlorine (if used) residual > 1 mg/L after 30-min contact time; **Domestic wastewater application on land with a low potential for public exposure:** fecal coliform <= 200/100 mL (average), <= 800/100 mL (maximum).
Iowa	**Disinfection Standards** 0.5 mg of chlorine/L for 15 min.
Maryland	**Treatment Standards** **Slow Rate Class I:** TSS < 90 mg/L, BOD < 70 mg/L; **Slow Rate Class II:** TSS < 10 mg/L, BOD < 10 mg/L; **Overland Flow:** TSS < 90 mg/L, BOD < 70 mg/L; **Rapid Infiltration:** TSS and BOD: case by case. **Disinfection Standards** **Slow Rate Class I:** fecal coliform < 200/100 mL (maximum), < 3/100 mL in golf courses (maximum); **Slow Rate Class II:** fecal coliform < 3/100 mL (maximum); **Overland Flow:** fecal coliform < 200/100 mL (maximum); **Rapid Infiltration:** case by case.
Massachu-setts	**Treatment Standards** **Urban Reuse - Spray irrigation of golf courses and landscaping projects:** turbidity <= 2 NTU, nitrogen < 10 mg/L, TSS < 5 mg/L, BOD <= 10 mg/L, pH 6–9; **Urban Reuse - Toilet flushing:** turbidity <= 5 NTU, nitrogen < 10 mg/L, TSS < 10 mg/L, BOD <= 30 mg/L, pH 6–9; **Indirect Aquifer Recharge:** turbidity <= 2 or 5 NTU, nitrogen < 10 mg/L, TSS < 5 or 10 mg/L, BOD <= 10 or 30 mg/L, pH 6–9. **Disinfection Standards** **Urban Reuse - Spray irrigation of golf courses and landscaping projects:** fecal coliform none detectable/100 mL in 7 days (mean), < 14/100 mL (maximum); **Urban Reuse - Toilet flushing:** fecal coliform < 100/100 mL (maximum); **Indirect Aquifer Recharge:** fecal coliform none detectable/100 mL in 7 days (mean), < 14/100 mL or 100/100 mL (maximum).
Missouri	**Disinfection Standards** fecal coliform < 200/100 mL (maximum), total residual chlorine of 0.5 mg/L after 15 min of contact time at peak flow.
Montana	**Treatment Standards** **Spray Irrigation of Food Crops:** TSS < 10 mg/L, BOD < 10 mg/L. **Disinfection Standards** **Spray Irrigation of Food Crops:** fecal coliform < 23/100 mL in 30 days; **Spray Irrigation of Fodder, Fiber, and Seed Crops:** fecal coliform < 23/100 mL in 7 days; **Landscape Irrigation:** fecal coliform < 200/100 mL in 7 days and < 400/100 mL in any 2 consecutive samples, or median < 2.2/100 mL and <

Table A. Summarized Guidelines and Regulations for Reclaimed Water

State	Treatment Standards, Disinfection Standards, and Design Requirements
	23/100 mL for irrigation of parks, playgrounds, schoolyards, unrestricted golf courses, and other areas where the public has similar access or exposure.
Nebraska	**<u>Disinfection Standards</u>** fecal coliform: maximum < 200 CFU/100 mL for a 30-day average, no more than 10% of the samples > 400 CFU/100 mL.
Nevada	**<u>Treatment Standards</u>** **A**: dissolved oxygen ≥ 6.0 mg/L. **<u>Disinfection Standards</u>** **A, B:** total coliform < 2.2/100 mL in 30 days (geometric mean), < 23/100 mL (maximum daily); **C:** fecal coliform < 23/100 mL in 30 days (geometric mean), < 240/100 mL (maximum daily); **D:** fecal coliform < 200/100 mL in 30 days (geometric mean), < 400/100 mL (maximum daily); **E:** none.
New Jersey	**<u>Treatment Standards</u>** **Type I RWBR - Public Access System, Type II RWBR - Restricted-access and Nonedible Crop Systems:** turbidity < 2 NTU, nitrogen < 10 mg/L, TSS < 5 mg/L; **Type III RWBR - Agricultural Edible Crop Systems, Type IV RWBR - Industrial Systems, Maintenance Operations and Construction** **<u>Disinfection Standards</u>** **Type I RWBR - Public Access System, Type II RWBR - Restricted-access and Nonedible Crop Systems:** fecal coliform < 2.2/100 mL in 7 days (mean), < 14/100 mL (maximum), 1-mg/L chlorine for 15 min, or Design UV dose of 100 mJ/cm^2 under maximum daily flow; **Type III RWBR - Agricultural Edible Crop Systems, Type IV RWBR - Industrial Systems, Maintenance Operations and Construction:** fecal coliform < 200/100 mL (monthly geometric mean), < 400/100 mL (weekly geometric mean); Type III water: >1 mg of chlorine/L for 15 min, or Design UV dose of 75 mJ/cm^2 under maximum daily.
New Mexico	**<u>Treatment Standards</u>** **Class 1A:** turbidity < 3 NTU (30-day average), < 5 NTU (maximum), BOD < 10 mg/L (30-day average), < 15 mg/L (maximum); **Class 1B:** TSS < 30 mg/L (30-day average), < 45 mg/L (maximum), BOD < 30 mg/L (30-day average), < 45 mg/L (maximum); **Class 2:** TSS < 30 mg/L (30-day average), < 45 mg/L (maximum), BOD < 30 mg/L (30-day average), < 45 mg/L (maximum); **Class 3:** TSS < 75 mg/L (30-day average), < 90 mg/L (maximum), BOD < 30 mg/L (30-day average), < 45 mg/L (maximum). **<u>Disinfection Standards</u>** **Class 1A:** fecal coliform < 5/100 mL (30-day average), < 23/100 mL (maximum); **Class 1B:** fecal coliform < 100/100 mL (30-day average), < 200/100 mL (maximum); **Class 2:** fecal coliform < 200/100 mL (30-day average), < 400/100 mL (maximum); **Class 3:** fecal coliform < 1000/100 mL (30-day average), < 5000/100 mL (maximum).
North Carolina	**<u>Treatment Standards</u>** turbidity < 10 NTU, nitrogen <= 4 mg/L (monthly), 6 mg/L (daily), TSS <= 5 mg/L (monthly), 10 mg/L (daily), BOD <= 10 mg/L (monthly), 15

Table A. Summarized Guidelines and Regulations for Reclaimed Water

State	Treatment Standards, Disinfection Standards, and Design Requirements
	mg/L (daily). **Disinfection Standards** fecal coliform <= 14/100 mL (monthly geometric mean), <= 25/100 mL (daily maximum).
North Dakota	**Treatment Standards** TSS < 30 mg/L, BOD < 25 mg/L. **Disinfection Standards** maximum fecal coliform < 200/100 mL (30-day consecutive period), and < 400/100 mL in 10% of samples during any 30-consecutive-day period.
Ohio	**Disinfection Standards** **Unrestricted-access sites:** fecal coliform < 23/100 mL (30-day average); **Restricted-access sites:** fecal coliform of 30-day average < 23/100 mL (<100 ft), <200/100 mL (100–200 ft), < 1000/100 mL (> 200ft); **Agricultural sites:** fecal coliform of 30-day average < 23/100 mL (<100 ft), <1000/100 mL (100–200 ft).
Oregon	**Treatment Standards** **IV:** 24-h mean < 2 NTU, 5% time during 24 h < 5 NTU. **Disinfection Standards** **I:** none; **II:** total coliform < 23 (7-day median), < 240/100 mL in 2 consecutive samples (maximum); **III:** total coliform < 2.2 (7-day median), < 23/100 mL (maximum); **IV:** total coliform < 2.2 (7-day median), < 23/100 mL (maximum).
South Carolina	**Disinfection Standards** fecal coliform < 200/100 mL (monthly average), < 400/100 mL (daily maximum) reclaimed water systems with application in areas with a high potential for contact.
South Dakota	**Disinfection Standards** total coliform < 200/100 mL (geometric mean).
Tennessee	**Treatment Standards** **Sites Open to Public Access:** <= 30 mg/L. **Disinfection Standards** **Sites Closed to Public Access:** All wastewater must be treated to a level afforded by lagoons. Disinfection is generally not required for restricted-access land treatment sites. The TDHE may, however, require disinfection when deemed necessary; **Sites Open to Public Access:** fecal coliform < 200/100 mL (average).
Texas	**Treatment Standards** **Type I:** turbidity < 3 NTU, BOD < 5 mg/L; **Type II:** BOD: system other than pond: < 20 mg/L, or < 15 mg/L ($CBOD_5$); pond system: < 30 mg/L. **Disinfection Standards**

Table A. Summarized Guidelines and Regulations for Reclaimed Water

State	Treatment Standards, Disinfection Standards, and Design Requirements
	Type I: fecal coliform < 20 CFU/100 mL (average), < 75 CFU/100 mL (maximum); **Type II**: fecal coliform < 200 CFU/100 mL (average), < 800 CFU/100 mL (maximum).
Utah	**Treatment Standards** **Type I Treated Domestic Wastewater Effluent Where Human Exposure is Likely:** turbidity: daily mean < 2 NTU, maximum < 5 NTU, TSS < 5 mg/L, BOD < 10 mg/L, pH 6–9; **Type II Treated Domestic Wastewater Effluent Where Human Exposure is Unlikely:** TSS: monthly arithmetic mean < 25 mg/L, weekly mean < 35 mg/L, BOD < 25 mg/L, pH 6–9. **Disinfection Standards** **Type I Treated Domestic Wastewater Effluent Where Human Exposure Is Likely:** *E. coli*: none detected, < 9/100 mL (maximum), chlorine > 1.0 mg/L after 30-min contact time at peak flow; **Type II Treated Domestic Wastewater Effluent Where Human Exposure Is Unlikely**: *E. coli* < 126/100 mL (weekly median), < 500/100 mL (maximum).
Vermont	**Treatment Standards** turbidity < 2 NTU (monthly average), < 5 NTU (single sample), total nitrogen < 5 mg/L, ammonia nitrogen < 1 mg/L, TSS < 5 mg/L, BOD < 10 mg/L. **Disinfection Standards** *E. coli* < 2.2/100 mL (geometric mean of 5 samples), < 25/100 mL (maximum), residual chlorine > 1 mg/L.
Virginia	**Treatment Standards** **Level 1:** fecal coliform: monthly geometric mean <= 14/100 mL, corrective action threshold (CAT) at > 49/100 mL, or *E. coli*: monthly geometric mean <= 11/100 mL, CAT > 35/100 mL, or enterococci: monthly geometric mean <= to 11/100 mL, CAT > 24/100 mL, total residual chlorine: CAT < 1.0 mg/L after a minimum contact time of 30 min at average flow or 20 min at peak flow, pH 6.0–9.0, 5-day BOD: monthly average <= to 10 mg/L, or CBOD: monthly average <= to 8 mg/L, turbidity: daily average of discrete measurements recorded over a 24-h period <= 2 NTU, CAT > 5 NTU. **Level 2:** fecal coliform: monthly geometric mean <= to 200/100 mL, CAT > 800/100 mL, or *E. coli*: monthly geometric mean<= 126/100 mL, CAT > 235/100 mL, or enterococci: monthly geometric mean <= to 35/100 mL, CAT > 104/100 mL, total residual chlorine: CAT < 1.0 mg/L after a minimum contact time of 30 min at average flow or 20 min at peak flow, pH 6.0–9.0, BOD: monthly average <= 30 mg/L, maximum weekly average 45 mg/L, or CBOD: monthly average <= 25 mg/L, maximum weekly average 40 mg/L, TSS: monthly average <= 30 mg/L, maximum weekly average = 45 mg/L.
Washing-ton	**Treatment Standards** turbidity <= 2 NTU (average), <= 5 NTU (maximum), TSS < 30 mg/L (monthly arithmetic mean of 24-h composite, collected daily), BOD < 30 mg/L (monthly arithmetic mean of 24-h composite, collected weekly), dissolved oxygen > 0. **Disinfection Standards** **A, B**: total coliform < 2.2/100 mL in last 7 days (median), < 23/100 mL (maximum); **C**: total coliform < 23/100 mL in last 7 days (median), < 240/100 mL (maximum);

Table A. Summarized Guidelines and Regulations for Reclaimed Water

State	Treatment Standards, Disinfection Standards, and Design Requirements
	D: total coliform < 240/100 mL in last 7 days (median). **<u>Design Requirements</u>** Concentration of chlorine > 1 mg/L for 30 min where chlorine is used, and chlorine residue of 0.5 mg/L should be maintained unless reclaimed water is used for impoundments and storage ponds and approved by Department of Health and Ecology.
Wisconsin	**<u>Treatment Standards</u>** **Absorption Pond:** nitrogen < 10 mg/L (after 1/1/90), < 20 (between 1/1/90 and 1/1/85), none (before 1/1/85), BOD < 50 mg/L (monthly average), TDS < 500 mg/L, Cl < 250 mg/L; **Spray Irrigation:** BOD < 50 mg/L (monthly average); **Ridge and Furrow:** BOD < 50 mg/L (monthly average); **Overland Flow:** case by case; **Other:** case by case.
Wyoming	**<u>Disinfection Standards</u>** **A:** fecal coliform < 2.2/100 mL (maximum); **B:** fecal coliform > 2.2, and < 200/100 mL (maximum); **C:** fecal coliform > 200, and < 1000/100 mL (maximum).

APPENDIX B

WEBSITES OF STATE GUIDELINES AND REGULATIONS FOR RECLAIMED WATER

Table B. Websites of State Guidelines and Regulations for Reclaimed Water

State	Titles	Websites
Alabama	Groundwater Maximum Contaminant Levels Applicable to Groundwater Affected by Land Treatment Sites; Based on regulations developed after P.L. 92-523 (The Safe Drinking Water Act), Title 40, Parts 141 and 143	http://www.adem.state.al.us/WaterDivision/Industrial/Guidance/guidance.htm
Alaska	Alaska Administrative Code, Title 18 - Environmental Conservation, Chapter 72, Article 2	http://www.dec.state.ak.us/regulations/index.htm
Arizona	Arizona Administrative Code Title 18 Environmental Quality, Chapter 9 Water Pollution Control, Title 18, Chapter 11 Water Quality Standards	http://www.azsos.gov/public_services/Table_of_Contents.htm
Arkansas		http://www.adeq.state.ar.us/regs/default.htm
California	"The Purple Book" Excerpts from the Health and Safety Code, Water Code, and Titles 22 and 17 of the California Code of Regulations	http://www.cdph.ca.gov/healthinfo/environhealth/water/Pages/Waterrecycling.aspx
Colorado	Colorado Department of Public Health and Environment, Policy 96-1 - Design Criteria Considered in the Review of Wastewater Treatment Facilities; Regulation 84 - Reclaimed Water Control Regulation; Regulation 62 - Regulations for Effluent Limitations	http://www.cdphe.state.co.us/op/wqcc/GeneralInfo/StatutesRegsPolicies/Policies/96-1_07.pdf; http://www.cdphe.state.co.us/regulations/wqccregs/100284wqccreclaimedwater2007.pdf; http://www.cdphe.state.co.us/regulations/wqccregs/100262wqcceffluentlimitations.pdf
Connecticut	Guidance and Regulations Governing Land Treatment of Wastes	http://www.ct.gov/dep/site/default.asp
Delaware	Guidance and Regulations Governing the Land Treatment Of Wastes	http://www.dnrec.state.de.us/dnrec2000/,;http://www.dnrec.state.de.us/water2000/Sections/GroundWat/GWDSRegulations.htm
Florida	Chapter 62-610 Reuse of Reclaimed Water and Land Application	http://www.dep.state.fl.us/legal/Rules/wastewater/62-610.pdf; http://www.dep.state.fl.us/legal/Rules/wastewater/62-600.pdf; http://www.dep.state.fl.us/water/reuse/apprules.htm
Georgia	Guidelines for Water Reclamation and Urban Water Reuse	http://www.gaepd.org/Files_PDF/techguide/wpb/reuse.pdf
Hawaii	Guidelines for the Treatment and Use of Recycled Water	http://hawaii.gov/health/environmental/water/wastewater/forms.html

Table B. Websites of State Guidelines and Regulations for Reclaimed Water

State	Titles	Websites
Idaho	58.01.17, Rules for the Reclamation and Reuse of Municipal and Industrial Wastewater	http://adm.idaho.gov/adminrules/rules/idapa58/58index.htm
Illinois	Title 35 of the Illinois Administrative Code Subtitle C Chapter II: Part 372, Illinois Design Standards for Slow Rate Land Application of Treated Wastewater	http://www.ipcb.state.il.us/SLR/IPCBandIEPAEnvironmental Regulations-Title35.asp
Indiana	Article 6.1 Land Application of Biosolid, Industrial Waste Product, and Pollutant Water	http://www.in.gov/legislative/iac/title327.html
Iowa	Iowa Wastewater Facilities Design Standards Chapter 21: Land Application of Wastewater	http://www.iowadnr.com/water/wastewater/downloads.html
Kansas	Administrative Rules and Regulations, 28-16. Water Pollution Control	http://www.kdheks.gov/pdf/regs/28-16.pdf
Kentucky		http://kentucky.gov/Default.html
Louisiana		http://www.state.la.us/
Maine		http://www.state.me.us/
Maryland	Guidelines for Land Treatment of Municipal Wastewaters	http://www.mde.state.md.us/assets/document/MDE-WMA-001%20(Land-Treatment%20Guidelines).pdf
Massachusetts	Reclaimed Water Use - Interim Guidelines (Wastewater Reuse)	http://www.mass.gov/dep/water/laws/policies.htm
Michigan		http://www.michigan.gov/deq/0,1607,7-135-3313_3682-14902--,00.html
Minnesota		http://www.state.mn.us/cgi-bin/portal/mn/jsp/home.do?agency=NorthStar
Mississippi		http://www.mississippi.gov/
Missouri	Division 20 - Clean Water Commission, Chapter 8 - Design Guides	http://www.sos.mo.gov/adrules/csr/current/10csr/10csr.asp
Montana	Design Standards for Wastewater Facilities	http://www.deq.state.mt.us/wqinfo/Circulars/DEQ2.PDF
Nebraska	NEBRASKA Administrative Code, Title 119 – Nebraska Department of Environmental Quality	http://www.deq.state.ne.us/
Nevada	NAC 445A.276 Reuse Categories: Requirements for Bacteriological Quality of Effluent	http://www.leg.state.nv.us/NAC/NAC-445A.html
New Hampshire		http://www.state.nh.us/
New Jersey	Technical Manual for Reclaimed Water for Beneficial Reuse	http://www.state.nj.us/dep/dwq/techman.htm
New Mexico		http://www.nmenv.state.nm.us; http://www.nmenv.state.nm.us/gwb/New_Pages/docs_policy/NMED_REUSE_1-24-07.pdf

Table B. Websites of State Guidelines and Regulations for Reclaimed Water

State	Titles	Websites
New York		http://www.dec.state.ny.us
North Carolina	Administrative Rules, Title 15A, Chapter 02, Subchapter T, Waste Not Discharged to Surface Waters, 15A NCAC 02T .0906 Reclaimed Water Effluent Standards	http://reports.oah.state.nc.us/ncac.asp
North Dakota	Division of Water Quality Criteria for Irrigation with Treated Wastewater Recommended Criteria for Land Disposal of Effluent	http://www.health.state.nd.us/wq/
Ohio	The Ohio State University Extension Bulletin 860 Reuse of Reclaimed Wastewater through Irrigation	http://ohioline.osu.edu/b860/
Oklahoma	252:621 Non-Industrial Impoundments and Land Application, 252:656 Water Pollution Control Facility Construction	http://www.deq.state.ok.us/mainlinks/deqrules.htm
Oregon	Division 55 340-055 Treatment and Monitoring Requirements for Use of Reclaimed Water	http://arcweb.sos.state.or.us/rules/OARs_300/OAR_340/340_055.html
Pennsylvania		http://www.dep.state.pa.us/dep/deputate/watermgt/Wqp/WQP_WM/WM_Sewage.htm
Rhode Island		http://www.state.ri.us/
South Carolina		http://www.scdhec.gov/
South Dakota	Chapter XII Recommended Design Criteria for Disposal of Effluent by Irrigation Chapter XIII Recommended Design Criteria for Groundwater Monitoring Wells Chapter XVI Recommended Design Criteria for Artificial Wetland Systems	http://www.state.sd.us/denr/DES/P&S/designcriteria/designT.html
Tennessee	Design Criteria for Sewage Works	http://www.state.tn.us/environment/; http://tennessee.gov/environment/wpc/publications/dcChapter1_6.pdf
Texas	Water Reclamation and Reuse Regulation (9VAC25-740)	http://info.sos.state.tx.us/pub/plsql/readtac$ext.viewtac
Utah	Utah Administrative Code, Environmental Quality, R-317-1-4	http://www.rules.utah.gov/publicat/code.htm
Vermont	Adopted Indirect Discharge Rules, Subchapter 5 – Technical Standards for Wastewater Disposal Systems and Potable Water Supplies	http://www.anr.state.vt.us/dec/ww/indirect.htm#IDRs
Virginia	Water Reclamation and Reuse Regulation (9VAC25-740)	http://www.deq.state.va.us/vpa/waterreuse.html
Washington	Water Reclamation and Reuse Standards; standards for wetlands and direct aquifer recharge are also included in section 2 and section 3.	http://www.ecy.wa.gov/programs/wq/reclaim/standards.pdf; http://www.ecy.wa.gov/biblio/97023.html
West Virginia	Title 64 Series 47 Chapter 16-1 Sewage Treatment and Collection System Design Standards	http://www.wvsos.com/csr/verify.asp?TitleSeries=64-47
Wisconsin	NR 206 Land Disposal of Municipal and Domestic Wastewaters	http://www.legis.state.wi.us/rsb/code/nr/nr200.html
Wyoming	Wyoming Water Quality Regulations Chapter 21-Reuse of Treated Wastewater	http://soswy.state.wy.us/RULES/2804.pdf

APPENDIX C

USES OF RECLAIMED WATER IN SELECTED STATES

Table C.1. Uses of Reclaimed Water in Arizona

Type of Reuse	Category		
	Class A	Class B	Class C
Irrigation of food crops	Allowed		
Recreational impoundments	Allowed		
Residential landscape irrigation	Allowed		
School ground landscape irrigation	Allowed		
Open-access landscape irrigation	Allowed		
Toilet and urinal flushing	Allowed		
Fire protection systems	Allowed		
Spray irrigation of an orchard or vineyard	Allowed		
Commercial closed loop air-conditioning systems	Allowed		
Vehicle and equipment washing (does not include self-service vehicle washes)	Allowed		
Snow-making	Allowed		
Surface irrigation of an orchard or vineyard	Allowed	Allowed	
Golf course irrigation	Allowed	Allowed	
Restricted-access landscape irrigation	Allowed	Allowed	
Landscape impoundment	Allowed	Allowed	
Dust control	Allowed	Allowed	
Soil compaction and similar construction activities	Allowed	Allowed	
Pasture for milking animals	Allowed	Allowed	
Livestock watering (dairy animals)	Allowed	Allowed	
Concrete and cement mixing	Allowed	Allowed	
Material washing and sieving	Allowed	Allowed	
Street cleaning	Allowed	Allowed	
Pasture for nondairy animals	Allowed	Allowed	Allowed
Livestock watering (nondairy animals)	Allowed	Allowed	Allowed
Irrigation of sod farms	Allowed	Allowed	Allowed

Table C.1. Uses of Reclaimed Water in Arizona

Type of Reuse	Category		
Irrigation of fiber, seed, forage, and similar crops	Allowed	Allowed	Allowed
Silviculture	Allowed	Allowed	Allowed

Table C.2. Uses of Reclaimed Water in California

Type of Reuse[1]	Category			
	Disinfected Tertiary Recycled Water	**Disinfected Secondary-2.2 Recycled Water**	**Disinfected Secondary-23 Recycled Water**	**Undisinfected Secondary Recycled Water**
Irrigation[2]				
Food crops, including all edible root crops, where the recycled water comes into contact with the edible portion of the crop	Allowed			
Parks and playgrounds	Allowed			
Schoolyards	Allowed			
Residential landscaping	Allowed			
Unrestricted-access golf courses	Allowed			
Any other irrigation use not specified and not prohibited by other sections of the California Code of Regulations	Allowed			
Food crops where edible portion is produced above ground and not contacted by recycled water	Allowed	Allowed		
Cemeteries	Allowed	Allowed	Allowed	
Freeway landscaping	Allowed	Allowed	Allowed	
Restricted-access golf courses	Allowed	Allowed	Allowed	
Ornamental nursery stock and sod farms where access by the general public is not restricted	Allowed	Allowed	Allowed	
Pasture for animals producing milk for human consumption	Allowed	Allowed	Allowed	
Any nonedible vegetation where access is controlled so that the irrigated area cannot be used as if it were part of a park, playground, or school yard	Allowed	Allowed	Allowed	
Orchards where the recycled water does not come into contact with the edible portion of the crop	Allowed	Allowed	Allowed	Allowed

Table C.2. Uses of Reclaimed Water in California

Type of Reuse[1]	Category			
Vineyards where the recycled water does not come into contact with the edible portion of the crop	Allowed	Allowed	Allowed	Allowed
Non food-bearing trees (Christmas tree farms are included in this category, provided no irrigation with recycled water occurs for a period of 14 days prior to harvest or access by the general public)	Allowed	Allowed	Allowed	Allowed
Fodder and fiber crops and pasture for animals not producing milk for human consumption	Allowed	Allowed	Allowed	Allowed
Seed crops not eaten by humans	Allowed	Allowed	Allowed	Allowed
Food crops that must undergo commercial pathogen-destroying processing before being consumed by humans	Allowed	Allowed	Allowed	Allowed
Ornamental nursery stock and sod farms, provided no irrigation with recycled water occurs for a period of 14 days prior to harvesting, retail sale, or access by the general public	Allowed	Allowed	Allowed	Allowed
Supply for Impoundment				
Nonrestricted recreational impoundments with supplemental monitoring for pathogenic organisms	Allowed[3]			
Restricted recreational impoundments and publicly accessible fish hatcheries	Allowed	Allowed		
Landscape impoundments without decorative fountains	Allowed	Allowed	Allowed	
Supply for Cooling or Air Conditioning				
Industrial or commercial cooling or air conditioning involving cooling tower, evaporative condenser, or spraying that creates a mist	Allowed[4]			
Industrial or commercial cooling or air conditioning not involving a cooling tower, evaporative condenser, or spraying that creates a mist	Allowed	Allowed	Allowed	
Other Uses[5]				
Flushing toilets and urinals	Allowed			
Priming drain traps	Allowed			
Industrial process water that may contact workers	Allowed			
Structural firefighting	Allowed			
Decorative fountains	Allowed			
Commercial laundries	Allowed			
Consolidation of backfill material around potable water pipelines	Allowed			
Artificial snow-making for commercial outdoor uses	Allowed			

Table C.2. Uses of Reclaimed Water in California

Type of Reuse[1]	Category			
Commercial car washes, including hand washes if the recycled water is not heated, where the general public is excluded from the washing process	Allowed			
Industrial boiler feed	Allowed	Allowed	Allowed	
Nonstructural firefighting	Allowed	Allowed	Allowed	
Backfill consolidation around nonpotable piping	Allowed	Allowed	Allowed	
Soil compaction	Allowed	Allowed	Allowed	
Mixing of concrete	Allowed	Allowed	Allowed	
Dust control on roads and streets	Allowed	Allowed	Allowed	
Cleaning of roads, sidewalks, and outdoor work areas	Allowed	Allowed	Allowed	
Industrial process water that will not come into contact with workers				
Flushing of sanitary sewers	Allowed	Allowed	Allowed	Allowed

Notes:

1. Exceptions: The requirements set forth in this chapter shall not apply to the use of recycled water on-site at a water recycling plant or wastewater treatment plant, provided that access by the public to the area of on-site recycled water use is restricted.
2. Exceptions: For filtration pursuant to Section 60301.320(a) coagulation need not be used as part of the treatment process, provided that the filter effluent turbidity does not exceed 2 NTU, the turbidity of the influent to the filters is continuously measured, the influent turbidity does not exceed 5 NTU for more than 15 min and never exceeds 10 NTU, and the capability to automatically activate chemical addition or divert the wastewater should the filter influent turbidity exceed 5 NTU for more than 15 min exists.
3. Exceptions: Disinfected tertiary recycled water that has not received conventional treatment may be used for nonrestricted recreational impoundments, provided the recycled water is monitored for the presence of pathogenic organisms in accordance with the following: (1) During the first 12 months of operation and use, the recycled water shall be sampled and analyzed monthly for *Giardia*, enteric viruses, and *Cryptosporidium*. Following the first 12 months of use, the recycled water shall be sampled and analyzed quarterly for *Giardia*, enteric viruses, and *Cryptosporidium*. The ongoing monitoring may be discontinued after the first 2 years of operation with the approval of the department. This monitoring shall be in addition to the monitoring set forth in Section 60321. (2) The samples shall be taken at a point following disinfection and prior to the point where the recycled water enters the use impoundment. The samples shall be analyzed by an approved laboratory.
4. Whenever a cooling system, using recycled water in conjunction with an air-conditioning facility, utilizes a cooling tower or otherwise creates a mist that could come into contact with employees or members of the public, the cooling system shall comply with the following: (1) A drift eliminator shall be used whenever the cooling system is in operation. (2) A chlorine or other biocide shall be used to treat the cooling system recirculating water to minimize the growth of *Legionella* and other microorganisms.
5. Recycled water used for the following shall be disinfected tertiary recycled water, except that for filtration being provided pursuant to Section 60301.320(a) coagulation need not be used as part of the treatment process, provided that the filter effluent turbidity does not exceed 2 NTU, the turbidity of the influent to the filters is continuously measured, the influent turbidity does not exceed 5 NTU for more than 15 min and never exceeds 10 NTU, and the capability to automatically activate chemical addition or divert the wastewater should the filter influent turbidity exceed 5 NTU for more than 15 min exists.

Table C.3. Uses of Reclaimed Water in Colorado

Type of Reuse	Category			
	Category 1	Category 2	Category 3	Additional Conditions Required 84.8(A)
Industrial				
Cooling tower	Allowed	Allowed	Allowed	1
Concrete mixing and washout	Allowed	Allowed	Allowed	2
Dust control	Allowed	Allowed	Allowed	3
Soil compaction	Allowed	Allowed	Allowed	3
Closed loop cooling system	Allowed	Allowed	Allowed	
Landscape Irrigation				
Restricted access	Allowed	Allowed	Allowed	
Unrestricted access		Allowed	Allowed	4
Resident controlled			Allowed	4,5
Commercial				
Mechanized street cleaning	Allowed	Allowed	Allowed	3
Zoo operations	Allowed	Allowed	Allowed	
Fire Protection				
Nonresidential fire protection		Allowed	Allowed	6
Residential fire protection			Allowed	6

Notes:

1. If there is a significant likelihood for aerosols to drift to public or worker areas, adequate signage is required. Consider supplemental disinfection and chlorine residual and/or public access restrictions.
2. Category 1 water is allowed in the mixing process only; using it to wash off trucks and to supply trucks is prohibited. Category 2 water may be used for mixing or washing or as truck supply water as long as the user complies with the requirements set forth in Section 84.9 of this regulation. Mixing and washing activities must be contained (e.g., flow to lined pit or to approved concrete washout area or within enclosed equipment), as to prevent any off-site runoff or discharge to groundwater. Truck drivers and workers shall be trained in the proper use and washout procedures when using reclaimed water.
3. Application rates shall minimize ponding on or runoff from the area approved for application or use.
4. No reclaimed water piping shall be extended to or supported from any residential structure, and there shall be no accessible above-grade outlets from the reclaimed water system at any residential structure. At least one exterior hose bib, supplied with potable water, shall be provided at each residential structure.
5. The treater shall develop and implement a public education program to inform residents and plumbing contractors and inspectors who deal with the resident-controlled landscape irrigation systems about the need to (a) strictly prohibit cross-connections between the reclaimed water and potable water systems; (b) clearly and distinctively identify the potable service lines and plumbing from the reclaimed water service lines and plumbing; and (c) avoid contact with and strictly minimize ponding or runoff of the reclaimed water. The treater shall implement a cross-connection inspection program and shall have the authority to discontinue reclaimed water service to any resident who flagrantly or repeatedly misuses reclaimed water in a manner inconsistent with this regulation. The treater shall maintain a map indicating all areas where reclaimed water is provided for resident-controlled landscape irrigation.

Table C.3. Uses of Reclaimed Water in Colorado

Type of Reuse	Category
6. The user shall develop and implement a program, including notices in fire department newsletters and fire department preplans, to educate the public and firefighters that reclaimed water is used for fire protection. The user shall develop a program to educate plumbing and fire protection system contractors and inspectors expected to access the fire protection system about the need to confirm that cross-connections between the reclaimed water and potable water systems do not exist and about the requirement to clearly identify the potable and reclaimed water systems throughout the building. All personnel authorized to use the reclaimed water for fire protection shall be educated to avoid contact with and strictly minimize ponding or runoff of the reclaimed water during nonemergency testing or training. An annual cross-connection inspection shall be made at each structure to which reclaimed water piping is extended for fire protection to ensure that no cross-connection exists. The person treating shall maintain a map indicating the location of all fire hydrants, sprinkler systems, and standpipe systems provided with reclaimed water.	

Table C.4. Uses of Reclaimed Water in Florida

Type of Reuse	Category					
	Slow Land Application Systems; Restricted Public Access	Slow Land Application Systems; Public Access Areas, Residential Irrigation, and Edible Crops	High-Rate Land Application Systems	Groundwater Recharge and Indirect Potable Reuse	Overland Flow Systems	Industrial Use
Slow land application systems	Allowed	Allowed				
Applied to vegetative land surfaces, cattle-grazing areas	Allowed					
Restricted public access areas	Allowed					
Public access areas		Allowed				
Residential irrigation		Allowed				
Golf courses		Allowed				
Cemeteries		Allowed				
Parks		Allowed				
Landscape areas		Allowed				
Highway medians		Allowed				
Fire protection		Allowed				
Aesthetic purposes (decorative ponds or fountains)		Allowed				
Irrigation of edible crops		Allowed				
Dust control on construction sites		Allowed				
Toilet flushing		Allowed				
Additional uses		Allowed				

Table C.4. Uses of Reclaimed Water in Florida

Type of Reuse	Category					
	Slow Land Application Systems; Restricted Public Access	Slow Land Application Systems; Public Access Areas, Residential Irrigation, and Edible Crops	High-Rate Land Application Systems	Groundwater Recharge and Indirect Potable Reuse	Overland Flow Systems	Industrial Use
Water supply for commercial laundries		Allowed				
Vehicle washing		Allowed				
Flushing of sanitary sewers and reclaimed water lines		Allowed				
Mixing of concrete		Allowed				
Manufacture of ice for ice rinks		Allowed				
Cleaning of roads, sidewalks, and outdoor work areas		Allowed				
High-rate land application systems			Allowed			
Injection to groundwaters				Allowed		
Salinity control				Allowed		
Discharge to surface waters				Allowed		
Indirect potable reuse				Allowed		
Overland flow systems (sprinkling or flooding upper reaches of terraced, sloped, vegetated surfaces [sod farms, forests, fodder crops, pasturelands, etc.])					Allowed	
Industrial use (cooling water, wash water, process water in industrial facilities)						Allowed
Treated industrial wastewater for land application						Allowed

Table C.5. Uses of Reclaimed Water in Hawaii

Type of Reuse	Category		
	R-1	R-2	R-3
Irrigation: (S)pray, (D)rip & Surface, S(U)bsurface, (A)LL=SD & U, Spray with (B)uffer, (N)ot Allowed, /=or			
Golf course landscapes	A	U/B	N
Freeway and cemetery landscapes	A	A	N
Food crops where recycled water contacts the edible portion of the crop, including all root crops	A[1]	N	N

Table C.5. Uses of Reclaimed Water in Hawaii

Type of Reuse	Category		
	R-1	**R-2**	**R-3**
Parks, elementary school yards, athletic fields, and landscapes around some residential property	A	U	N
Roadside and median landscapes	A	U/B	N
Inedible vegetation in areas with limited public exposure	A	AB	U
Sod farms	A	AB	N
Ornamental plants for commercial use	A	AB	N
Food crops above ground and not contacted by irrigation	A	U	N
Pastures for milking and other animals	A	U	N
Fodder, fiber, and seed crops not eaten by humans	A	AB	DU
Orchards and vineyards bearing food crops	A	D/U	DU
Orchards and vineyards not bearing food crops during irrigation	A	AB	DU
Timber and trees not bearing food crops	A	AB	DU
Food crops undergoing commercial pathogen-destroying process before consumption	A	AB	DU
Supply to Impoundments			
Restricted recreational impoundments	A	N	N
Basins at fish hatcheries	A	N	N
Landscape impoundments without decorative fountain	A	A	N
Landscape impoundments with decorative fountain	A	N	N
Supply to Other Uses			
Flushing of toilets and urinals	A	N	N
Structural firefighting	A	A	N
Nonstructural firefighting	A	A	N
Commercial and public laundries	A	N	N
Cooling of saws while cutting pavement	A	N	N
Decorative fountains	A	N	N
Washing of yards, lots, and sidewalks	A	N	N
Flushing of sanitary sewers	A	A	N
High-pressure water blasting to clean surfaces	A	N	N
Industrial process without exposure of workers	A	A	N
Industrial process with exposure of workers	A	N	N
Cooling or air-conditioning system without tower, evaporative condenser, spraying, or other features that emit vapor or droplets	A	A	N
Cooling or air-conditioning system with tower, evaporative condenser, spraying, or other features that emit vapor or droplets	A	N	N

Table C.5. Uses of Reclaimed Water in Hawaii

Type of Reuse	Category		
	R-1	R-2	R-3
Industrial boiler feed	A	A	N
Water jetting for consolidation of backfill material around potable water piping during water shortages	A	N	N
Water jetting for consolidation of backfill material around piping for recycled water, sewage, storm drainage, and gas, as well as electrical conduits	A	A	N
Washing aggregate and making concrete	A	A	N
Dampening roads and other surfaces for dust control	A	A	N
Dampening brushes and street surfaces in street sweeping	A	A	N

Note:
1. Allowed under the following conditions: The turbidity of the influent to the filters is continuously measured, the influent turbidity does not exceed 5 NTU for more than 15 min and never exceeds 10 NTU, and the capability to automatically activate chemical addition or divert the wastewater should the filter influent turbidity exceed 5 NTU for more than 15 min exists. The UV disinfection unit must conform to Appendix K: UV Disinfection Guidelines for R-1 Water.

Table C.6. Uses of Reclaimed Water in Idaho

Type of Reuse	Category				
	A	B	C	D	E
Residential irrigation at individual homes	Allowed				
Groundwater recharge using surface spreading, seepage ponds, or other unlined surface water features	Allowed				
Groundwater recharge using subsurface distribution	Allowed				
Fire suppression from dedicated, marked hydrants	Allowed				
Dust suppression at construction sites	Allowed				
Contact with any edible portion of raw food crops	Allowed	Allowed			
Irrigation of golf courses, parks, playgrounds, school yards	Allowed	Allowed			
Irrigation of orchards and vineyards during the fruiting season, if no fruit harvested for raw use comes in contact with the irrigation water or ground or if the water contacts only the inedible portion of raw food crops	Allowed	Allowed	Allowed		
Irrigation of cemeteries or roadside vegetation	Allowed	Allowed	Allowed		
Toilet flushing at industrial and commercial sites	Allowed	Allowed	Allowed		
Irrigation of fodder, seed, or processed food crops	Allowed	Allowed	Allowed	Allowed	
Irrigation of forested sites	Allowed	Allowed	Allowed	Allowed	Allowed

Table C.7. Uses of Reclaimed Water in Nevada

Type of Reuse	Category				
	Class A	Class B	Class C	Class D	Class E
Spray irrigation of land used as a cemetery, commercial lawn, golf course, greenbelt, or park even if: (1) Public access to the area of use is not controlled; and (2) Human contact with the treated effluent can reasonably be expected to occur	Allowed				
An impoundment in which swimming is prohibited even if: (1) Public access to the impoundment is not controlled; and (2) Human contact with the treated effluent can reasonably be expected to occur	Allowed				
Any other use that is approved by the Division	Allowed				
Spray irrigation of land used as a cemetery, commercial lawn, golf course, greenbelt or park if: (1) Public access to the area of use is controlled; and (2) Human contact with the treated effluent cannot reasonably be expected to occur	Allowed	Allowed			
Subsurface irrigation of land used as a commercial lawn, greenbelt, or park	Allowed	Allowed			
Cooling water in an industrial process	Allowed	Allowed			
Firefighting operations in an urban area if approved by the fire department, fire protection district, or other firefighting agency in whose district the fire occurs	Allowed	Allowed			
Any other use that is approved by the Division	Allowed	Allowed			
Spray irrigation of land used as a cemetery, golf course, or greenbelt if: (1) Public access to the area of use is controlled; (2) Human contact with the treated effluent does not occur; and (3) A buffer zone of not less than 100 ft is maintained	Allowed	Allowed	Allowed		
Watering of nursery stock if public access to the area of use is controlled	Allowed	Allowed	Allowed		
Establishment, restoration, or maintenance of a wetland if public access to the wetland is controlled	Allowed	Allowed	Allowed		
Washing of gravel used in concrete mixing	Allowed	Allowed	Allowed		
Feed water for a boiler	Allowed	Allowed	Allowed		
An impoundment if: (1) Public access to the impoundment is controlled; and (2) Human contact with the treated effluent cannot reasonably be expected to occur	Allowed	Allowed	Allowed		
Firefighting of forest or other wilderness fires if approved by the fire department, fire protection district, or other firefighting agency in whose district the fire occurs	Allowed	Allowed	Allowed		
Spray irrigation of land used for agricultural purposes if: (1) Public access to the area of use is prohibited; and (2) A buffer zone of not less than 400 ft is maintained	Allowed	Allowed	Allowed	Allowed	
Surface irrigation of land used: (1) As greenbelt if: (I) Public access to the area of use is prohibited; and (II) Human contact with the treated effluent does not occur. (2) For agricultural purposes; and (3) For the cultivation of fruit-bearing trees or nut-bearing trees	Allowed	Allowed	Allowed	Allowed	

Table C.7. Uses of Reclaimed Water in Nevada

Type of Reuse	Category				
	Class A	Class B	Class C	Class D	Class E
Subsurface irrigation of land used for agricultural purposes if public access is controlled	Allowed	Allowed	Allowed	Allowed	
Dust control	Allowed	Allowed	Allowed	Allowed	
Soil compaction	Allowed	Allowed	Allowed	Allowed	
Flushing sewer lines	Allowed	Allowed	Allowed	Allowed	
An impoundment if: (1) Public access to the impoundment is prohibited; (2) All human activities involving contact with the treated effluent are prohibited; and (3) Human contact with the treated effluent does not occur	Allowed	Allowed	Allowed	Allowed	
Spray irrigation of land used for agricultural purposes if: (1) Public access to the area of use is prohibited; and (2) A buffer zone of not less than 800 ft is maintained	Allowed	Allowed	Allowed	Allowed	Allowed

Table C.8. Uses of Reclaimed Water in New Mexico

Type of Reuse	Category			
	Class 1A	Class 1B	Class 2	Class 3
All Class 1 uses. No setback limit to dwelling unit or occupied establishment	Allowed			
Backfill around potable water pipes	Allowed			
Irrigation of food crops[1]	Allowed			
Impoundments (recreational or ornamental)	Allowed	Allowed		
Irrigation of parks, school yards, golf courses	Allowed	Allowed		
Irrigation of urban landscaping	Allowed	Allowed		
Snow-making	Allowed	Allowed		
Street cleaning	Allowed	Allowed		
Toilet flushing	Allowed	Allowed		
Backfill around nonpotable piping	Allowed	Allowed		
Concrete mixing	Allowed	Allowed	Allowed	
Dust control	Allowed	Allowed	Allowed	
Irrigation of fodder, fiber, and seed crops for milk-producing animals	Allowed	Allowed	Allowed	
Irrigation of roadway median landscapes	Allowed	Allowed	Allowed	
Irrigation of sod farms	Allowed	Allowed	Allowed	
Livestock watering	Allowed	Allowed	Allowed	
Soil compaction	Allowed	Allowed	Allowed	

Table C.8. Uses of Reclaimed Water in New Mexico

Type of Reuse	Category			
Irrigation of fodder, fiber, and seed crops for non-milk-producing animals	Allowed	Allowed	Allowed	Allowed
Irrigation of forest trees (silviculture)	Allowed	Allowed	Allowed	Allowed

Note:
1. Irrigation of food crops should be allowed for food crops when there is no contact between the edible portion of the crop and the wastewater. Spray irrigation is prohibited for food crops.

Table C.9. Uses of Reclaimed Water in Oregon

Type of Reuse	Category			
	Level I	Level II	Level III	Level IV
Buffers for irrigation:	Surface: 10 ft Spray: site-speci fic	Surface 10 ft Spray: 70 ft	10 ft	None required
Agricultural food crops	N/A	N/A	N/A	Unrestricted
Processed food crops	N/A	1	1	Unrestricted
Orchards and vineyards	N/A	2	2	Unrestricted
Fodder, fiber, and seed crops not for human ingestion	3	1	1	Unrestricted
Pasture for animals	N/A	4	4	Unrestricted
Sod	N/A	1	1	Unrestricted
Ornamental nursery stock	N/A	1	1	Unrestricted
Christmas trees	N/A	1	1	Unrestricted
Firewood	N/A	1	1	Unrestricted
Commercial timber	3	1	1	Unrestricted
Parks, playgrounds, school yards, golf courses with contiguous residences	N/A	N/A	N/A	5,6
Golf courses without contiguous residences	N/A	5,7	5,7	5,6
Cemeteries, highway medians, landscapes without frequent public access	N/A	5,7	5,7	5,6
Industrial or commercial use	N/A	9,10,11,12	9,10,11,12	9,10,12
Construction use	N/A	9,10,11,12,13	9,10,11,12, 13	9,10,12,13
Impoundments: unrestricted	N/A	N/A	N/A	8,10
Restricted	N/A	N/A	8,10,14	8,10
Landscape impoundments	N/A	8,10,14	8,10,14	8,10

Notes:
1. Advisory Notice Only: The Oregon State Health Division recommends that there should be no irrigation of this level of effluent for 3 days prior to harvesting.

Table C.9. Uses of Reclaimed Water in Oregon

Type of Reuse	Category

2. Surface irrigation where edible portion of crop does not contact the ground and where fruit or nuts shall not be harvested off the ground.
3. The Department may permit spraying if it can be demonstrated that public health and the environment will be adequately protected from aerosols. Advisory Notice Only: The Oregon State Health Division recommends that there should be no irrigation of this level of effluent for 30 days prior to harvesting.
4. Surface or spray irrigation: no animals shall be on the pasture during irrigation.
5. Signs shall be posted around the perimeter of the facility's perimeter and other locations indicating that reclaimed water is used for irrigation and is not safe for drinking, and in the case of effluent quality Levels II and III for body contact (e.g., for Level IV, ATTENTION: RECLAIMED WATER USED FOR IRRIGATION DO NOT DRINK × ATENCION: RECLAMADO DESPERDICIO DE AGUA USADO PARA LA IRRIGACION NO BEBA EL AGUA; for Levels II and III, ATTENTION: RECLAIMED WATER USED FOR IRRIGATION AVOID CONTACT DO NOT DRINK × ATENCION: RECLAMADO DESPERDICIO DE AGUA USADO PARA LA IRRIGACION EVITE EL CONTACTO NO BEBA EL AGUA).
6. Reclaimed water shall be applied in a manner so that it is not sprayed onto areas where food is prepared or served or onto drinking fountains.
7. Reclaimed water shall be applied in a manner so that it is not sprayed within 100 ft from areas where food is prepared or served or where drinking fountains are located.
8. Signs shall be posted around the perimeter and other locations indicating that reclaimed water is used and is not safe for drinking and in the case of effluent quality Levels II and III for body contact (e.g., for Level IV, ATTENTION: RECLAIMED WATER DO NOT DRINK × ATENCION: RECLAMADO DESPERDICIO DE AGUA NO BEBA EL AGUA; for Levels II and III, ATTENTION: RECLAIMED WATER AVOID CONTACT DO NOT DRINK × ATENCION: RECLAMADO DESPERDICIO DE AGUA EVITE EL CONTACTO NO BEBA EL AGUA).
9. The Department may impose more-stringent limits on the use of reclaimed water if it believes they are necessary to protect public health and the environment.
10. There shall be no disposal of reclaimed waters into surface or groundwaters without authorization by an NPDES or Water Pollution Control Facility (WPCF) permit.
11. Use of reclaimed water in evaporative cooling systems shall be approved only if the user can demonstrate that aerosols will not present a hazard to public health.
12. Members of the public and employed personnel at the site of the use of reclaimed water shall be notified that the water is reclaimed water. Stipulations for how this notification will be provided shall be specified in the reclaimed water use plan.
13. Unless decontaminated in a manner approved in writing by the Oregon Health Division, tanker trucks or trailers that transport and/or use reclaimed water may not transport potable water intended for use as domestic water. A tanker truck or trailer that transports and/or uses reclaimed water shall have the words "NONPOTABLE WATER" written in 6-in.-high letters on each side and the rear of the truck. The words "NONPOTABLE WATER" shall not be removed until decontamination as approved by the Health Division has occurred.
14. Aerators or decorative fixtures that may generate aerosols shall not be used unless approved in writing by the Department. Approval will be considered if it can be demonstrated that aerosols will be confined to the area of the impoundment or a restricted area around the impoundment.

Table C.10. Uses of Reclaimed Water in Virginia

Type of Reuse	Category[a]	
	Level 1	**Level 2**
Urban - Unrestricted access All types of landscape irrigation in public access areas (i.e., golf courses, cemeteries, public parks, school yards, and athletic fields) Toilet flushing – nonresidential Firefighting or fire protection and fire suppression in nonresidential buildings	Allowed	

Table C.10. Uses of Reclaimed Water in Virginia

Type of Reuse	Category[a]	
	Level 1	**Level 2**
Outdoor domestic or residential reuse (i.e., lawn watering and noncommercial car washing) Commercial car washes Commercial air-conditioning systems		
Irrigation – Unrestricted access[b] Irrigation for any food crops not commercially processed, including crops eaten raw	Allowed	
Irrigation – Restricted access[b, c] Irrigation for any food crops commercially processed Irrigation for nonfood crops and turf, including fodder, fiber and seed crops; pasture for foraging livestock; sod farms; ornamental nurseries; and silviculture	Allowed	Allowed
Landscape Impoundments[d] Potential for public access or contact	Allowed	
Landscape Impoundments[d] No potential for public access or contact	Allowed	Allowed
Construction[e] Soil compaction Dust control Washing of aggregate Manufacture of concrete	Allowed	Allowed
Industrial[e] Commercial laundries	Allowed	
Industrial[e] Livestock watering[f] Aquaculture[g] Stack scrubbing Street washing Boiler feed Ship ballast Once-through cooling[h] Recirculating cooling towers[h]	Allowed	Allowed

Notes:
a For reclaimed industrial wastewater, minimum standards required shall be determined on a case-by-case basis relative to the proposed reuse or reuses.
b Reclaimed water treated to Level 1 or 2 may be used for surface irrigation, including spray irrigation. Reclaimed water treated to Level 2 may be used for spray irrigation if

Table C.10. Uses of Reclaimed Water in Virginia

Type of Reuse	Category[a]	
	Level 1	Level 2

the area to be irrigated has restricted public access and has appropriate setbacks in accordance with 9VAC25-740-170. Reclaimed water treated to Level 1 or 2 may be used for irrigation of food crops eaten raw, excluding root crops, only when there will be no direct contact (or indirect contact via aerosol carry) between the reclaimed water and edible portions of the crop.

c For irrigation with reclaimed water treated to Level 2, the following shall be prohibited unless Level 1 disinfection is provided:

1. Grazing by milking animals on the irrigation reuse site for 15 days after irrigation with reclaimed water ceases, and
2. Harvesting, retail sale, or access by the general public to ornamental nursery stock or sod farms for 14 days after irrigation with reclaimed water ceases.

d Landscape impoundments may also be used to store reclaimed water for other subsequent reuses of that reclaimed water, such as irrigation, if included in an inventory of reclaimed water storage facilities submitted to the board pursuant to 9VAC25-740-110 C 15.

e Worker contact with reclaimed water treated to Level 2 shall be minimized. Level 1 disinfection shall be provided when worker contact with reclaimed water is likely.

f Level 1 disinfection shall be provided when the reclaimed water is consumed by milking livestock.

g Level 1 disinfection shall be provided for aquaculture production of fish to be consumed raw, such as for sushi.

h Windblown spray generated by once-through cooling or recirculating cooling towers using reclaimed water treated to Level 2 shall not reach areas accessible to workers or the public unless Level 1 disinfection is provided. See also setback requirements in 9VAC25-740-170 for open cooling towers.

Table C.11. Uses of Reclaimed Water in Washington

Type of Reuse	Category			
	Class A	Class B	Class C	Class D
Irrigation of Nonfood Crops				
Trees and fodder, fiber, and seed crops	Allowed	Allowed	Allowed	Allowed
Sod ornamental plants for commercial use and pasture to which milking cows or goats have access	Allowed	Allowed	Allowed	
Irrigation of Food Crops				
Spray irrigation				
All food crops	Allowed			
Food crops which undergo physical or chemical processing sufficient to destroy all pathogenic agents	Allowed	Allowed	Allowed	Allowed
Surface irrigation				
Food crops where there is no reclaimed water contact with edible portion of crop	Allowed	Allowed		
Root crops	Allowed			
Orchards and vineyards	Allowed	Allowed	Allowed	Allowed
Food crops which undergo physical or chemical processing sufficient to destroy all pathogenic agents	Allowed	Allowed	Allowed	Allowed
Landscape Irrigation				
Restricted-access areas (e.g., cemeteries and freeway landscapes)	Allowed	Allowed	Allowed	
Open-access areas (e.g., golf courses, parks, playgrounds, school yards, and residential landscapes)	Allowed			

Table C.11. Uses of Reclaimed Water in Washington

Type of Reuse	Category			
	Class A	Class B	Class C	Class D
Impoundments				
Landscape impoundments	Allowed	Allowed	Allowed	
Restricted recreational impoundments	Allowed	Allowed		
Nonrestricted recreational impoundments	Allowed			
Fish Hatchery Basins	Allowed	Allowed		
Decorative Fountains	Allowed			
Flushing of Sanitary Sewers	Allowed	Allowed	Allowed	Allowed
Street Cleaning				
Street sweeping, brush dampening	Allowed	Allowed	Allowed	
Street washing, spray	Allowed			
Washing of Corporation Yards, Lots, and Sidewalks	Allowed	Allowed		
Dust Control (Dampening of Unpaved Roads and Other Surfaces)	Allowed	Allowed	Allowed	
Dampening of Soil for Compaction (at Construction Sites, Landfills, etc.)	Allowed	Allowed	Allowed	
Water Jetting for Consolidation of Backfill around Pipelines				
Pipelines for reclaimed water, sewage, storm drainage, and gas and conduits for electricity	Allowed	Allowed	Allowed	
Firefighting and Protection				
Dumping from aircraft	Allowed	Allowed	Allowed	
Hydrants or sprinkler systems in buildings	Allowed			
Toilet and Urinal Flushing	Allowed			
Ship Ballast	Allowed	Allowed	Allowed	
Washing of Aggregate and Making of Concrete	Allowed	Allowed	Allowed	
Industrial Boiler Feed	Allowed	Allowed	Allowed	
Industrial Cooling				
Aerosols or other mist not created	Allowed	Allowed	Allowed	
Aerosols or other mist created (e.g., use in cooling towers, forced-air evaporation, or spraying)	Allowed			
Industrial Process				
Without exposure of workers	Allowed	Allowed	Allowed	
With exposure of workers	Allowed			

Table C.12. Uses of Reclaimed Water in Wyoming

Type of Reuse	Category		
	A	B	C
Irrigation			
Land with a high potential for public exposure	Allowed		
Land with a moderate potential for public exposure	Allowed	Allowed	
Land with a low potential for public exposure	Allowed	Allowed	Allowed
Direct-human-consumption food crops	Allowed	Allowed	
Indirect-human-consumption food crops	Allowed	Allowed	Allowed

APPENDIX D

SUGGESTED GUIDELINES FOR WATER REUSE BY USEPA AND USAID[1]

Table D. Suggested Guidelines for Water Reuse by USEPA and USAID

Types of Reuse	Treatment	Reclaimed Water Quality[2]	Reclaimed Water Monitoring	Setback Distances[3]	Comments
Urban Reuse All types of landscape irrigation, (e.g., golf courses, parks, cemeteries) – also vehicle washing, toilet flushing, use in fire protection systems and commercial air conditioners, and other uses with similar access or exposure to the water	Secondary;[4] Filtration,[5] Disinfection[6]	pH = 6–9; < 10-mg/L BOD;[7] < 2 NTU;[8] No detectable fecal coli/100 mL;[9,10] 1-mg/L Cl_2 residual (minimum)[11]	pH - weekly; BOD - weekly; Turbidity continuous; Coliform - daily; Cl_2 residual continuous	50 ft (15 m) to potable water supply wells	See Appendix E. At controlled-access irrigation sites where design and operational measures significantly reduce the potential of public contact with reclaimed water, a lower level of treatment, e.g., secondary treatment and disinfection to achieve < 14 fecal coli/100 mL, may be appropriate. Chemical (coagulant and/or polymer) addition prior to filtration may be necessary to meet water quality recommendations. The reclaimed water should not contain measurable levels of viable pathogens. Reclaimed water should be clear and odorless. A higher chlorine residual and/or a longer contact time may be necessary to ensure that viruses and parasites are inactivated or destroyed. A chlorine residual of 0.5 mg/L or greater in the distribution system is recommended to reduce odors, slime, and bacterial regrowth.
Restricted-access Area Irrigation Sod farms, silviculture sites, and other areas where public access is prohibited, restricted, or infrequent	Secondary;[4] Disinfection[6]	pH = 6–9; < 30-mg/L BOD;[7] < 30-mg/L TSS; < 200 fecal coli/100 mL;[9, 13, 14] 1-mg/L Cl_2 residual (minimum)[11]	pH - weekly; BOD - weekly; TSS - daily; Coliform - daily; Cl_2 residual continuous	300 ft (90 m) to potable water supply wells; 100 ft (30 m) to areas accessible to the public (if spray irrigation)	See Appendix E. If spray irrigation, TSS less than 30 mg/L may be necessary to avoid clogging of sprinkler heads.
Agricultural Reuse – Food Crops Not	Secondary;[4] Filtration,[5]	pH = 6–9; < 10-mg/L BOD;[7]	pH - weekly; BOD - weekly;	50 ft (15 m) to potable water	See Appendix E. Chemical (coagulant and/or polymer) addition prior to

Table D. Suggested Guidelines for Water Reuse by USEPA and USAID

Types of Reuse	Treatment	Reclaimed Water Quality[2]	Reclaimed Water Monitoring	Setback Distances[3]	Comments
Commercially Processed[15] Surface or spray irrigation of any food crop, including crops eaten raw	Disinfection[6]	< 2 NTU[8] No detectable fecal coli/100 mL;[9,10] 1-mg/L Cl_2 residual (minimum)[11]	Turbidity continuous Coliform - daily; Cl_2 residual continuous	supply wells	filtration may be necessary to meet water quality recommendations. The reclaimed water should not contain measurable levels of viable pathogens.[12] A higher chlorine residual and/or a longer contact time may be necessary to ensure that viruses and parasites are inactivated or destroyed. High nutrient levels may adversely affect some crops during certain growth stages.
Agricultural Reuse – Food Crops Commercially Processed[15] Surface irrigation of orchards and vineyards	Secondary;[4] Disinfection[6]	pH = 6–9; < 30-mg/L BOD;[7] < 30-mg/L TSS; < 200 fecal coli/100 mL;[9, 13, 14] 1-mg/L Cl_2 residual (minimum)[11]	pH - weekly; BOD - weekly; TSS - daily; Coliform - daily; Cl_2 residual continuous	300 ft (90 m) to potable water supply wells; 100 ft (30 m) to areas accessible to the public (if spray irrigation)	See Appendix E. If spray irrigation, TSS less than 30 mg/L may be necessary to avoid clogging of sprinkler heads. High nutrient levels may adversely affect some crops during certain growth stages.
Agricultural Reuse – Nonfood Crops Pasture for milking animals; fodder, fiber, and seed crops	Secondary;[4] Disinfection[6]	pH = 6–9; < 30-mg/L BOD;[7] < 30-mg/L TSS; < 200 fecal coli/100 mL[9, 13, 14] 1-mg/L Cl_2 residual (minimum)[11]	pH - weekly; BOD - weekly; TSS - daily; Coliform - daily; Cl_2 residual continuous	300 ft (90 m) to potable water supply wells; 100 ft (30 m) to areas accessible to the public (if spray irrigation)	See Appendix E. If spray irrigation, TSS less than 30 mg/L may be necessary to avoid clogging of sprinkler heads. High nutrient levels may adversely affect some crops during certain growth stages. Milking animals should be prohibited from grazing for 15 days after irrigation ceases. A higher level of disinfection, e.g., to achieve < 14 fecal coli/100 mL, should be provided if this waiting period is not observed.
Recreational Impoundments Incidental contact (e.g., fishing and boating) and full-body contact with reclaimed water allowed	Secondary;[4] Filtration;[5] Disinfection[6]	pH = 6–9; < 10-mg/L BOD;[7] < 2 NTU;[8] No detectable fecal coli/100 mL;[9, 10] 1-mg/L Cl_2 residual (minimum)[11]	pH - weekly; BOD - weekly; Turbidity continuous; Coliform - daily; Cl_2 residual continuous	500 ft (150 m) to potable water supply wells (minimum) if bottom not sealed	Dechlorination may be necessary to protect aquatic species of flora and fauna. Reclaimed water should be unirritating to skin and eyes. Reclaimed water should be clear and odorless. Nutrient removal may be necessary to avoid algal growth in impoundments. Chemical (coagulant and/or polymer) addition prior to filtration may be necessary to meet water quality recommendations. The reclaimed water should not contain measurable levels of viable pathogens.[12] A higher chlorine residual and/or a longer contact time may be necessary to

Table D. Suggested Guidelines for Water Reuse by USEPA and USAID

Types of Reuse	Treatment	Reclaimed Water Quality[2]	Reclaimed Water Monitoring	Setback Distances[3]	Comments
					ensure that viruses and parasites are inactivated or destroyed. Fish caught in impoundments can be consumed.
Landscape Impoundments Aesthetic impoundment where public contact with reclaimed water is not allowed	Secondary;[4] Disinfection[6]	< 30-mg/L BOD;[7] < 30-mg/L TSS; < 200 fecal coli/100 mL;[9, 13, 14] 1-mg/L Cl_2 residual (minimum)[11]	pH - weekly; TSS - daily; Coliform - daily; Cl_2 residual continuous	500 ft (150 m) to potable water supply wells (minimum) if bottom not sealed	Nutrient removal may be necessary to avoid algal growth in impoundments. Dechlorination may be necessary to protect aquatic species of flora and fauna.
Construction Use Soil compaction, dust control, washing aggregate, making concrete	Secondary;[4] Disinfection[6]	< 30-mg/L BOD;[7] < 30-mg/L TSS; < 200 fecal coli/100 mL;[9, 13, 14] 1-mg/L Cl_2 residual (minimum)[11]	BOD - weekly; TSS - daily; Coliform - daily; Cl_2 residual continuous		Worker contact with reclaimed water should be minimized. A higher level of disinfection, e.g., to achieve < 14 fecal coli/100 mL, should be provided when frequent work contact with reclaimed water is likely.
Industrial Reuse Once-through cooling	Secondary;[4] Disinfection[6]	pH = 6–9; < 30-mg/L BOD;[7] < 30-mg/L TSS; < 200 fecal coli/100 mL;[9, 13, 14] 1-mg/L Cl_2 residual (minimum)[11]	pH - weekly; BOD - weekly; TSS - daily; Coliform - daily; Cl_2 residual continuous	300 ft (90 m) to areas accessible to the public	Windblown spray should not reach areas accessible to workers or the public.
Recirculating cooling towers	Secondary;[4] Disinfection[6] (chemical coagulation and filtration 5 may be needed)	Variable depends on recirculation ratio: pH = 6–9; < 30-mg/L BOD;[7] < 30-mg/L TSS; < 200 fecal coli/100 mL;[9, 13, 14] 1-mg/L Cl_2 residual (minimum)[11]	pH - weekly; BOD - weekly; TSS - daily; Coliform - daily; Cl_2 residual continuous	300 ft (90 m) to areas accessible to the public; may be reduced or eliminated if high level of disinfection is provided.	Windblown spray should not reach areas accessible to workers or the public. Additional treatment by user is usually provided to prevent scaling, corrosion, biological growth, fouling, and foaming.

Table D. Suggested Guidelines for Water Reuse by USEPA and USAID

Types of Reuse	Treatment	Reclaimed Water Quality[2]	Reclaimed Water Monitoring	Setback Distances[3]	Comments
Other Industrial Uses	Depends on site-specific uses				
Environmental Reuse Wetlands, marshes, wildlife habitat, stream augmentation	Variable; Secondary;[4] Disinfection[6] (minimum)	Variable, but not to exceed: < 30-mg/L BOD;[7] < 30-mg/L TSS; < 200 fecal coli/100 mL[9, 13, 14]	BOD - weekly; TSS - daily; Coliform - daily; Cl_2 residual continuous		Dechlorination may be necessary to protect aquatic species of flora and fauna. Possible effects on groundwater should be evaluated. Receiving water quality requirements may necessitate additional treatment. The temperature of the reclaimed water should not adversely affect ecosystem.
Groundwater Recharge Spreading or injection into aquifers not used for public water supply	Site-specific and use-dependent; Primary (minimum) for spreading; Secondary[4] (minimum) for injection	Site-specific and use dependent	Depends on treatment and use	Site-specific	Facility should be designed to ensure that no reclaimed water reaches potable water supply aquifers. For spreading projects, secondary treatment may be needed to prevent clogging. For injection projects, filtration and disinfection may be needed to prevent clogging.
Indirect Potable Reuse Groundwater recharge by spreading into potable aquifers	Secondary;[4] Disinfection;[6] May also need filtration[5] and/or advanced wastewater treatment[16]	Secondary;[4] Disinfection;[6] Meet drinking water standards after percolation through vadose zone	Includes, but not limited to, the following: pH - daily; Coliform daily; Cl_2 residual continuous; Drinking water standards quarterly; Other[17] - depends on constituent. BOD - weekly; turbidity continuous	500 ft (150 m) to extraction wells; May vary depending on treatment provided and site-specific conditions	The depth to groundwater (i.e., thickness to the vadose zone) should be at least 6 ft (2 m) at the maximum groundwater mounding point. The reclaimed water should be retained underground for at least 6 months prior to withdrawal. Recommended treatment is site-specific and depends on factors such as type of soil, percolation rate, thickness of vadose zone, native groundwater quality, and dilution. Monitoring wells are necessary to detect the influence of the recharge operation on the groundwater. The reclaimed water should not contain measurable levels of viable pathogens after percolation through the vadose zone.[12]

Table D. Suggested Guidelines for Water Reuse by USEPA and USAID

Types of Reuse	Treatment	Reclaimed Water Quality[2]	Reclaimed Water Monitoring	Setback Distances[3]	Comments
Indirect Potable Reuse Groundwater recharge by injection into potable aquifers	Secondary;[4] Filtration;[5] Disinfection;[6] Advanced wastewater treatment[16]	Includes, but not limited to, the following: pH = 6.5–8.5; < 2 NTU;[8] No detectable total coli/100 mL;[9,10] 1-mg/L Cl_2 residual (minimum);[11] < 3-mg/L TOC; < 0.2-mg/L TOX; Meet drinking water standards	Includes, but not limited to, the following: pH - daily; Turbidity continuous; Total coliform daily; Cl_2 residual continuous; Drinking water standards quarterly; Other[17] - depends on constituent	2000 ft (600 m) to extraction wells; May vary depending on site-specific conditions	The reclaimed water should be retained underground for at least 9 months prior to withdrawal. Monitoring wells are necessary to detect the influence of the recharge operation on the groundwater. Recommended quality limits should be met at the point of injection. The reclaimed water should not contain measurable levels of viable pathogens after percolation through the vadose zone.[12] A higher chlorine residual and/or a longer contact time may be necessary to ensure virus and protozoan inactivation.
Indirect Potable Reuse Augmentation of surface supplies	Secondary;[4] Filtration;[5] Disinfection;[6] Advanced wastewater treatment[16]	Includes, but not limited to, the following: pH = 6.5–8.5; < 2 NTU;[8] No detectable total coli/100 mL;[9,10] 1-mg/L Cl_2 residual (minimum);[11] < 3-mg/L TOC; Meet drinking water standards	Includes, but not limited to, the following: pH - daily; Turbidity continuous; Total coliform daily; Cl_2 residual continuous; Drinking water standards quarterly; Other[17] - depends on constituent	Site-specific	Recommended level of treatment is site-specific and depends on factors such as receiving water quality, time and distance to point of withdrawal, and dilution and subsequent treatment prior to distribution for potable uses. The reclaimed water should not contain measurable levels of viable pathogens.[12] A higher chlorine residual and/or a longer contact time may be necessary to ensure virus and protozoan inactivation.

Notes:
1. These guidelines are based on water reclamation and reuse practices in the United States, and they are especially directed at states that have not developed their own regulations or guidelines. While the guidelines should be useful in many areas outside the United States, local conditions may limit the applicability of the guidelines in some countries. It is explicitly stated that the direct application of these suggested guidelines will not be used by USAID as strict criteria for funding.
2. Unless otherwise noted, recommended quality limits apply to the reclaimed water at the point of discharge from the treatment facility.
3. Setback distances are recommended to protect potable water supply sources from contamination and to protect humans from unreasonable health risks due to exposure to reclaimed water.

Table D. Suggested Guidelines for Water Reuse by USEPA and USAID

Types of Reuse	Treatment	Reclaimed Water Quality[2]	Reclaimed Water Monitoring	Setback Distances[3]	Comments

4. Secondary treatment processes include activated sludge processes, trickling filters, and RBCs and may include stabilization pond systems. Secondary treatment should produce effluent in which both the BOD and TSS do not exceed 30 mg/L.
5. Filtration means the passing of wastewater through natural undisturbed soils or filter media such as sand and/or anthracite or filter cloth or the passing of wastewater through microfilters or other membrane processes.
6. Disinfection means the destruction, inactivation, or removal of pathogenic microorganisms by chemical, physical, or biological means. Disinfection may be accomplished by chlorination, UV radiation, ozonation, other chemical disinfectants, membrane processes, or other processes. The use of chlorine as defining the level of disinfection does not preclude the use of other disinfection processes as an acceptable means of providing disinfection for reclaimed water.
7. As determined from the BOD_5.
8. The recommended turbidity limit should be met prior to disinfection. The average turbidity should be based on a 24-h time period. The turbidity should not exceed 5 NTU at any time. If TSS is used in lieu of turbidity, the TSS should not exceed 5 mg/L.
9. Unless otherwise noted, recommended coliform limits are median values determined from the bacteriological results of the last 7 days for which analyses have been completed. Either the membrane filter or fermentation-tube technique may be used.
10. The number of fecal coliform organisms should not exceed 14/100 mL in any sample.
11. Total chlorine residual should be met after a minimum contact time of 30 min.
12. It is advisable to fully characterize the microbiological quality of the reclaimed water prior to implementation of a reuse program.
13. The number of fecal coliform organisms should not exceed 800/100 mL in any sample.
14. Some stabilization pond systems may be able to meet this coliform limit without disinfection.
15. Commercially processed food crops are those that, prior to sale to the public or others, have undergone chemical or physical processing sufficient to destroy pathogens.
16. Advanced wastewater treatment processes include chemical clarification, carbon adsorption, RO and other membrane processes, air stripping, UF, and ion exchange.
17. Monitoring should include inorganic and organic compounds, or classes of compounds, that are known or suspected to be toxic, carcinogenic, teratogenic, or mutagenic and are not included in the drinking water standards.

APPENDIX E

RECOMMENDED LIMITS FOR CONSTITUENTS IN RECLAIMED WATER FOR IRRIGATION BY USEPA AND USAID

Table E. Recommended Limits for Constituents in Reclaimed Water for Irrigation by USEPA and USAID

Constituent	Long-Term Use (mg/L)	Short-Term Use (mg/L)	Remarks
Aluminum	5	20	Can cause a loss of productivity in acid soils, but soils at pH 5.5 to 8.0 will precipitate the ion and eliminate toxicity.
Arsenic	0.1	2	Toxicity to plants varies widely, ranging from 12 mg/L for Sudan grass to less than 0.05 mg/L for rice.
Beryllium	0.1	0.5	Toxicity to plants varies widely, ranging from 5 mg/L for kale to 0.5 mg/L for bush beans.
Boron	0.75	2	Essential to plant growth, with optimum yields for many obtained at a few tenths of a milligram per liter in nutrient solutions. Toxic to many sensitive plants (e.g., citrus) at 1 mg/L. Usually sufficient quantities in reclaimed water to correct soil deficiencies. Most grasses are relatively tolerant at 2.0 to 10 mg/L.
Cadmium	0.01	0.05	Toxic to beans, beets, and turnips at concentrations as low as 0.1 mg/L in nutrient solution. Conservative limits recommended.
Chromium	0.1	1	Not generally recognized as an essential growth element. Conservative limits recommended because of lack of knowledge on toxicity to plants.
Cobalt	0.05	5	Toxic to tomato plants at 0.1 mg/L in nutrient solution. Tends to be inactivated by neutral and alkaline soils.
Copper	0.2	5	Toxic to a number of plants at 0.1 to 1.0 mg/L in nutrient solution.
Fluoride	1	15	Inactivated by neutral and alkaline soils.
Iron	5	20	Not toxic to plants in aerated soils but can contribute to soil acidification and loss of essential phosphorus and molybdenum.
Lead	5	10	Can inhibit plant cell growth at very high concentrations.
Lithium	2.5	2.5	Tolerated by most crops at concentrations up to 5 mg/L; mobile in soil. Toxic to citrus at low doses—recommended limit is 0.075 mg/L.
Manganese	0.2	10	Toxic to a number of crops at a few tenths of a milligram to a few milligrams per liter in acidic soils.
Molybdenum	0.01	0.05	Nontoxic to plants at normal concentrations in soil and water. Can be toxic to livestock if forage is grown in soils with high levels of available molybdenum.

Table E. Recommended Limits for Constituents in Reclaimed Water for Irrigation by USEPA and USAID

Constituent	Long-Term Use (mg/L)	Short-Term Use (mg/L)	Remarks
Nickel	0.2	2	Toxic to a number of plants at 0.5 to 1.0 mg/L; reduced toxicity at neutral or alkaline pH.
Selenium	0.02	0.02	Toxic to plants at low concentrations and to livestock if forage is grown in soils with low levels of selenium.
Tin, tungsten, and titanium	—	—	Effectively excluded by plants; specific tolerance levels unknown.
Vanadium	0.1	1	Toxic to many plants at relatively low concentrations.
Zinc	2	10	Toxic to many plants at widely varied concentrations; reduced toxicity at increased pH (6 or above) and in fine-textured or organic soils.
Constituent	**Recommended Limit**		**Remarks**
pH	6		Most effects of pH on plant growth are indirect (e.g., pH effects on heavy metals' toxicity described above).
TDS	500 to 2000 mg/L		Below 500 mg/L, no detrimental effects are usually noticed. Between 500 and 1000 mg/L, TDS in irrigation water can affect sensitive plants. At 1000 to 2000 mg/L, TDS levels can affect many crops and careful management practices should be followed. Above 2000 mg/L, water can be used regularly only for tolerant plants on permeable soils.
Free chlorine residual	<1 mg/L		Concentrations greater than 5 mg/L cause severe damage to most plants. Some sensitive plants may be damaged at levels as low as 0.05 mg/L.

APPENDIX F

RECOMMENDED MINIMUM VERIFICATION MONITORING OF MICROBIAL PERFORMANCE TARGETS FOR WASTEWATER AND EXCRETA USE IN AGRICULTURE AND AQUACULTURE BY THE WHO

Table F. Recommended Minimum Verification Monitoring of Microbial Performance Targets for Wastewater and Excreta Use in Agriculture and Aquaculture by WHO

Activity/Exposure	**Water Quality Monitoring[a] Parameters**	
Agriculture	*E. coli* per 100 mL[b] (arithmetic mean)	Helminth eggs per liter[b] (arithmetic mean)
Unrestricted irrigation		
Root crops	$\leq 0.10^{3}$	≤ 0.1
Leaf crops	$\leq 0.10^{4}$	
Drip irrigation, high-growing crops	$\leq 0.10^{5}$	
Restricted irrigation		
Labor-intensive, high-contact agriculture	$\leq 0.10^{4}$	≤ 0.1
Highly mechanized agriculture	$\leq 0.10^{5}$	
Septic tank	$\leq 0.10^{6}$	
Aquaculture	*E. coli* per 100 mL[b] (arithmetic mean)	Viable trematode eggs per liter[b]
Produce consumers		
Pond	$\leq 0.10^{4}$	Not detected
Wastewater	$\leq 0.10^{5}$	Not detected
Excreta	$\leq 0.10^{6}$	Not detected
Workers, local communities		
Pond	$\leq 0.10^{3}$	No viable trematode eggs
Wastewater	$\leq 0.10^{4}$	No viable trematode eggs
Excreta	$\leq 0.10^{5}$	No viable trematode eggs

Notes:
[a]Monitoring should be conducted at the point of use or the point of effluent discharge. Frequency of monitoring is as follows:
- Urban areas: one sample every 2 weeks for *E. coli* and one sample per month for helminth eggs.
- Rural areas: one sample every month for *E. coli* and one sample every 1–2 months for helminth eggs.

Five-liter composite samples are required for helminth eggs prepared from grab samples taken six times per day. Monitoring for trematode eggs is difficult because of a lack of standardized procedures. The inactivation of trematode eggs should be evaluated as part of the validation of the system.
[b]For excreta, weights may be used instead of volumes, depending on the type of excreta: 100 mL of wastewater is equivalent to 1–4 g of total solids; 1 L = 10–40 g of total solids. The required *E. coli* or helminth numbers would be the same per unit of weight.

APPENDIX G

REGULATIONS FOR OPERATOR CERTIFICATION IN CALIFORNIA

Title 23. Waters
Division 3. State Water Resources Control Board
and Regional Water Quality Control Boards
Chapter 26. Classification of Wastewater Treatment Plants
and Operator Certification
Article 1. General Provisions

§ 3670. Purpose.

The primary purpose of the Wastewater Treatment Plant Classification, Operator Certification, and Contract Operator Registration Program is to protect public health and the environment by providing for the effective operation of wastewater and water recycling treatment plants through the certification of wastewater treatment plant operators.

§ 3670.1. Certification Requirements for Operation of Wastewater Treatment Plants.

No person shall operate a wastewater treatment plant within the meaning of these regulations unless that person has been certified by the division as a wastewater treatment plant operator or operator-in-training at a grade appropriate for the class of plant being operated.

§ 3670.2. Certification Requirement for Operation of Water Recycling Treatment Plants.

(a) Except as provided in subsection (b) below, no person shall operate a water recycling treatment plant unless that person has been certified by the division as a wastewater treatment plant operator or operator-in-training at a grade appropriate for the class of plant being operated.

(b) A person certified by the Department of Health Services as a water treatment plant operator may operate a water recycling treatment plant at a grade appropriate for the class of plant operated.

(c) The State Board may refuse to approve use of a certificate issued by the Department of Health Services or suspend or revoke its approval of the use of the certificate if the operator commits any of the prohibited acts described in Article 7 (commencing with section 3710) of Chapter 26 of Division 3 of the California Code of Regulations.

§ 3671. Definitions.

The following definitions shall apply to this chapter:

(a) “Activated sludge treatment” means a wastewater treatment process in which predominantly biodegradable pollutants in wastewater are adsorbed and/or absorbed by a suspended mass of living aerobic organisms called “activated sludge”. The suspended mass is subsequently separated from the treated wastewater by a sedimentation process either for further use in the process or for disposal.

(b) “Agency” or “municipality” means any government agency created by federal law or any city, town, county, district, or other government created by or pursuant to state law which owns or operates a wastewater treatment plant. “Agency” also includes any privately-owned organization which owns or operates a wastewater treatment plant regulated by the Public Utilities Commission pursuant to Sections 216 and 230.6 of, and Chapter 4 (commencing with Section 701) of Part 1 of division 1 of the Public Utilities Code.

(c) “Appellant” means a person who appeals a decision made by the Office of Operator Certification or division Chief regarding denial of an application, the results of an examination, or disciplinary action taken.

(d) “Applicant” means a person who files an application for an examination, certification, renewal, or reinstatement as a wastewater treatment plant operator or operator-in-training.

(e) “Basic science courses” means college-level courses in the combined fields of mathematics, physics, chemistry, and biology.

(f) “Biological filtration treatment” (biofiltration) means a wastewater treatment process in which predominantly biodegradable pollutants in wastewater are adsorbed and/or absorbed by masses of living aerobic organisms and which are attached to stationary support media as the wastewater is caused to trickle over the media. Settleable material that may have sloughed from the medium surfaces is subsequently separated from the treated wastewater by a sedimentation process for disposal.

(g) "Board" or "State Water Board" as used in this chapter means the five members of the State Water Resources Control Board.

(h) "Chief Plant Operator" means a supervisor who is certified as an operator and who is responsible for the overall operation of a wastewater treatment plant.

(i) "Contract operator" means any person or entity who enters a promissory agreement to operate a wastewater treatment plant.

(j) "Direct supervision" means the oversight and inspection of the work performance of an operator-in-training by the supervisor, without an intervening person, to ensure the safe and proper execution of the duties of the operator-in-training.

(k) "Division" means that unit of the division of the board in which the Office of Operator Certification is located.

(1) "Extended aeration treatment" means a modification of the activated sludge treatment process which utilizes long aeration periods to promote aerobic digestion of the biomass.

(m) "Maintenance" means those activities which will be credited toward operator experience under the certification program. Those activities are limited to the day-to-day servicing, adjustment or regulation of equipment which are performed by an operator and are necessary to maintain reliable operation of major treatment processes.

(n) "Office of Operator Certification" means that unit of the division which administers the Wastewater Treatment Plant Classification and Operator Certification Program.

(o) "Operates" means the performance of day-to-day activities primarily consisting of the control of any process which may affect the quality of the discharge of a wastewater treatment plant. "Operates" may include performance of day-to-day maintenance work so long as the primary function of the operator is control of the process. "Operates" does not include maintenance functions which are not necessary for the reliable operation of major treatment processes.

(p) "Operator" means any person operating a wastewater treatment plant and who occupies a position and performs duties for which the Office of Operator Certification requires an operator certificate.

(q) "Operator-in-training" means any person who operates a wastewater treatment plant under the direct supervision of a certified operator while gaining experience to qualify for an operator certificate.

(r) "Pond treatment" means processing in a pond in which biological oxidation of organic matter is effected by natural or artificially accelerated transfer of oxygen to the water.

(s) "Preliminary treatment" means a process or processes to remove or reduce in size solids which could damage equipment or reduce effectiveness of other treatment processes.

(t) "Primary treatment" means a wastewater treatment process that allows those substances in wastewater that readily settle or float to be separated from the water being treated.

(u) "Secondary treatment" means treatment beyond primary treatment to remove colloidal and dissolved organic matter and further remove suspended matter, usually by biological processes such as activated sludge and biological filtration treatment.

(v) "Shift supervisor" means a certified operator who oversees and directs the operation or a phase of operation of a wastewater treatment plant during a specific work period and who reports to a supervisor or a chief plant operator.

(w) "Supervisor" means a certified operator who oversees and directs the operation of a wastewater treatment plant, who inspects the performance of other operators of a wastewater treatment plant, and who reports to the chief plant operator.

(x) "Tertiary treatment" (advanced waste treatment) means treatment beyond secondary treatment, which may include filtration, coagulation and nutrient removal, but excluding disinfection.

(y) "Wastewater treatment plant" means either of the following:

(l) Any facility owned by a state, local, or federal agency and used in the treatment or reclamation of sewage and industrial wastes.

(2) Any privately owned facility used in the treatment or reclamation of sewage and industrial wastes, and regulated by the Public Utilities Commission pursuant to Sections 216 and

230.6 of, and Chapter 4 (commencing with Section 701) of Part 1 of Division 1, of the Public Utilities Code.

(z) "Water recycling treatment plant" means a treatment plant that receives and further treats secondary and/or tertiary effluent from a wastewater treatment plant.

Article 2. Classification of Wastewater Treatment Plants and Agency Reporting Requirements

§ 3675. Classification of Wastewater and Water Recycling Treatment Plants.

(a) The division shall classify all wastewater treatment plants, including water recycling treatment plants, according to the following criteria:

Class	Treatment Process	Design Flow (in millions of gallons per day)
I	Pond	All
	Primary	1.0 or less
II	Primary	Greater than 1.0 through 5.0
	Biofiltration	1.0 or less
	Extended Aeration	All
III	Primary	Greater than 5.0 through 20.0
	Biofiltration	Greater than 1.0 through 10.0
	Activated Sludge	5.0 or less
	Tertiary	1.0 or less
IV	Primary	Greater than 20.0
	Biofiltration	Greater than 10.0 through 30.0
	Activated Sludge	Greater than 5.0 through 20.0
	Tertiary	Greater than 1.0 through 10.0
V	Biofiltration	Greater than 30.0
	Activated Sludge	Greater than 20.0
	Tertiary	Greater than 10.0

(b) Plants may be classified in a group different than indicated in this section if:

(1) they have characteristics which make operation more difficult than the operation of other similar plants of the same flow range; or,

(2) the conditions of flow or the use of the receiving waters require an unusually high degree of plant operational control; or,

(3) they use an approved method of wastewater treatment which is not included in this section.

§ 3676. Reporting Requirements by Agencies to the Division.

(a) Within 30 calendar days after a plant begins operating, each agency shall submit to the division a description of the plant's treatment processes, a design f low of the plant, an organization chart, and job descriptions and duty rosters for plant personnel.

(b) Each agency shall notify the division in writing within 30 calendar days of a change in the employment of the person designated as chief plant operator and any change in the reportable items in subsection (a) above which may affect the classification of the wastewater treatment plant.

(c) Each agency shall notify the division in writing within 30 calendar days of any final disciplinary action resulting in suspension, demotion, or discharge of a certified operator or operator-in-training if the disciplinary action is the result of the operator's commission of any of the acts which are grounds for discipline listed in Section 3710. The notice shall identify the name of the operator or operator-in-training, the specific violations and the disciplinary action taken.

(d) Reports regarding final disciplinary action received from agencies shall be retained in state board files for a period of three years unless the state board takes disciplinary action. If the state board takes disciplinary action, reports submitted by agencies shall remain in state board files for ten years.

Article 3. Grades of Operator Certification for the Operation of Wastewater Treatment Plants

§ 3680. Grades of Operator Certification.

(a) Chief Plant Operators - For all plant classes, each chief plant operator shall possess a valid operator certificate of a grade at least equivalent to the class of plant operated.

(b) Supervisors and Shift Supervisors

(l) In Class II, III, and IV plants, supervisors and shift supervisors shall possess valid operator certificates no more than one grade lower than the class of plant operated.

(2) In Class V plants, shift supervisors shall possess at least valid Grade III certificates and supervisors shall possess at least Grade IV certificates.

(c) Operators - Each operator shall possess at least a valid Grade I certificate or a valid operator-in-training certificate. In Class IV and V plants. 50 percent of the operators shall possess at least valid Grade II certificates or valid operator-in-training certificates at the Grade II or higher level.

Article 4. Minimum Qualifications

§ 3683. Education and Experience Requirements.

(a) No person shall be issued a certificate unless that person passes a written examination specified by these regulations and meets the education and experience requirements prescribed by this article.

(b) Persons may apply to take an operator certification examination if:

(1) they have completed the education necessary for the certificate prior to the final filing date for the examination, in accordance with the provisions of subsection (c) of this section; and,

(2) there is sufficient time to gain the experience necessary to qualify for the certificate for which they are applying within four years of June 30 or December 31 (whichever is sooner) following an examination for Grades II, III. IV, and V and within 2 years of June 30 or December 31 (whichever is sooner) following an examination for Grade I.

(c) Eligibility for certification shall be based on the following qualifications for each grade of wastewater treatment plant operator. Educational points shall be credited pursuant to the provisions of Section 3685.

(1) Grade I:

Education: Six educational points; AND,

Experience: One year of experience performing the functions of a wastewater treatment plant operator

(2) Grade II:

(A) Education: Graduation from high school or equivalent as specified in Section 3686 and six educational points; AND,

Experience: Two years of experience performing the functions of a wastewater treatment plant operator; OR,

(B) Experience: One and one-half years of experience performing the functions of a wastewater treatment plant operator while certified as a Grade I operator.

(3) Grade III:

(A) Education: An associate degree or completion of 60 semester units at a college or university, either of which includes 15 semester units of basic science courses; AND,

Experience: Two years of experience performing the functions of a wastewater treatment plant operator; OR,

(B) Education: Graduation from high school or equivalent as specified in Section 3686 and 16 educational points; AND,

Experience: Fours years of experience performing the functions of a wastewater treatment plant operator; OR,

(C) Experience: Three years of experience performing the functions of a wastewater treatment plant operator while certified as a Grade II operator.

(4) Grade IV:

(A) Education: A bachelor’s degree with a major related to wastewater treatment and which includes a minimum of 30 semester units of basic science courses; AND, Experience: Two years of experience performing the functions of a wastewater treatment plant operator; OR,

(B) Education: An associate degree or completion of 60 semester units at a college or university, either of which includes 15 semester units of basic science courses; AND,
Experience: Fours years of experience performing the functions of a wastewater treatment plant operator; OR,

(C) Education: Graduation from high school or equivalent as specified in Section 3686 and 32 educational points; AND,
Experience: Six years of experience performing the functions of a wastewater treatment plant operator; OR,

(D) Experience: Fours years of experience performing the functions of a wastewater treatment plant operator while certified as a Grade III operator.

(5) Grade V:

(A) Credential: A valid license as a civil or chemical engineer issued by the California Department of Consumer Affairs, Board of Registration for Professional Engineers and Land Surveyors; AND,
Experience: Four years of experience performing the functions of a wastewater treatment plant operator; OR,

(B) Education: A bachelor's degree with a major related to wastewater treatment and which includes a minimum of 30 semester units of basic science courses; AND,
Experience: Five years of experience performing the functions of a wastewater treatment plant operator; OR,

(C) Education: An associate degree or completion of 60 semester units at a college or university, either of which includes 15 semester units of basic science courses; AND,
Experience: Six years of experience performing the functions of a wastewater treatment plant operator; OR,

(D) Education: Graduation from high school or equivalent as specified in Section 3686 and 48 educational points; AND,
Experience: Ten years of experience performing the functions of a wastewater treatment plant operator; OR,

(E) Experience: Six years of experience performing the functions of a wastewater treatment plant operator while certified as a Grade IV operator.

§ 3684. Experience Credits.

(a) Applicants may be credited with one year of experience if they have had two or more years of full-time experience in the operation of a water treatment plant regulated by the California Department of Health Services or by a government agency in another state and while in possession of a valid water treatment plant operator certificate, if:

(1) the water treatment plant where the experience was gained uses two or more of the following processes: coagulation, sedimentation, aeration, filtration, oxidation. or disinfection; and,

(2) at the time of their application for certification, they have had one year of full-time experience in the operation of a wastewater treatment plant.

(b) Applicants, who have one year of experience in the operation of a wastewater treatment plant may substitute 16 educational points for one year of experience. Those educational points used to substitute for experience at one grade may not be used again to substitute for experience at another grade. The substitution may not be made by applicants qualifying under the provisions of Sections 3683 (c) (1) and 3683 (c) (4) (A).

§ 3685. Educational Points.

(a) Pursuant to the provisions of this article, applicants may be required to obtain educational points to qualify for certification. Educational points may be earned as follows:

(1) One completed three-unit semester course which is directly related to wastewater treatment and which is part of the curriculum of an accredited college or university is equal to eight educational points. Completed courses which result in more or less than

three units or which are quarter units rather than semester units will be credited with educational points on a proportional basis.

(2) All other courses will be assigned educational points at the rate of one educational point per 10 hours of completed classroom instruction. Subjects which are directly related to wastewater treatment shall be assigned full credit for educational points. Subjects which are indirectly related shall be given one half credit.

(3) One Continuing Education Unit which is directly related to wastewater treatment is equal to one educational point.

(b) Applicants may not substitute experience for educational points.

§ 3686. High School Equivalence.

High school equivalence may be obtained by substituting six educational points for each uncompleted year of high school through grade 12 or by passing an approved General Educational Development test, or by obtaining a Certificate of Proficiency issued by the State Board of Education in accordance with Section 48412 of the Education Code.

Article 5. Examination and Certification of Wastewater Treatment Plant Operators

§ 3700. Application for Examination.

(a) Content - An application for examination shall contain but not be limited to the following information:

(1) the applicant’s full name, mailing address, work telephone number, and date of birth;

(2) information regarding former employment, current operator status, other operator certificates held in California or other states, engineering registrations held, and education and experience gained;

(3) if employed as an operator, the original signature of the chief plant operator, verifying the applicant’s experience as an operator;

(4) the applicant’s original signature;

(5) copies of college transcripts, grade cards, or certificates of completion for courses related to wastewater treatment to verify completion of education requirements;

(6) any additional information, evidence, statements, or documents to support the application for examination as requested by the division; and,

(7) the application fee and examination fee as prescribed by Article 8.

(b) Submittal - Applications for examination shall be postmarked by the final filing date as specified in this subsection. Applications postmarked after the final filing date shall be held over and processed for the next scheduled examination.

Date of Examination	Final Filing Date
April 10, 1999	February 1, 1999
October 2, 1999	August 1, 1999
April 1, 2000	February 1, 2000
October 7, 2000	August 1, 2000
April 7, 2001	February 1, 2001
October 6, 2001	August 1, 2001
April 6, 2002	February 1, 2002
October 5, 2002	August 1, 2002
April 5, 2003	February 1, 2003
October 4, 2003	August 1, 2003
April 3, 2004	February 1, 2004
October 2, 2004	August 1, 2004

(c) Division review - The division shall review applications and supporting documents to determine eligibility for examination.

Unless otherwise specified by this chapter, division evaluation of experience gained in California will be based on work performed while employed in a position which requires operator certification in California. Evaluation of experience gained outside California will be based on work performed while employed in a position comparable to one which requires operator certification in California. Division evaluation of experience will be based on the actual work performed by the applicant without respect to job titles assigned by the employing agencies.

(d) Notice - The division shall notify applicants in writing within 30 calendar days of receipt of an application whether it is complete or deficient. If there is a deficiency, the division shall identify the deficiency and inform the applicant in writing of the specific information required.

(e) Deficient applications - Applications which do not contain proof of completion of education requirements and the correct application and examination fees shall be considered deficient applications. Deficient applications shall not be processed for the current examination. The applicant shall be required to reapply to take a subsequent examination.

(f) Processing times - the division's median, minimum, and maximum processing times for applications for examination between September 1989 and September 1991 were:

Median - 30 days
Minimum - 3 days
Maximum - 112 days

§ 3701. Examinations.

(a) Written examinations for each wastewater treatment plant operator grade shall contain questions to determine applicants' knowledge of wastewater treatment plant operation. Mathematical problems related to process control and evaluation will be included. Each higher grade examination will require progressively more detailed knowledge of the subject matter.

(b) Content by grade

(l) Grade I examinations shall contain questions regarding knowledge of basic safety practices and hazards related to the operation of wastewater treatment plants; wastewater constituents including simple and routine sampling and analysis procedures; procedures involved in operating and maintaining preliminary and primary treatment facilities including sludge digestion and disinfection; specifics regarding the operation of stabilization ponds; and state regulations regarding the classification of wastewater treatment plants and operator certification.

(2) Grade II examinations shall contain questions regarding knowledge of those components of the Grade I examination as prescribed in (1) above; commonly used processes for preliminary, primary, and secondary treatment including disinfection, sludge handling, and digestion; routine sampling and analysis procedures for evaluation of process and overall plant performance; and basic supervision responsibilities.

(3) Grade III examinations shall contain questions regarding knowledge of those components of the Grade I and II examinations as prescribed in (1) and (2) above; limitations, controls, and performance calculations for primary and secondary treatment and sludge-handling processes; basic principles of tertiary treatment processes; state regulations regarding water recycling; and public health issues.

(4) Grade IV examinations shall contain questions regarding knowledge of those components of the Grade I, II, and III examinations as prescribed in (1), (2), and (3) above; limitations, controls, and performance calculations for tertiary treatment processes; wastewater treatment requirements and practices for water reclamation and reuse; supervision and management responsibilities including energy management, safety program development and control, and operator training and budget development and control.

(5) Grade V examinations shall contain questions regarding knowledge of those components of the Grades I, II, III, and IV examinations as prescribed in (1), (2), (3), and (4) above.

(c) Frequency - A minimum of two examinations shall be given each year.

(d) Dishonest conduct - An applicant who engages in dishonest conduct during an examination shall have his or her examination materials confiscated, shall not have the examination graded, and shall be denied the opportunity to take the next scheduled examination. The application and examination fees paid by the applicant shall not be refunded. The applicant also may be subject to administrative sanctions pursuant to Article 7 and Section 13627 of the Water Code.

(e) Confidentiality of examination questions - Examination questions are confidential. Any person who copies questions or removes all or part of any examination from the examination room or who conveys or exposes all or part of any examination for an unauthorized use may be denied certification pursuant to the provisions of Article 7. The applicant also may be subject to administrative sanctions pursuant to Article 7 and Section 13627 of the Water Code.

(f) Notification of results - Within 90 calendar days after an examination, the division shall notify applicants in writing whether they have passed or failed the examination.

(1) If an applicant fails the examination, he or she may be eligible to take a subsequent examination upon request and upon submitting an application and examination fee prescribed by Article 8. The request for re-examination must be postmarked by the final filing date set forth in Section 3700.

(2) An applicant who passes the examination and who had completed the education and experience requirements before taking the examination shall be instructed in the notice of examination results to remit the applicable certification fee. Within 30 calendar days of receiving the certification fee, the division shall issue the operator certificate.

(3) An applicant who passes the examination before completing the experience requirements shall apply for certification upon completing the requirements in accordance with the provisions of Section 3702.

(g) Expiration of examination results - Examination results are valid for four years from June 30 or December 31 following the examination (whichever date is sooner).

§ 3702. Application for Certification.

(a) If an applicant is qualified for certification at the time of the examination, and has documented such qualification in the application for examination, no application for certification is required. However, if an applicant must gain experience after the final filing date for the examination before being eligible for certification, an application for certification is required in accordance with the provisions of this section.

(b) An application for certification shall include but not be limited to:

(1) the applicant’s full name, mailing address, work telephone number, and date of birth;

(2) all employment, education, and experience information not reported on the application for examination, including current employment and current operator status;

(3) the date when the applicant passed the examination;

(4) information regarding current employment and current operator status;

(5) the applicant’s original signature;

(6) if employed at a wastewater treatment plant, the chief plant operator’s original signature; AND,

(7) the certification fee prescribed by Article 8.

§ 3702.1. Issuance of Certificates.

(a) Operator certificates issued by the division shall contain but not be limited to the following:

(1) The operator’s name and grade;

(2) The certificate number;

(3) The issue date of the certificate;

(4) The State Water Board seal;

(5) The name, “State Water Resources Control Board”; AND,

(6) The signature of a board member or board member designee.

(b) Upon successful completion of the application and examination process and within 30 calendar days of payment of the certification fee prescribed by Article 8, the board shall issue an operator certificate or operator-in-training certificate.

(c) The issue date of a certificate shall be the date of receipt of an application for examination and certification which meets the requirements of these regulations.

(d) The division may refuse to issue a certificate if it has determined that the applicant has committed any act which is grounds for disciplinary action as specified in section 3710.

§ 3702.2. Application for Certificate Renewal.

(a) Renewal dates - Except as specified in Subsection 3709 (d), operator certificates are renewable every two years. Certificates issued for applications with a postmark between May 1 and October 31 shall have a renewal date of June 30. Certificates issued for applications with a postmark between November 1 and April 30 shall have a renewal date of December 31.

(b) Division notice - At least 60 calendar days prior to expiration of an operator certificate, the division shall provide written notification of the expiration date to the certificate holder at his or her address of record. Failure to receive a notice of renewal does not relieve the certificate holder from the responsibility of renewing a certificate on or before the expiration date.

(c) Content - An application for renewal shall include but not be limited to:

(1) the applicant's name, mailing address, grade, certificate number, and classification or title;

(2) if employed by a wastewater treatment plant as an operator, the name, telephone number, and mailing address of the wastewater treatment plant where employed and the name of the supervisor;

(3) the renewal fee prescribed by Article 8.

(d) Submittal - A certificate holder who wishes to renew a certificate shall submit to the division a completed application as specified in subsection (c) of this section. The application shall be postmarked no later than the expiration date on the certificate.

(e) Division review - Within 15 calendar days of receipt of an application for renewal, the division shall notify the certificate holder if the application is deficient. If there is a deficiency, the division shall inform the certificate holder by telephone or letter of the specific information necessary to complete the application for renewal. Deficiencies will not prevent the Office of Operator Certification from issuing a new certificate if the application and fee are postmarked by the expiration date of the certificate.

§ 3702.3. Issuance of Renewal Certificate.

An operator certificate shall indicate the first expiration date of the certificate. Thereafter, a renewal certificate shall be issued in accordance with the provisions of Section 3702.2 and this section.

(a) Within 30 calendar days of receipt of a completed application for renewal, the division shall issue a renewal certificate or inform the applicant of the reason the certificate will not be issued.

(b) The renewal certificate shall not be issued until any unpaid fees have been paid.

(c) The division may refuse to renew a certificate if it has determined that the applicant has operated a wastewater treatment plant while the operator certificate was expired or at a grade for which the applicant was not certified or that the applicant has committed any act which is grounds for disciplinary action.

(d) A renewal certificate shall contain but not be limited to the following:

(1) The certificate holder's name and address;

(2) The certificate number and grade;

(3) The expiration date of the certificate.

§ 3702.4. Reinstatement.

(a) An expired operator certificate may be reinstated within one year following the expiration of the certificate, provided the holder of the expired certificate applies for renewal and reinstatement as prescribed by Subsection (b) of this section. A certificate which has been expired for more than one year shall not be reinstated. If the applicant wishes to become certified again, he or she must meet all requirements for an initial operator certificate.

(b) The application for reinstatement shall be considered complete when it includes the renewal and reinstatement fees prescribed by Article 8 and all the information required to renew the certificate as prescribed by Section 3702.2.

(c) The division may refuse to reinstate a certificate if it has determined that the applicant has operated a wastewater treatment plant while his or her certificate was expired or at a grade for which he or she was not certified or has committed any act which is grounds for disciplinary action.

(d) The expiration date of a reinstated certificate shall remain the same as if the certificate had not expired.

§ 3702.5. Replacement.

A certificate which has been lost, stolen, or destroyed may be replaced by the division, provided the operator or operator-in-training submits a signed statement explaining the circumstances of the loss, theft or destruction of the certificate. A replacement fee prescribed by Article 8 must be submitted with the signed statement.

§ 3703. Posting Certificates.

Certified operators and operators-in-training shall display their valid certificates at the wastewater treatment plant where employed.

§ 3704. Reciprocity with Other States.

(a) The division may issue Grades I and II operator certificates by reciprocity in accordance with the procedures set forth in Article 5. No examination or examination fee will be required of persons who hold comparable certifications in other states, provided:

(1) the experience and education requirements of that state are comparable to the division's requirements;

(2) the applicant has passed a written examination within the preceding four years in another state that is comparable to the examination given by the division;

(3) reciprocal privileges are granted by the other state to operators certified by the division;

(4) the applicant completes an application for operator certification and meets the minimum qualifications for certification in California; AND,

(5) the applicant pays the application, certification, and reciprocity fees prescribed by Article 8.

(b) The division may refuse to issue an operator's certificate by reciprocity if it has determined that the applicant's certificate to operate a wastewater treatment plant has been revoked or suspended in another state, or if the applicant has been otherwise disciplined in another state for any of the violations set forth in Section 3710.

§ 3707. Employment of an Operator-in-Training.

An agency may employ a person to act in the capacity of any grade of certified operator, provided the person is certified as an operator-in-training, is under the direct supervision of a certified operator of the same or higher grade, and is performing the duties of the grade of operator for which the certificate was issued.

§ 3708. Application for Operator-in-Training Examination and Certification.

(a) Persons may apply for examination and operator-in-training certification in accordance with the procedures set forth in Article 5.

(b) Applicants for Grade I operator-in-training certification may, but are not required to, pass the Grade I examination prior to issuance of the Grade I operator-in-training certificate.

(c) Persons may apply for operator-in-training certification at the Grades II, III, IV, and V levels if they:

(1) meet the minimum education requirements and could meet the minimum experience requirements for the grade for which they are applying as prescribed in Article 4 within four years of June 1 or December 1 following the examination (whichever date is sooner); and,

(2) pass the examination at the grade for which they are applying; and,

(3) make application for examination and operator-in-training certification in accordance with the procedures set forth in Sections 3700, 3701, and 3702 of Article 5; and,

(4) supply the name and telephone number of the supervising operator.

(d) Applications for operator-in-training certification at any grade must be signed by the chief plant operator of the plant where the operator-in-training is to be employed.

Article 6. Operators-in-Training

§ 3709. Issuance, Renewal, and Replacement of Operator-in-Training Certificates.

(a) Operator-in-training certificates shall be issued in the name of the applicant to the mailing address of the employing wastewater treatment plant. Operator-in-training certificates are valid only while the operator is employed at the plant for which the certificate was issued. The expiration date of the operator-in-training certificate shall not exceed the expiration date of the applicant's examination results.

(b) Operator-in-training certificates issued by the division shall contain but not be limited to the following:

(1) The name and grade of the operator-in-training;

(2) The issue date of the certificate; and,

(3) The name of the wastewater treatment plant at which the operator-in-training is to be employed.

(c) Operator-in-training certificates shall be issued, renewed, reinstated, and replaced in accordance with the provisions of Article 5 unless otherwise specified in this article.

(d) Operator-in-training certificates at the Grade I level are valid for up to two years. If the Grade I operator passes the Grade I examination before the expiration of the Grade I operator-in-training certificate, that certificate may be renewed one time for two years. If the Grade I operator-in-training does not pass the Grade I examination before the expiration of the Grade I operator-in-training certificate, the Grade I operator-in-training certificate shall not be renewed. Operator-in-training certificates at the Grades II, III, IV, and V levels are valid for up to two years and may be renewed once pursuant to the provisions of Section 3702.2.

(e) A person certified as an operator-in-training at any grade must complete the education and experience requirements and obtain an operator certificate at that grade or higher before being eligible to apply for an operator-in-training certificate at a higher grade.

Article 7. Prohibited Acts, Disciplinary Action, and Appeal Process

§ 3710. Grounds for Discipline.

(a) A certified operator or operator-in-training may be subject to administrative sanctions including reprimand or denial, suspension, probation, or revocation of a certificate pursuant to Section 13627 of the Water Code for performing, or allowing or causing another to perform, any of the following acts:

(1) willfully or negligently violating, causing, or allowing violation of these regulations;

(2) without regard to intent or negligence, operating or allowing the operation of a wastewater treatment plant by a person who is not certified at the grade necessary for the position or whose certificate has expired;

(3) submitting false or misleading information on any document provided to the division including applications for examination, certification, or renewal;

(4) engaging in dishonest conduct during an examination, or violating confidentiality of examination questions;

(5) using fraud or deception in the course of employment as an operator;

(6) failing to use care or good judgment in the course of employment as an operator or failing to apply knowledge or ability in the performance of duties;

(7) willfully or negligently causing or violating or allowing the violation of appropriate waste discharge requirements as prescribed by Article 4 of Chapter 4 of Division 7 of the Water Code, or the violation of Section 402 of the Clean Water Act which contains the provisions of the National Pollutant Discharge Elimination System permit.

(b) A chief plant operator may be subject to disciplinary actions specified in subsection (a) for willfully or negligently failing to ensure that an operator-in-training is directly supervised as required by section 3707.

§ 3711. Appeals.

Applicants or certificate holders may appeal discretionary decisions made by the Office of Operator Certification regarding denial of an application, the results of an examination, or disciplinary action taken. Appeals must be in writing and postmarked within 30 calendar days of receipt of the Office of Operator Certification decision. Appellants must include with their requests, all documents and evidence to be considered by division staff in its review of the appeal.

§ 3712. Action by Division.

After consideration of an appeal and within 30 calendar days of receipt of the appeal, division staff shall make a recommendation to the division chief. The division chief shall review the evidence and the division recommendation and shall make a determination within 30 calendar days of receipt of the recommendation. The determination shall be in writing, labeled as the division chief's determination, and shall inform the appellant that the determination is final and conclusive unless the appellant petitions the board for review in accordance with the provisions of Section 3713.

§ 3713. Petition for Review by Board.

(a) An appellant who wishes to appeal the division chief's determination may petition the board for a review. The petition must be in writing and postmarked no later than 30 calendar days after the date of receipt of the determination by the appellant.

(b) A petition for review by the board shall contain:

(1) the name and address of the appellant;

(2) the appellant's argument against the Office of Operator Certification decision and the division chief's determination;

(3) the specific action which the appellant seeks from the board.

(c) The appellant may make a written request for a hearing for the purpose of presenting evidence not considered by the division or for presenting oral arguments or both. Any request to present evidence not provided to the division must include a statement as to why the evidence was not presented to the division.

§ 3714. Defective Petitions.

Within 30 calendar days of receipt by the board of a petition which does not comply with the provisions of Section 3713, the board shall notify the appellant in writing in what respect the petition is defective and that an amended petition must be postmarked within 30 calendar days of receipt of notice of the deficiency. If a properly amended petition is not postmarked within 30 calendar days, the petition shall be dismissed unless the appellant can show good cause for an extension of time.

§ 3715. Action by Board.

(a) After consideration of the appellant's petition and the division chief's determination, the board shall:

(1) refuse to consider the petition if it does not meet the requirements of Sections 3713 and 3714; or,

(2) deny the appellant's petition upon a finding that the division chief's determination was proper; or,

(3) set aside or modify the division chief's determination; or,

(4) direct the division to take other appropriate action.

(b) Before taking final action, the board may, in its discretion, hold a hearing for the purpose of oral argument or receipt of additional evidence or both, or the board may provide for an informal meeting between the appellant, division staff, and one or more members of the board and other persons as the board deems suitable for the purpose of attempting to resolve the dispute between the appellant and the division.

(c) If a hearing is scheduled, the board shall mail a notice to the appellant indicating the date, time, and place of the hearing and of the issues to be considered. The hearing shall be conducted in a manner deemed most suitable for securing all relevant evidence without unnecessary delay.

§ 3716. Appeal of Division Processing Times.

(a) The Office of Operator Certification shall process applications for examination and certification within the time limits prescribed by this chapter. Persons whose applications for examination or certification have not been processed within the time limits prescribed by these regulations, may appeal to the board for a refund of fees in accordance with the provisions of Section 3711. If the board finds that the time limits have not been met, and the Office of Operator Certification has not shown good cause why the time limits have not been met, the board shall direct the Office of Operator Certification to reimburse all fees paid by the appellant in connection with the pending application for examination or certification.

(b) The Office of Operator Certification shall have good cause for exceeding the time limits when:

(1) the number of applications to be processed exceeds by 15 percent the number processed in the same calendar quarter of the preceding year.

(2) the Office of Operator Certification must rely on another public or private entity for all or part of the processing and delay is caused by the other entity.

(3) the delay is caused by a delay or omission of the applicant.

Article 8. Fees

§ 3717. Operator and Operator-In-Training Fees.

Except as provided by Section 3716, application fees are nonrefundable.

(a) Application fee for certification as an operator-in-training:

Grade I: $ 95
Grade II: $130
Grade III: $170
Grade IV: $190
Grade V: $190

(b) Application fee for an examination:

Grade I: $40
Grade II: $50
Grade III: $70
Grade IV: $80
Grade V: $80

(c) Examination fees are:
Grade I: $ 40
Grade II: $ 50
Grade III: $125
Grade IV: $170
Grade V: $170

(d) Operator certification fees are:
Grade I: $ 95
Grade II: $130
Grade III: $170
Grade IV: $190
Grade V: $190

(e) Operator and operator-in-training certification renewal fees are:
Grade I: $ 95
Grade II: $130
Grade III: $170
Grade IV: $190
Grade V: $190

(f) Reinstatement fee - The reinstatement fee for all grades is $50.

(g) Replacement fee - The fee for replacing a lost, damaged or destroyed certificate is $20.

(h) Reciprocal fee - In addition to the application and certification fees, applicants for reciprocal certification shall pay a fee of $50 to cover the cost of verifying and evaluating out-of-state experience and reviewing out-of-state examinations.

Article 9. Advisory Committee

§ 3718. Advisory Committee Membership and Responsibilities.

(a) The advisory committee appointed pursuant to Section 13631 of the Water Code shall consist of nine members. The members of the committee in office on January 1, 1992, shall continue as members of the advisory committee, and their terms shall expire as follows:

(1) On June 30, 1992, one representative from a statewide organization representing local sanitation agencies; one representative from a statewide organization representing wastewater treatment plant operators and supervisors; one representative from a university or state college; and, one representative from an organized labor union which represents wastewater treatment plant operators.

(2) On June 30, 1994, the remaining five members whose terms are scheduled to expire on June 30, 1993.

(b) Thereafter, all members shall serve for a period of four years at which time they shall be eligible for reappointment.

(c) The committee shall meet when necessary to review all proposed regulations and make recommendations to the board prior to adoption of any regulations or changes therein and approve any course for operator training.

Article 10. Wastewater Treatment Plant Contract Operators

§ 3719. Registration Requirement.

No person or entity shall enter a contract to operate a wastewater treatment plant unless that person or entity has been registered by the division as a contract operator. The registration authorizes the contract operator to operate one or more wastewater treatment plants. All wastewater treatment plant operators employed by the contract operator must be certified according to the provisions of this chapter.

§ 3719.10. Term of Registration.

Contract operator registrations shall be valid for a period of one year from the date of issue.

§ 3719.11. Application for Registration.

(a) Application Content - An application for registration as a contract operator shall include but not be limited to:
  (1) the name, street address, and telephone number of the person or entity contracting to operate the wastewater treatment plant(s);
  (2) the name, address, and telephone number, if known, of the wastewater treatment plant(s) to be operated and the duration of each contract;
  (3) the name and grade of each wastewater treatment plant operator employed at the plant(s);
  (4) the name and grade of the chief plant operator for each wastewater treatment plant to be operated;
  (5) the original signature of the person authorized by the contract operator to enter the contract;
  (6) the registration fee as prescribed by section 3719.19.

(b) Application submittal - For persons operating wastewater treatment plants on or before the effective date of these regulations, applications for registration shall be postmarked within 60 calendar days after the effective date of the regulations. If a contract to operate a wastewater treatment plant is entered into after the effective date of these regulations and the contract operator is not already registered, the application for registration shall be submitted and the registration issued before contract operations begin.

(c) Division review of application and notice to applicant - The division shall review applications for registration and shall notify applicants in writing within 30 calendar days of receipt whether the application is deficient. If there is a deficiency, the division shall inform the applicant by telephone or letter of the specific information required to complete the application.

§ 3719.12. Issuance/content of Certificate of Registration.

(a) Content of certificate of registration - The certificate of registration issued by the division shall be in the form of a wall certificate and shall contain but not be limited to:
  (1) the applicant's name, business address, and registration number;
  (2) the issue and expiration date of the registration;
  (3) the State Water Board seal; AND,
  (4) the signature of a State Water Board member or member designee.

(b) Issuance of certificate of registration - Unless otherwise specified in subsection (c), within 30 calendar days of receipt of a complete and approved application for registration, the division shall issue a contract operator certificate of registration. The division shall also issue one wall certificate to the contract operator for each wastewater treatment plant operated. The certificate shall include the name of the wastewater treatment plant to be operated in addition to the items in subsection (a) (1) through (4) above. Certificates are not transferable.

(c) Refusal to issue a certificate of registration - The division may refuse to issue a certificate of registration if it has determined that the applicant has committed any act which is grounds for disciplinary action as specified in section 3710 of Article 7 or section 3719.17 of this article.

§ 3719.13. Renewal of Registration.

(a) Division notice of renewal date - At least 60 calendar days prior to the expiration of a contract operator registration, the division shall provide written notification of the expiration date to the registration holder at his or her address of record. Failure to receive a notice of renewal does not relieve the registration holder from the responsibility of renewing a registration on or before the expiration date.

(b) Content of renewal application - An application for renewal of a contract operator registration shall include but not be limited to:
  (1) the name, business address, telephone number, and registration number of the person or entity contracting to operate the wastewater treatment plant(s);
  (2) the name, address, and telephone number of all wastewater treatment plants operated and the duration of each contract;
  (3) the name and grade of each wastewater treatment plant operator employed at the plant(s);
  (4) the name and grade of the chief plant operator for each wastewater treatment plant to be operated;
  (5) the original signature of the person authorized by the contract operator to enter the contract; AND,

(6) the renewal fee as prescribed by section 3719.19.

(c) Renewal application submittal - A registration holder who wishes to renew a registration shall submit to the division a completed application as specified in subsection (b). The application for renewal shall be postmarked no later than 30 calendar days before the expiration of the registration. If the application for renewal is postmarked later than 30 calendar days before expiration, the registration holder shall pay a late fee in an amount prescribed by section 3719.19.

(d) Division review of renewal application and notice to applicant - The division shall review the renewal application and shall notify the registration holder within 30 calendar days whether the application is deficient. If there is a deficiency, the division shall inform the registration holder by telephone or letter of the specific information necessary to complete the application for renewal.

§ 3719.14. Issuance/Content of Renewed Certification of Registration.

(a) Content of renewed certificate of registration - A renewed contract operator registration shall be in the form of a wall certificate and shall contain but not be limited to:

(1) the registration holder's name, business address, and registration number;

(2) the original issue date and next expiration date of the registration;

(3) the State Water Board seal; AND,

(4) the signature of a State Water Board member or member designee.

(b) Issuance of renewed certificate of registration - Within 30 calendar days of the receipt of a complete and approved renewal application, the division shall issue a certificate of registration or inform the applicant of the reason the certificate will not be issued. The division shall also issue one wall certificate to the contract operator for each wastewater treatment plant operated. The certificate shall include the name of the wastewater treatment plant operated in addition to the items in subsection (a) (1) through (4) above.

(c) Refusal to renew registration - The registration shall not be renewed until any unpaid fees or fines have been paid. The division may refuse to renew a registration if it has determined that the applicant has operated a wastewater treatment plant while the registration was expired or has committed any act which is grounds for disciplinary action pursuant to section 3710 of Article 7 or section 3719.17 of this article.

§ 3719.15. Replacement of Certificate of Registration.

A certificate of registration which has been lost, stolen, or destroyed may be replaced by the division. The replacement fee as prescribed by section 3719.19 must be submitted with a request for replacement.

§ 3719.16. Posting the Certificate of Registration.

A valid, unexpired certificate of registration shall be displayed and clearly visible at each wastewater treatment plant where the registration holder has a contract to provide services.

§ 3719.17. Prohibited Acts and Disciplinary Action.

Grounds for discipline - The State Water Board may refuse to grant, or may suspend or revoke, any registration for good cause, including but not limited to any of the following reasons:

(a) willfully or negligently violating, causing, or allowing the violation of Articles 1 through 10 of Chapter 26;

(b) without regard to intent or negligence, operating or allowing the operation of a wastewater treatment plant by a person who is not certified at the grade necessary for the position or whose certificate has expired;

(c) operating a wastewater treatment plant without a valid and current registration;

(d) submitting false or misleading information on any document provided to the division including applications for registration or registration renewal;

(e) using fraud or deception in the course of contracting to operate a wastewater treatment plant including, but not limited to, submitting false or misleading documents to the owner(s) of the wastewater treatment plant under contract;

(f) failing to use care or good judgment while operating a wastewater treatment plant;

(g) willfully or negligently causing or violating or allowing the violation of appropriate waste discharge requirements as prescribed by Article 4 of Chapter 4 of Division 7 of the Water Code, or the violation of Section 402 of the Clean Water Act which contains the provisions of the National Pollutant Discharge Elimination System permit.

§ 3719.18. Appeals.

Applicants or registration holders may appeal discretionary decisions made by the division regarding denial of an application for registration, registration renewal, or disciplinary action taken.

Appeals shall be processed in accordance with the provisions of sections 3712 through 3716 of Article 7.

§ 3719.19. Wastewater Treatment Plant Contract Operator Registration Fees.

Contract operator fees are as follows:

(a) Initial Registration Fee - The initial contract operator registration fee is $100. For each operator employed by the contract operator in California, a fee of $25 shall also be paid by the contract operator up to a maximum of $500 in combined contract operator registration fees and employee registration fees.

(b) Renewal Fee - The annual renewal fee is $100 plus $25 for each person employed by the contract operator in California up to a maximum of $500 in combined contract operator fees and employee registration fees.

(c) Late fee - Each contract operator who fails to have a renewal application postmarked at least 30 days before expiration shall pay a late fee of $50 in addition to the renewal fee.

(d) Replacement Fee - The fee for replacing lost, damaged, or destroyed certificates is $30.

APPENDIX H

ADDITIONAL ALTERNATIVE TREATMENT SYSTEMS

Two alternative treatment systems are discussed in this appendix. Although these two systems have not been as widely installed as other treatment trains mentioned earlier in this report, they show many potential benefits for cost-effective small-scale water reclamation.

H.1. PONWRS

The point-of-need water recycling system (PONWRS) was developed by Great Circle Water. The general concept of the PONWRS is to remove pathogens without removing nutrients. This system mines the sewer for nutrients, leaving the solids. The PONWRS is a nonbiological treatment system and is relatively easy to start up and maintain. As there are no open reactors in the PONWRS, potential odor is reduced. The design does not include a way to handle solids.

The flow diagram of a PONWRS is shown in Figure H.1. The PONWRS consists of the following subprocesses: vortex separation, filtration, gas flotation, and UV disinfection. Raw wastewater is removed from a sewer trunk line, pumped via a chopper pump into the vortex separation unit, and then sent through the remaining PONWRS process. The PONWRS is currently installed only as a pilot unit at the Dublin San Ramon Services District in Pleasanton, CA.

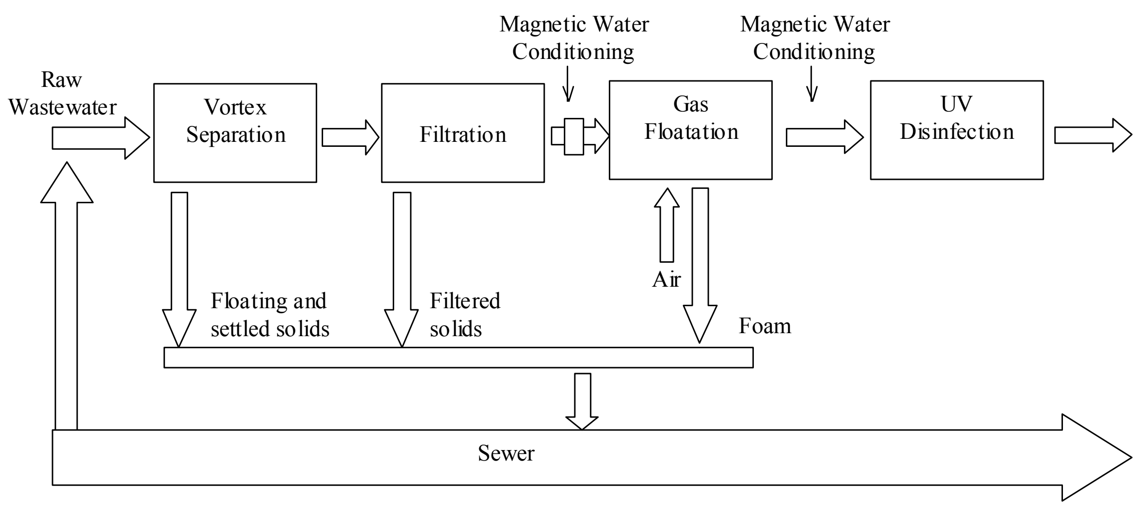

Figure H.1. Flow chart of the Great Circle Water PONWRS.

H.2. IMANS®

The Integrated Membrane System (IMANS®), like the PONWRS, utilizes nonbiological processes to remove pathogens. The nonbiological process allows for rapidly starting and stopping the processing of water on demand. Unlike the PONWRS, the IMANS® can be designed to handle solids. The flow diagram of an IMANS® is shown in Figure H.2.

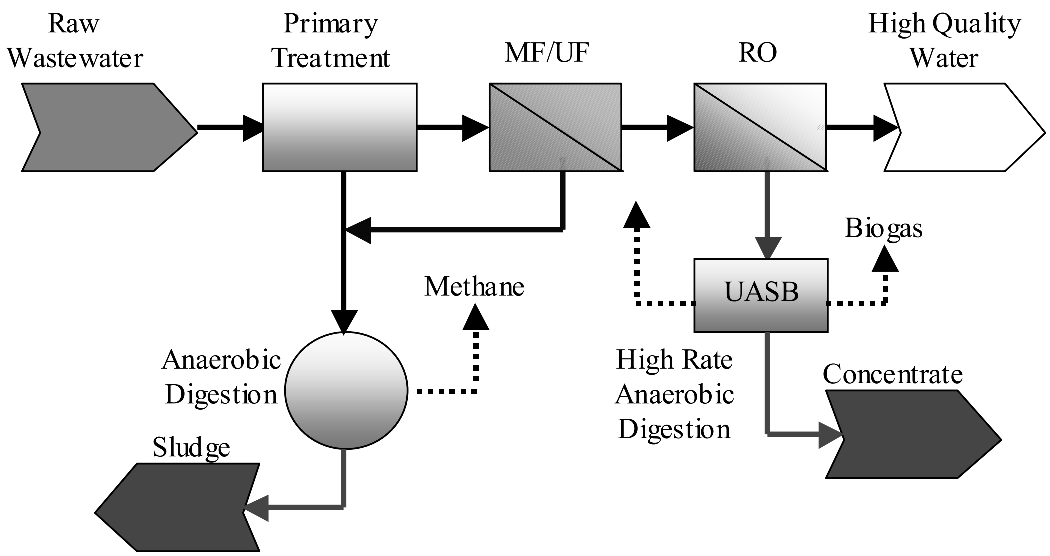

Figure H.2. Flow chart of IMANS®.

The IMANS® approach involves conventional primary settling of the wastewater, followed by microfiltration (MF) or ultrafiltration (UF). Solid material removed by the MF membranes may be returned to the anaerobic digesters with the solids from primary clarification. The MF product stream containing soluble organic material is treated in a reverse osmosis (RO) or nanofiltration (NF) process. The RO permeate is a high-quality water ready for final disinfection and use, while the RO brine contains rejected salts and concentrated soluble organic material yet is free of suspended material. This organic-rich concentrate is then stabilized in an anaerobic digestion process. The system eliminates the need for conventional secondary activated sludge treatment.

The advantages of IMANS® are the low construction costs and small carbon footprint due to the absence of secondary activated sludge treatment and the energy saving from biogas produced through anaerobic digestion. The system also can be tailored to meet discharge needs, and there is less odor as no open reactors are used. A 0.2-mgd IMANS® has been built and tested at the Orange County Sanitation District in California.

APPENDIX I

UTILITY SURVEY

I. Utility and Contact Information

Utility name ______
Utility location ______
Utility website ______
Your name ______
Your title ______
Your mailing address ______
Your phone and fax ______
Your e-mail ______
Other contact ______

II. Utility Process Description – Flow

	Influent	Effluent
BOD		
TSS		
Are there water quality components that require special treatment?		
Example: Arsenic		
Design flow		
Daily average flow		
Dry flow		
Wet flow		

Please provide a description of your current treatment system in the format and space provided:

primary – secondary – tertiary – disinfection – reuse

III. **<u>Utility Construction and Upgrades</u>:** Please provide the dollar amount, year of each cost, and source of funding.

Please circle the corresponding process and provide a description of the components in the space provided below:

Construction Cost & Year	$ year: source: primary – secondary – tertiary – disinfection – reuse
Upgrade Cost & Year	$ year: source: upgrade components:
Upgrade Cost & Year	$ year: source: upgrade components:
Expected Future Upgrade Cost & Year	$ year: source: upgrade components:

IV. **<u>Operations and Maintenance</u>**

Current Annual Operations & Maintenance	$	
Electricity Costs	$	
Chemical (Disinfection) Costs	$	
Testing Costs	$	
Estimated Time and/or Costs Dealing with Regulatory Actions (permitting, fines, etc.)	$	time:

Staff Costs	# staff	h/wk	training level	grade level	pay ($/mo.)	mandatory certification requirement
Operations director						
Lead person						
Utility person II						
Utility person I						
Utility maintenance						
Seasonal laborer						
Other information						

V. **Utility Process Description – Equipment:** MAKE COPIES AS NEEDED

Process:
Equipment:
Automated: Y N
# of units:
Capacity:
Land requirement (acres, square feet, etc.):
Maintenance requirement (h/wk): 0–5 5–10 10–15 15+
Operator level required to operate/maintain: I II III IV V
Notes:

Process:
Equipment:
Automated: Y N
# of units:
Capacity:
Land requirement (acres, square feet, etc.):
Maintenance requirement (h/wk): 0–5 5–10 10–15 15+
Operator level required to operate/maintain: I II III IV V
Notes:

VI. **Influent Water Quality**

Nitrogen	______
Phosphorus	______
Fecal coliform (average)	______
Fecal coliform (maximum)	______
E. coli	______
Giardia	______
Cryptosporidium	______
Enterovirus	______
Settleable solids	______
Total suspended solids (TSS)	______
Total dissolved solids (TDS)	______
Biological oxygen demand (BOD_5)	______
Chemical oxygen demand (COD)	______
Total organic carbon (TOC)	______
pH	______
Minimum winter water temperature	______
Other	______

VII. **Treatment Requirement**

	Required? (Yes or No)	Regulated Level
Secondary treatment (BOD removal)		
Ammonia removal (nitrification)		
Nitrogen removal (denitrification)		
Phosphorus removal		
Filtration (turbidity/TSS reduction)		
Disinfection		
Fecal coliform (average)		
Fecal coliform (maximum)		
E. coli		
Chlorine residual		
Contact time		
CT value		
Total suspended solids (TSS)		
Turbidity (NTU)		
Chemical oxygen demand (COD)		
Total organic carbon (TOC)		
Total organic halogen (TOX)		
Dissolved oxygen (DO)		
Hydrogen sulfide (H_2S)		
pH		
Disinfection by-products (THMs, HAAs, nitrosoamines)		
Metals		
Toxicity		
Other		

VIII. **Anecdotal Information and Potential Process Options:** Please circle Yes or No, estimate how much time is spent (if appropriate), and provide a brief explanation in the space provided.

Please provide any information regarding the decision to install or not install a reuse system.

____
____
____
____
____
____
____

Are there issues associated with the treatment process such as permitting, community acceptance, and negative responses from environmental groups?

Treatment: ______________________________
Y/N ______________________________
time: ______________________________
Reuse: ______________________________
Y/N ______________________________
time: ______________________________

Are there issues with odors, aesthetics, vectors, or attractive nuisances?

Treatment: ______________________________
Y/N ______________________________
time: ______________________________
Reuse: ______________________________
Y/N ______________________________
time: ______________________________

Does the treatment facility produce ancillary (additional) benefits?

Treatment: ______________________________
Y/N ______________________________
____
Reuse: ______________________________
Y/N ______________________________
____

If you could redesign the system, would you and why?

Treatment: ______________________________
Y/N ______________________________
____
Reuse: ______________________________
Y/N ______________________________
____

Does the treatment address any nonregulated treatment objectives?

____
Y/N ______________________________
____
____

Other requirements and questions?

____
____
____
____
____
____

Thank you for your participation!

APPENDIX J

DATA

Table J.1. Facility Details and Costs

Process	#	Ammonia Removal (Nitrification)	Nitrogen Removal (Denitrification)	Phosphorus Removal	Filtration	Disinfection	Flow (mgd)	Present Worth Cost ($M)	Unit Present Cost ($M/mgd)	Adjusted Construction Cost ($M)	Unit Construction Cost ($M/mgd)	Adjusted Annual O&M Cost ($M)	Unit Annual O&M Cost ($/1000 gal)
A.1) Activated Sludge	1	Yes	Yes		Yes	Yes	1.500	**$49.34**	**$32.90**	**$13.99**	**$9.33**	**$1.70**	**$3.11**
	2	Yes		Yes		Yes	0.149	**$2.79**	**$18.71**	**$1.86**	**$12.49**	**$0.04**	**$0.82**
	3				Yes	Yes	1.500			**$4.71**	**$3.14**		
	4	Yes	Yes		Yes	Yes	3.160	**$61.88**	**$19.58**	**$29.43**	**$9.31**	**$1.56**	**$1.35**
	5						3.690	**$169.50**	**$45.94**	**$41.06**	**$11.13**	**$6.18**	**$4.59**
	6	Yes				Yes	0.900	**$36.12**	**$40.14**	**$4.87**	**$5.41**	**$1.50**	**$4.58**
	7	Yes					2.500			**$7.61**	**$3.04**		
	8						0.220			**$0.84**	**$3.84**		
	9	Yes				Yes	2.345	**$27.71**	**$11.82**	**$20.10**	**$8.57**	**$0.37**	**$0.43**
	10	Yes				Yes	2.307	**$34.12**	**$14.79**	**$23.28**	**$10.09**	**$0.52**	**$0.62**
	11						4.000			**$2.29**	**$0.57**		
	12						0.350	**$22.70**	**$64.87**	**$8.65**	**$24.72**	**$0.68**	**$5.30**
	13					Yes	0.733	**$17.93**	**$24.46**	**$4.30**	**$5.87**	**$0.66**	**$2.45**
	14	Yes				Yes	1.804	**$19.11**	**$10.59**	**$6.40**	**$3.55**	**$0.61**	**$0.93**
	15		Yes			Yes	1.500			**$5.03**	**$3.35**		
	16					Yes	1.000	**$27.14**	**$27.14**	**$4.08**	**$4.08**	**$1.11**	**$3.04**
	17				Yes	Yes	0.250	**$8.04**	**$32.16**	**$3.93**	**$15.74**	**$0.20**	**$2.17**
	18					Yes	0.700	**$8.15**	**$11.64**	**$1.65**	**$2.36**	**$0.31**	**$1.22**
	19					Yes	0.700	**$6.89**	**$9.85**	**$0.75**	**$1.08**	**$0.30**	**$1.16**
	20						2.000	**$28.03**	**$14.02**	**$6.08**	**$3.04**	**$1.06**	**$1.45**
	21						0.300	**$5.05**	**$16.82**	**$1.80**	**$6.00**	**$0.16**	**$1.43**
	22					Yes	0.600	**$14.56**	**$24.27**	**$1.81**	**$3.01**	**$0.61**	**$2.80**
	23						0.150	**$5.71**	**$38.09**	**$1.94**	**$12.96**	**$0.18**	**$3.31**

Table J.1. Facility Details and Costs

Process	#	Ammonia Removal (Nitrification)	Nitrogen Removal (Denitrification)	Phosphorus Removal	Filtration	Disinfection	Flow (mgd)	Present Worth Cost ($M)	Unit Present Cost ($M/mgd)	Adjusted Construction Cost ($M)	Unit Construction Cost ($M/mgd)	Adjusted Annual O&M Cost ($M)	Unit Annual O&M Cost ($/1000 gal)
	24						1.000	**$6.76**	**$6.76**	**$4.01**	**$4.01**	**$0.13**	**$0.36**
	25						0.160					**$0.37**	**$6.34**
	26	Yes					0.065	**$4.46**	**$68.56**	**$1.37**	**$21.06**	**$0.15**	**$6.27**
A.2) Extended Aeration	27	Yes				Yes	0.840	**$49.30**	**$58.69**	**$10.20**	**$12.14**	**$1.88**	**$6.14**
	28	Yes				Yes	0.150	**$3.30**	**$22.02**	**$0.78**	**$5.20**	**$0.12**	**$2.22**
	29	Yes				Yes	0.100	**$11.59**	**$115.89**	**$5.59**	**$55.86**	**$0.29**	**$7.92**
	30	Yes			Yes		0.240	**$11.94**	**$49.74**	**$10.44**	**$43.50**	**$0.07**	**$0.82**
	31	Yes				Yes	0.200	**$7.45**	**$37.23**	**$1.76**	**$8.79**	**$0.27**	**$3.75**
	32	Yes				Yes	0.060	**$20.43**	**$340.49**	**$5.67**	**$94.57**	**$0.71**	**$32.44**
	33	Yes				Yes	0.230	**$4.78**	**$20.80**	**$1.59**	**$6.90**	**$0.15**	**$1.83**
	34	Yes			Yes	Yes	1.000	**$22.71**	**$22.71**	**$3.50**	**$3.50**	**$0.93**	**$2.53**
	35	Yes					0.400	**$12.27**	**$30.67**	**$1.57**	**$3.92**	**$0.52**	**$3.53**
	36	Yes					0.200	**$5.42**	**$27.11**	**$1.00**	**$4.98**	**$0.21**	**$2.92**
	37	Yes			Yes		0.125	**$15.49**	**$123.95**	**$7.78**	**$62.25**	**$0.37**	**$8.14**
	38					Yes	0.100					**$0.16**	**$4.38**
	39					Yes	0.490					**$0.57**	**$3.19**
	40					Yes	0.400					**$0.32**	**$2.22**
	41						1.000					**$1.51**	**$4.15**
	42						0.220					**$0.50**	**$6.22**
	43		Yes			Yes	0.294	**$54.67**	**$185.86**	**$17.49**	**$59.44**	**$1.79**	**$16.68**
A.3) Intermittent Aeration	44	Yes	Yes				2.000			**$12.32**	**$6.16**		
A.4) A/O	45	Yes	Yes		Yes	Yes	0.839	**$21.76**	**$25.95**	**$10.05**	**$11.99**	**$0.56**	**$1.84**
	46	Yes	Yes	Yes	Yes	Yes	1.500	**$65.63**	**$43.76**	**$26.14**	**$17.43**	**$1.90**	**$3.47**
	47	Yes	Yes	Yes	Yes	Yes	2.000	**$92.46**	**$46.23**	**$34.64**	**$17.32**	**$2.78**	**$3.81**
	48	Yes	Yes		Yes	Yes	3.500			**$8.72**	**$2.49**		
A.5) A2/O	49	Yes	Yes			Yes	2.500			**$9.66**	**$3.87**		
A.6) Bardenpho	50	Yes	Yes				1.500					**$1.17**	**$2.13**
	51	Yes	Yes	Yes		Yes	3.000			**$16.23**	**$5.41**		

Table J.1. Facility Details and Costs

Process	#	Ammonia Removal (Nitrification)	Nitrogen Removal (Denitrification)	Phosphorus Removal	Filtration	Disinfection	Flow (mgd)	Present Worth Cost ($M)	Unit Present Cost ($M/mgd)	Adjusted Construction Cost ($M)	Unit Construction Cost ($M/mgd)	Adjusted Annual O&M Cost ($M)	Unit Annual O&M Cost ($/1000 gal)
	52	Yes	Yes	Yes			3.000			**$18.06**	**$6.02**		
	53	Yes	Yes	Yes		Yes	4.000	**$60.45**	**$15.11**	**$11.32**	**$2.83**	**$2.36**	**$1.62**
	54	Yes	Yes	Yes			5.000			**$42.11**	**$8.42**		
	55	Yes	Yes	Yes			5.000			**$29.88**	**$5.98**		
	56	Yes	Yes	Yes			2.250	**$51.32**	**$22.81**	**$18.73**	**$8.33**	**$1.57**	**$1.91**
	57	Yes	Yes	Yes			1.700	**$24.22**	**$14.25**	**$12.25**	**$7.21**	**$0.58**	**$0.93**
	58	Yes	Yes		Yes	Yes	4.000	**$42.99**	**$10.75**	**$23.54**	**$5.89**	**$0.94**	**$0.64**
	59	Yes	Yes				5.000			**$42.11**	**$8.42**		
A.7) BNR	60	Yes	Yes	Yes	Yes	Yes	0.800			**$10.67**	**$13.34**		
	61	Yes	Yes	Yes	Yes	Yes	1.000			**$20.54**	**$20.54**		
	62	Yes	Yes	Yes	Yes	Yes	1.000			**$4.30**	**$4.30**		
	63	Yes	Yes	Yes	Yes	Yes	1.000			**$13.48**	**$13.48**		
	64	Yes	Yes	Yes	Yes	Yes	1.500			**$12.05**	**$8.04**		
	65	Yes				Yes	2.660	**$48.07**	**$18.07**	**$14.76**	**$5.55**	**$1.60**	**$1.65**
	66	Yes					1.600	**$40.14**	**$25.09**	**$6.08**	**$3.80**	**$1.64**	**$2.81**
A.8) MLE	67	Yes				Yes	1.000			**$9.21**	**$9.21**		
	68	Yes					2.500			**$13.75**	**$5.50**		
	69	Yes					3.000			**$20.02**	**$6.67**		
	70	Yes	Yes				0.500			**$4.15**	**$8.30**		
	71	Yes	Yes				2.300			**$25.42**	**$11.05**		
A.9) Schreiber N&D	72	Yes	Yes	Yes		Yes	0.500	**$32.31**	**$64.61**	**$7.56**	**$15.12**	**$1.19**	**$6.53**
A.10) In-Channel Denitrification	73	Yes	Yes			Yes	1.200	**$34.95**	**$29.12**	**$5.87**	**$4.89**	**$1.40**	**$3.20**
A.11) ICEAS	74	Yes	Yes			Yes	0.500	**$31.02**	**$62.04**	**$3.72**	**$7.43**	**$1.31**	**$7.20**
	75	Yes	Yes			Yes	1.200			**$7.99**	**$6.66**		
	76	Yes	Yes				2.800			**$18.89**	**$6.75**		
	77	Yes	Yes			Yes	0.350	**$21.73**	**$62.07**	**$0.99**	**$2.84**	**$1.00**	**$7.81**
	78	Yes	Yes			Yes	1.500	**$26.01**	**$17.34**	**$1.17**	**$0.78**	**$1.20**	**$2.18**

Table J.1. Facility Details and Costs

Process	#	Ammonia Removal (Nitrification)	Nitrogen Removal (Denitrification)	Phosphorus Removal	Filtration	Disinfection	Flow (mgd)	Present Worth Cost ($M)	Unit Present Cost ($M/mgd)	Adjusted Construction Cost ($M)	Unit Construction Cost ($M/mgd)	Adjusted Annual O&M Cost ($M)	Unit Annual O&M Cost ($/1000 gal)
	79	Yes	Yes			Yes	1.500	**$26.99**	**$17.99**	**$9.37**	**$6.24**	**$0.85**	**$1.55**
	80	Yes	Yes				0.213	**$13.91**	**$65.33**	**$4.47**	**$20.97**	**$0.45**	**$5.85**
A.12) Trickling Filter	81	Yes			Yes		1.000					**$0.53**	**$1.46**
	82	Yes			Yes		0.200	**$17.96**	**$89.82**	**$9.58**	**$47.92**	**$0.40**	**$5.53**
A.13) RBC	83	Yes				Yes	0.300					**$0.28**	**$2.55**
B.1) Package Plant	84	Yes			Yes	Yes	0.100	**$4.63**	**$46.26**	**$0.59**	**$5.89**	**$0.19**	**$5.32**
	85	Yes	Yes			Yes	0.230	**$24.25**	**$105.44**	**$6.76**	**$29.38**	**$0.84**	**$10.03**
	86	Yes					0.025	**$3.65**	**$145.99**	**$2.78**	**$111.15**	**$0.04**	**$4.60**
	87	Yes					0.150	**$4.13**	**$27.53**	**$3.42**	**$22.79**	**$0.03**	**$0.63**
	88	Yes					0.090	**$5.25**	**$58.38**	**$4.13**	**$45.89**	**$0.05**	**$1.65**
	89						0.016					**$0.09**	**$14.98**
B.2) SBR	90	Yes	Yes		Yes	Yes	0.750	**$19.28**	**$25.71**	**$8.24**	**$10.98**	**$0.53**	**$1.94**
	91	Yes	Yes				0.050	**$15.43**	**$308.63**	**$9.84**	**$196.84**	**$0.27**	**$14.75**
	92	Yes	Yes				0.500	**$9.21**	**$18.42**	**$3.44**	**$6.88**	**$0.28**	**$1.52**
	93	Yes	Yes				0.500			**$6.19**	**$12.38**		
	94	Yes	Yes			Yes	0.350	**$9.73**	**$27.80**	**$5.19**	**$14.83**	**$0.22**	**$1.71**
	95	Yes	Yes				0.250			**$8.31**	**$33.24**		
	96	Yes	Yes			Yes	0.400	**$11.36**	**$28.39**	**$6.80**	**$16.99**	**$0.22**	**$1.50**
	97	Yes	Yes				0.260			**$2.91**	**$11.19**		
	98	Yes	Yes				0.498	**$14.04**	**$28.19**	**$7.36**	**$14.77**	**$0.32**	**$1.77**
	99	Yes	Yes				1.000	**$16.78**	**$16.78**	**$13.97**	**$13.97**	**$0.14**	**$0.37**
	100	Yes	Yes				0.250	**$13.73**	**$54.92**	**$10.80**	**$43.21**	**$0.14**	**$1.54**
	101	Yes	Yes		Yes	Yes	0.594	**$13.29**	**$22.37**	**$3.42**	**$5.75**	**$0.48**	**$2.19**
	102	Yes	Yes				1.500			**$5.38**	**$3.59**		
	103	Yes	Yes	Yes		Yes	2.000			**$18.11**	**$9.05**		
	104	Yes	Yes				2.400			**$11.87**	**$4.95**		
	105	Yes	Yes				3.000			**$15.27**	**$5.09**		
	106	Yes	Yes				1.000			**$24.13**	**$24.13**		
	107	Yes	Yes				3.600	**$19.37**	**$5.38**	**$8.45**	**$2.35**	**$0.53**	**$0.40**

Table J.1. Facility Details and Costs

Process	#	Ammonia Removal (Nitrification)	Nitrogen Removal (Denitrification)	Phosphorus Removal	Filtration	Disinfection	Flow (mgd)	Present Worth Cost ($M)	Unit Present Cost ($M/mgd)	Adjusted Construction Cost ($M)	Unit Construction Cost ($M/mgd)	Adjusted Annual O&M Cost ($M)	Unit Annual O&M Cost ($/1000 gal)
	108	Yes	Yes				1.000			**$3.43**	**$3.43**		
	109	Yes	Yes				0.500	**$12.38**	**$24.75**	**$7.10**	**$14.20**	**$0.25**	**$1.39**
	110	Yes	Yes	Yes	Yes	Yes	2.250			**$11.27**	**$5.01**		
	111	Yes	Yes	Yes		Yes	1.250	**$22.47**	**$17.98**	**$9.82**	**$7.85**	**$0.61**	**$1.34**
	112	Yes	Yes		Yes	Yes	1.860	**$112.96**	**$60.73**	**$40.32**	**$21.68**	**$3.50**	**$5.15**
	113	Yes	Yes			Yes	1.400	**$21.30**	**$15.21**	**$18.18**	**$12.98**	**$0.15**	**$0.29**
	114	Yes	Yes			Yes	0.350	**$8.58**	**$24.50**	**$4.16**	**$11.89**	**$0.21**	**$1.66**
	115	Yes	Yes		Yes		2.600			**$22.65**	**$8.71**		
	116	Yes	Yes		Yes		0.250	**$10.85**	**$43.41**	**$6.64**	**$26.57**	**$0.20**	**$2.22**
	117	Yes	Yes			Yes	0.400	**$10.32**	**$25.81**	**$2.34**	**$5.86**	**$0.38**	**$2.63**
	118	Yes	Yes			Yes	1.000	**$11.58**	**$11.58**	**$4.18**	**$4.18**	**$0.36**	**$0.98**
	119	Yes	Yes		Yes	Yes	0.260	**$12.40**	**$47.69**	**$2.98**	**$11.48**	**$0.45**	**$4.78**
	120	Yes	Yes				0.250	**$7.39**	**$29.57**	**$1.60**	**$6.39**	**$0.28**	**$3.06**
	121	Yes	Yes				1.000	**$155.57**	**$155.57**	**$28.40**	**$28.40**	**$6.12**	**$16.77**
	122	Yes	Yes		Yes	Yes	0.498	**$30.53**	**$61.30**	**$10.54**	**$21.16**	**$0.96**	**$5.29**
	123					Yes	0.101	**$6.87**	**$67.97**	**$2.65**	**$26.24**	**$0.20**	**$5.50**
B.3) OD	124						1.000					**$1.37**	**$3.75**
	125	Yes				Yes	0.900	**$10.54**	**$11.71**	**$4.15**	**$4.61**	**$0.31**	**$0.94**
	126	Yes	Yes	Yes		Yes	4.000	**$39.76**	**$9.94**	**$23.77**	**$5.94**	**$0.77**	**$0.53**
	127	Yes			Yes	Yes	0.175	**$6.45**	**$36.83**	**$1.46**	**$8.32**	**$0.24**	**$3.76**
	128	Yes					1.200			**$6.61**	**$5.51**		
	129	Yes					1.000	**$12.05**	**$12.05**	**$7.13**	**$7.13**	**$0.24**	**$0.65**
	130	Yes			Yes	Yes	1.800			**$25.71**	**$14.29**		
	131	Yes		Yes		Yes	0.773	**$43.31**	**$56.03**	**$10.49**	**$13.57**	**$1.58**	**$5.60**
	132	Yes	Yes				1.900	**$24.63**	**$12.96**	**$9.22**	**$4.85**	**$0.74**	**$1.07**
	133	Yes	Yes	Yes		Yes	0.990			**$7.90**	**$7.98**		
	134	Yes			Yes	Yes	1.980	**$38.62**	**$19.51**	**$30.09**	**$15.20**	**$0.41**	**$0.57**
	135	Yes			Yes	Yes	0.500	**$11.82**	**$23.65**	**$5.35**	**$10.69**	**$0.31**	**$1.71**
	136	Yes				Yes	0.275	**$9.47**	**$34.44**	**$1.63**	**$5.92**	**$0.38**	**$3.76**

Table J.1. Facility Details and Costs

Process	#	Ammonia Removal (Nitrification)	Nitrogen Removal (Denitrification)	Phosphorus Removal	Filtration	Disinfection	Flow (mgd)	Present Worth Cost ($M)	Unit Present Cost ($M/mgd)	Adjusted Construction Cost ($M)	Unit Construction Cost ($M/mgd)	Adjusted Annual O&M Cost ($M)	Unit Annual O&M Cost ($/1000 gal)
	137	Yes					0.400	**$20.97**	**$52.42**	**$5.84**	**$14.60**	**$0.73**	**$4.99**
	138	Yes					1.142	**$15.05**	**$13.18**	**$2.47**	**$2.16**	**$0.61**	**$1.45**
	139	Yes					0.200	**$11.47**	**$57.33**	**$2.88**	**$14.41**	**$0.41**	**$5.66**
	140	Yes				Yes	2.500			**$8.30**	**$3.32**		
	141	Yes				Yes	1.500	**$46.62**	**$31.08**	**$6.34**	**$4.23**	**$1.94**	**$3.54**
	142	Yes					0.800	**$49.90**	**$62.38**	**$25.03**	**$31.29**	**$1.20**	**$4.10**
	143	Yes	Yes	Yes			1.740	**$39.09**	**$22.47**	**$12.55**	**$7.21**	**$1.28**	**$2.01**
B.4) Biological Filtration	144	Yes			Yes	Yes	0.017			**$0.85**	**$49.94**		
	145	Yes			Yes	Yes	0.120			**$1.02**	**$8.50**		
	146	Yes			Yes	Yes	0.090			**$2.45**	**$27.23**		
C.1) MBR	147	Yes		Yes	Yes	Yes	0.300	**$6.43**	**$21.43**	**$2.48**	**$8.28**	**$0.19**	**$1.74**
	148	Yes		Yes	Yes	Yes	0.400			**$6.28**	**$15.70**		
	149	Yes		Yes	Yes	Yes	0.040			**$2.42**	**$60.52**		
	150	Yes		Yes	Yes	Yes	0.150			**$1.66**	**$11.04**		
	151	Yes		Yes	Yes	Yes	0.300			**$7.61**	**$25.38**		
	152	Yes		Yes	Yes	Yes	0.370			**$12.18**	**$32.92**		
	153	Yes		Yes	Yes	Yes	0.370			**$13.43**	**$36.29**		
	154	Yes		Yes	Yes	Yes	0.400			**$4.77**	**$11.93**		
	155	Yes		Yes	Yes	Yes	0.500			**$6.68**	**$13.35**		
	156	Yes		Yes	Yes	Yes	0.500			**$15.16**	**$30.31**		
	157	Yes		Yes	Yes	Yes	0.600			**$7.71**	**$12.85**		
	158	Yes		Yes	Yes	Yes	0.670			**$7.01**	**$10.47**		
	159	Yes		Yes	Yes	Yes	0.700			**$24.95**	**$35.64**		
	160	Yes		Yes	Yes	Yes	0.750			**$10.17**	**$13.57**		
	161	Yes		Yes	Yes	Yes	0.900			**$10.21**	**$11.35**		
	162	Yes		Yes	Yes	Yes	1.000			**$16.04**	**$16.04**		
	163	Yes		Yes	Yes	Yes	0.025	**$11.11**	**$444.59**	**$9.63**	**$385.06**	**$0.07**	**$7.85**
	164	Yes		Yes	Yes	Yes	0.900	**$19.99**	**$22.22**	**$17.78**	**$19.76**	**$0.11**	**$0.32**
	165	Yes		Yes	Yes	Yes	1.100	**$18.69**	**$16.99**	**$15.05**	**$13.68**	**$0.18**	**$0.44**

Table J.1. Facility Details and Costs

Process	#	Ammonia Removal (Nitrification)	Nitrogen Removal (Denitrification)	Phosphorus Removal	Filtration	Disinfection	Flow (mgd)	Present Worth Cost ($M)	Unit Present Cost ($M/mgd)	Adjusted Construction Cost ($M)	Unit Construction Cost ($M/mgd)	Adjusted Annual O&M Cost ($M)	Unit Annual O&M Cost ($/1000 gal)
	166	Yes		Yes	Yes	Yes	1.100			**$11.36**	**$10.33**		
	167	Yes		Yes	Yes	Yes	2.500			**$19.12**	**$7.65**		
	168	Yes		Yes	Yes	Yes	2.500	**$43.90**	**$17.56**	**$20.30**	**$8.12**	**$1.14**	**$1.25**
	169	Yes		Yes	Yes	Yes	3.810			**$33.12**	**$8.69**		
	170	Yes		Yes	Yes	Yes	4.000			**$28.94**	**$7.24**		
D.1) Pond	171	Yes		Yes			1.000	**$21.25**	**$21.25**	**$7.77**	**$7.77**	**$0.65**	**$1.78**
	172	Yes		Yes			0.117	**$5.86**	**$50.13**	**$4.06**	**$34.76**	**$0.09**	**$2.03**
	173	Yes		Yes			0.750	**$23.75**	**$31.67**	**$7.54**	**$10.05**	**$0.78**	**$2.85**
	174	Yes		Yes	Yes	Yes	1.000	**$17.91**	**$17.91**	**$4.40**	**$4.40**	**$0.65**	**$1.78**
	175	Yes		Yes			0.300	**$17.07**	**$56.90**	**$8.49**	**$28.31**	**$0.41**	**$3.77**
	176	Yes		Yes			2.000	**$17.94**	**$8.97**	**$14.30**	**$7.15**	**$0.18**	**$0.24**
	177	Yes		Yes			0.220					**$0.14**	**$1.79**
	178	Yes		Yes			0.020	**$1.39**	**$69.40**	**$0.56**	**$28.06**	**$0.04**	**$5.45**
	179	Yes		Yes		Yes	0.165	**$8.57**	**$51.95**	**$2.86**	**$17.33**	**$0.28**	**$4.57**
	180	Yes		Yes		Yes	0.060	**$7.30**	**$121.62**	**$2.85**	**$47.54**	**$0.21**	**$9.77**
	181	Yes		Yes			0.100	**$6.57**	**$65.72**	**$2.62**	**$26.21**	**$0.19**	**$5.21**
D.2) Lagoon	182	Yes		Yes			0.180			**$3.24**	**$17.99**		
	183	Yes		Yes			0.020	**$3.55**	**$177.56**	**$2.78**	**$139.15**	**$0.04**	**$5.07**
	184	Yes		Yes			1.000			**$5.96**	**$5.96**		
	185	Yes		Yes			0.490	**$4.16**	**$8.48**	**$1.10**	**$2.25**	**$0.15**	**$0.82**
	186	Yes		Yes			0.350					**$0.08**	**$0.65**
	187	Yes		Yes	Yes	Yes	0.260					**$0.39**	**$4.08**
	188	Yes		Yes			0.250					**$0.27**	**$2.95**
	189	Yes		Yes			0.750					**$0.29**	**$1.06**
	190	Yes		Yes		Yes	0.175	**$8.67**	**$49.54**	**$2.41**	**$13.77**	**$0.30**	**$4.72**
	191	Yes		Yes		Yes	0.100	**$2.91**	**$29.12**	**$0.78**	**$7.76**	**$0.10**	**$2.82**
	192	Yes		Yes	Yes		0.104	**$1.30**	**$12.50**	**$0.62**	**$5.93**	**$0.03**	**$0.87**
	193	Yes		Yes	Yes		0.387	**$21.16**	**$54.67**	**$1.56**	**$4.03**	**$0.94**	**$6.68**
	194	Yes		Yes			0.240			**$1.21**	**$5.06**		

Table J.1. Facility Details and Costs

Process	#	Ammonia Removal (Nitrification)	Nitrogen Removal (Denitrification)	Phosphorus Removal	Filtration	Disinfection	Flow (mgd)	Present Worth Cost ($M)	Unit Present Cost ($M/mgd)	Adjusted Construction Cost ($M)	Unit Construction Cost ($M/mgd)	Adjusted Annual O&M Cost ($M)	Unit Annual O&M Cost ($/1000 gal)
	195	Yes		Yes			0.120	**$3.63**	**$30.28**	**$1.31**	**$10.91**	**$0.11**	**$2.55**
	196	Yes		Yes			0.350	**$30.12**	**$86.06**	**$2.79**	**$7.97**	**$1.32**	**$10.30**
	197	Yes		Yes		Yes	0.040	**$4.67**	**$116.80**	**$1.07**	**$26.68**	**$0.17**	**$11.89**
	198	Yes		Yes			0.750	**$9.62**	**$12.82**	**$1.46**	**$1.94**	**$0.39**	**$1.43**
	199	Yes		Yes			0.750					**$0.51**	**$1.87**
D.3) Wetland	200	Yes		Yes			0.007			**$0.74**	**$111.32**		
	201	Yes		Yes			0.010			**$1.13**	**$112.38**		
	202	Yes		Yes			0.009			**$0.53**	**$59.49**		
	203	Yes		Yes			0.009			**$0.60**	**$65.18**		
	204	Yes		Yes			0.007			**$1.09**	**$158.54**		
	205	Yes		Yes			0.016			**$0.73**	**$46.55**		
	206	Yes		Yes			0.006			**$0.80**	**$137.22**		
	207	Yes		Yes			0.009			**$0.88**	**$95.39**		
	208	Yes		Yes			0.066			**$3.55**	**$53.58**		
	209	Yes		Yes			0.054			**$2.03**	**$37.21**		
	210	Yes		Yes			0.019			**$0.63**	**$33.27**		
	211	Yes		Yes			0.010			**$0.65**	**$63.10**		
	212	Yes		Yes			0.999			**$4.07**	**$4.07**		
	213	Yes		Yes			1.000			**$1.76**	**$1.76**		
	214	Yes		Yes			0.280			**$1.54**	**$5.50**		
	215	Yes		Yes			0.050			**$0.42**	**$8.45**		
	216	Yes		Yes			0.075			**$0.59**	**$7.80**		
	217	Yes		Yes			0.100			**$0.62**	**$6.23**		
	218	Yes		Yes			0.065			**$0.46**	**$7.12**		
	219	Yes		Yes			0.240			**$1.32**	**$5.50**		
	220	Yes		Yes			0.100			**$0.63**	**$6.29**		
	221	Yes		Yes			0.680			**$1.69**	**$2.49**		
	222	Yes		Yes			1.000			**$2.75**	**$2.75**		
	223	Yes		Yes			0.360			**$0.74**	**$2.05**		

Table J.1. Facility Details and Costs

Process	#	Ammonia Removal (Nitrification)	Nitrogen Removal (Denitrification)	Phosphorus Removal	Filtration	Disinfection	Flow (mgd)	Present Worth Cost ($M)	Unit Present Cost ($M/mgd)	Adjusted Construction Cost ($M)	Unit Construction Cost ($M/mgd)	Adjusted Annual O&M Cost ($M)	Unit Annual O&M Cost ($/1000 gal)
	224	Yes		Yes			0.180			**$0.59**	**$3.30**		
	225	Yes		Yes			0.040			**$0.38**	**$9.41**		
	226	Yes		Yes			0.060			**$1.42**	**$23.65**		
	227	Yes		Yes			1.180	**$9.34**	**$7.92**	**$7.20**	**$6.10**	**$0.10**	**$0.24**
	228	Yes		Yes			0.100			**$2.75**	**$27.53**		
E.1) LM	229	Yes	Yes	Yes	Yes		0.040	**$3.61**	**$90.24**	**$1.94**	**$48.43**	**$0.08**	**$5.51**
	230	Yes	Yes	Yes	Yes		0.080	**$5.95**	**$74.41**	**$2.96**	**$37.05**	**$0.14**	**$4.93**
	231	Yes	Yes	Yes	Yes		1.000	**$32.26**	**$32.26**	**$16.66**	**$16.66**	**$0.75**	**$2.06**
	232	Yes	Yes	Yes	Yes		0.040	**$3.37**	**$84.33**	**$1.80**	**$44.95**	**$0.08**	**$5.19**
	233	Yes	Yes	Yes	Yes		0.080	**$5.56**	**$69.54**	**$2.75**	**$34.39**	**$0.14**	**$4.64**
	234	Yes	Yes	Yes	Yes		1.000	**$28.45**	**$28.45**	**$14.80**	**$14.80**	**$0.66**	**$1.80**

Table J.2. Construction Costs

Process	#	State	Utility Zip Code	R.S. Means Location Factor	Date of Construction	Raw Construction Cost ($)	ENR Construction Cost Index (CCI)	Adjusted Construction Cost with ENR Index and Location Factor	Filtration Cost	UV Cost	Total Construction Cost
A.1) Activated Sludge	1	CA	950	1.125	6/1/1995	$10,000,000	5432	$13,992,800			**$13,992,800**
	2	NH	033	0.913	6/1/2005	$1,463,200	7415	$1,848,156	$12,369		**$1,860,524**
	3	AZ	852	0.878	10/5/1986	$2,100,000	4342	$4,710,336			**$4,710,336**
	4	FL	323	0.813	6/1/1974	$5,948,366	2126	$29,428,002			**$29,428,002**
	5	FL	336	0.939	11/1/1988	$19,923,000	4567	$39,726,018	$161,208	$1,174,998	**$41,062,224**
	6	CO	800	0.969	9/1/1986	$2,365,500	4333	$4,817,563	$52,140		**$4,869,703**
	7	MD	210	0.943	1/1/1986	$3,000,000	4205	$6,469,347	$118,067	$1,020,069	**$7,607,484**
	8	GA	315	0.761	1/21/1986	$143,495	4205	$383,445	$16,893	$444,592	**$844,930**
	9	CO	816	1.079	6/1/1980	$8,055,000	3193	$19,992,269	$112,174		**$20,104,443**
	10	CO	315	0.932	6/1/1981	$10,610,000	4201	$23,172,009	$110,717		**$23,282,727**
	11	AR	718	0.735	6/1/2006	$604,200	7700	$912,892	$171,959	$1,209,946	**$2,294,798**
	12	GA	302	0.913	6/1/2008	$7,111,111	8185	$8,137,011	$24,492	$490,512	**$8,652,016**
	13	FL	324	0.798	6/1/2001	$2,511,398	6318	$4,259,415	$44,245		**$4,303,659**
	14	FL	324	0.798	6/1/2006	$4,533,020	7700	$6,308,279	$90,942		**$6,399,222**
	15	FL	323	0.813	6/1/2005	$3,489,000	7415	$4,948,985	$78,460		**$5,027,446**
	16	FL	338	0.860	6/1/2006	$3,117,600	7700	$4,025,762	$56,725		**$4,082,488**
	17	GA	302	0.913	6/1/2008	$3,438,206	8185	$3,934,226	$0		**$3,934,226**
	18	TN	373	0.804	6/1/2001	$955,000	6318	$1,607,624	$42,644		**$1,650,268**
	19	TN	373	0.804	6/1/2008	$575,000	8586	$712,259	$42,644		**$754,903**
	20	TN	370	0.882	6/1/2002	$3,396,000	6532	$5,040,456	$98,765	$940,659	**$6,079,879**
	21	TN	370	0.882	6/1/2001	$850,000	6318	$1,304,330	$21,651	$474,763	**$1,800,745**
	22	TN	371	0.882	6/1/2008	$1,494,000	8185	$1,769,621	$37,696		**$1,807,317**
	23	TN	377	0.799	6/1/2006	$1,095,100	7700	$1,522,065	$12,435	$409,967	**$1,944,467**
	24	FL	338	0.860	6/1/2005	$2,401,900	7415	$3,220,789	$56,725	$731,304	**$4,008,818**
	25	GA	302	0.913	6/1/2007		7939				
	26	CA	961	1.079	6/1/2007	$1,021,063	7939	$1,019,254	$6370	$343,451	**$1,369,074**
A.2) Extended Aeration	27	CA	945	1.148	6/1/2001	$8,500,000	6238	$10,149,592	$49,340		**$10,198,932**
	28	CA	932	1.066	6/1/2001	$597,387	6238	$768,192	$12,435		**$780,627**
	29	CA	953	1.173	6/1/2008	$6,262,206	8185	$5,577,346	$8990		**$5,586,336**

Table J.2. Construction Costs

Process	#	State	Utility Zip Code	R.S. Means Location Factor	Date of Construction	Raw Construction Cost ($)	ENR Construction Cost Index (CCI)	Adjusted Construction Cost with ENR Index and Location Factor	Filtration Cost	UV Cost	Total Construction Cost
	30	AR	725	0.733	6/1/2008	$7,006,700	8185	$9,986,373		$452,857	**$10,439,230**
	31	GA	318	0.823	6/1/2001	$1,060,000	6318	$1,743,184	$15,653		**$1,758,837**
	32	GA	304	0.734	6/1/2003	$3,264,358	6709	$5,668,405	$5974		**$5,674,379**
	33	NC	284	0.773	6/1/1997	$831,800	5860	$1,570,214	$17,505		**$1,587,718**
	34	NC	284	0.773	6/1/1999	$1,909,651	6039	$3,498,052			**$3,498,052**
	35	TN	371	0.882	6/1/1999	$645,000	6039	$1,035,483	$27,254	$504,576	**$1,567,313**
	36	TN	378	0.799	6/1/1995	$429,200	8432	$544,753	$15,653	$435,711	**$996,117**
	37	AR	725	0.733	6/1/2000	$3,950,000	6238	$7,386,941		$394,445	**$7,781,386**
	38	GA	318	0.823	6/1/2002		6532				
	39	GA	308	0.805	6/1/2002		6532				
	40	GA	304	0.734	6/1/2002		6532				
	41	TN	373	0.804	6/1/2007		7939				
	42	FL	339	0.822	6/1/1998		4525				
	43	CA	954	1.121	6/1/1996	$12,813,907	5597	$17,463,752	$21,312		**$17,485,065**
A.3) Intermittent Aeration	44	GA	310	0.811	6/1/1970	$1,477,400	1381	$11,279,776	$98,765	$940,659	**$12,319,199**
A.4) A/O	45	PA	180	1.041	2/1/1988	$5,475,000	4473	$10,054,290			**$10,054,290**
	46	NJ	079	1.104	11/20/1989	$15,677,576	4645	$26,142,134			**$26,142,134**
	47	NJ	786	0.809	11/19/1990	$15,665,847	4780	$34,641,315			**$34,641,315**
	48	TX	780	0.777	1/1/1987	$3,445,000	4349	$8,717,575			**$8,717,575**
A.5) A2/O	49	TX	786	0.809	5/22/1990	$4,039,099	4473	$9,544,518	$118,067		**$9,662,585**
A.6) Bardenpho	50	NH	038	0.962	8/7/1986		4330				
	51	FL	336	0.939	3/29/1986	$8,300,000	4697	$16,091,956	$136,607		**$16,228,564**
	52	IN	477	0.956	5/22/1989	$8,614,000	4578	$16,830,154	$136,607	$1,089,904	**$18,056,666**
	53	FL	346	0.939	4/1/1983	$4,900,000	4001	$11,152,670	$171,959		**$11,324,629**
	54	FL	327	0.919	11/1/1988	$19,923,000	4567	$40,590,567	$205,567	$1,312,091	**$42,108,225**
	55	MO	630	1.037	6/11/1989	$15,820,000	4599	$28,364,898	$205,567	$1,312,091	**$29,882,555**
	56	FL	329	0.954	8/7/1986	$8,523,628	4330	$17,644,328	$108,523	$981,772	**$18,734,623**
	57	AZ	855	0.836	12/27/1982	$4,356,000	3950	$11,279,800	$86,723	$886,741	**$12,253,265**
	58	AZ	960	1.100	7/1/1991	$14,700,000	4854	$23,541,915			**$23,541,915**

Table J.2. Construction Costs

Process	#	State	Utility Zip Code	R.S. Means Location Factor	Date of Construction	Raw Construction Cost ($)	ENR Construction Cost Index (CCI)	Adjusted Construction Cost with ENR Index and Location Factor	Filtration Cost	UV Cost	Total Construction Cost
	59	FL	327	0.919	11/1/1988	$19,923,000	4567	$40,590,567	$205,567	$1,312,091	**$42,108,225**
A.7) BNR	60	AZ	852	0.878	6/4/2003	$7,350,000	6709	$10,669,693			**$10,669,693**
	61	AZ	853	0.836	4/3/1997	$11,643,889	5799	$20,537,878			**$20,537,878**
	62	CA	930	1.091	9/30/2004	$4,000,000	7298	$4,295,842			**$4,295,842**
	63	CA	928	1.086	1/26/2000	$10,497,896	6130	$13,484,314			**$13,484,314**
	64	CA	930	1.091	8/3/1995	$8,468,000	5506	$12,054,156			**$12,054,156**
	65	TX	719	0.722	2/1/1980	$3,872,000	3134	$14,632,417	$124,075		**$14,756,491**
	66	TX	719	0.722	5/1/1973	$920,083	2126	$5,125,585	$82,618	$867,430	**$6,075,633**
A.8) MLE	67	FL	327	0.919	2/27/1988	$4,400,000	4473	$9,152,825	$56,725		**$9,209,551**
	68	KY	416	0.796	11/25/1982	$4,600,000	3917	$12,615,605	$118,067	$1,020,069	**$13,753,742**
	69	FL	336	0.939	6/22/1987	$9,052,271	4387	$18,790,625	$136,607	$1,089,904	**$20,017,137**
	70	FL	320	0.864	10/14/1990	$1,731,000	4771	$3,590,797	$32,580	$528,984	**$4,152,361**
	71	MO	658	0.908	6/26/1988	$11,686,000	4525	$24,320,828	$110,448	$989,641	**$25,420,917**
A.9) Schreiber N&D	72	PA	155	0.940	5/13/1988	$3,719,000	4493	$7,529,720	$32,580		**$7,562,300**
A.10) In-Channel Denitrification	73	NY	125	1.087	6/1/1983	$3,000,000	4066	$5,804,185	$65,633		**$5,869,818**
A.11) ICEAS	74	IN	473	0.930	4/1/1990	$1,876,840	4685	$3,683,423	$32,580		**$3,716,003**
	75	AZ	850	0.895	6/1/1988	$3,750,000	4519	$7,928,350	$65,633		**$7,993,983**
	76	PA	179	0.943	3/8/1994	$10,500,000	5381	$17,694,224	$129,272	$1,062,933	**$18,886,428**
	77	PA	154	0.973	1/5/1995	$600,000	5443	$968,762	$24,492		**$993,254**
	78	PA	180	1.041	6/30/1988	$600,000	4525	$1,089,178	$78,460		**$1,167,638**
	79	NC	286	0.678	4/20/1995	$4,000,000	5432	$9,287,257	$78,460		**$9,365,717**
	80	PA	172	0.933	4/1/1989	$2,000,000	4572	$4,009,212	$16,462	$441,559	**$4,467,233**
A.12) Trickling Filter	81	TN	385	0.756	6/1/2000		6238				
	82	TN	377	0.799	6/1/1992	$4,496,516	5260	$9,148,724		$435,711	**$9,584,435**
A.13) RBC	83	FL	320	0.864	6/1/2002		6532				
B.1) Package Plant	84	AR	727	0.718	6/1/2007	$392,500	7939	$588,798			**$588,798**
	85	CA	953	1.173	6/1/1994	$5,000,000	5408	$6,739,881	$17,505		**$6,757,386**
	86	NC	273	0.787	6/1/2008	$1,879,630	8185	$2,495,145	$2966	$280,553	**$2,778,664**

Table J.2. Construction Costs

Process	#	State	Utility Zip Code	R.S. Means Location Factor	Date of Construction	Raw Construction Cost ($)	ENR Construction Cost Index (CCI)	Adjusted Construction Cost with ENR Index and Location Factor	Filtration Cost	UV Cost	Total Construction Cost
	87	WV	267	0.929	6/1/2008	$2,664,400	8185	$2,996,277	$12,435	$409,967	**$3,418,679**
	88	FL	338	0.860	6/1/2000	$2,355,283	6238	$3,754,189	$8264	$367,946	**$4,130,399**
	89	WV	251	0.984	6/1/1994		5408				
B.2) SBR	90	FL	339	0.822	6/1/1998	$4,668,104	5895	$8,237,621			**$8,237,621**
	91	NV	984	0.998	10/1/2004	$8,119,601	7314	$9,511,939	$5164	$324,895	**$9,841,998**
	92	OH	433	0.915	3/1/1994	$1,603,000	5200	$2,880,885	$32,580	$528,984	**$3,442,450**
	93	TN	380	0.893	3/1/1993	$3,000,000	5106	$5,626,080	$32,580	$528,984	**$6,187,644**
	94	NH	031	0.969	1/12/1988	$2,610,060	4459	$5,165,426	$24,492		**$5,189,918**
	95	ME	039	0.855	4/1/1993	$4,000,000	5106	$7,834,837	$18,712	$456,788	**$8,310,337**
	96	MI	480	1.009	4/15/1987	$3,482,486	4360	$6,769,064	$27,254		**$6,796,318**
	97	GA	302	0.913	10/1/1990	$1,237,779	4771	$2,429,852	$19,309	$460,596	**$2,909,757**
	98	IA	506	0.835	8/24/1981	$2,400,000	3616	$6,796,937	$32,476	$528,535	**$7,357,948**
	99	NV	894	0.998	12/1/2007	$12,443,190	8090	$13,179,342	$56,725	$731,304	**$13,967,372**
	100	GA	301	0.913	6/1/1998	$6,500,000	5895	$10,327,036	$18,712	$456,788	**$10,802,536**
	101	AZ	853	0.836	6/1/2000	$2,084,000	6238	$3,417,142			**$3,417,142**
	102	MA	012	1.048	8/1/1992	$2,750,000	5032	$4,459,105	$78,460	$847,333	**$5,384,899**
	103	MN	559	1.065	10/1/1987	$10,000,000	4459	$18,006,522	$98,765	$0	**$18,105,286**
	104	AZ	852	0.878	5/1/1995	$6,000,000	5433	$10,755,583	$114,274	$1,005,057	**$11,874,913**
	105	OK	731	0.839	1/1/1987	$6,000,000	4354	$14,044,872	$136,607	$1,089,904	**$15,271,383**
	106	CT	63	1.067	7/1/1993	$15,300,000	5252	$23,346,361	$56,725	$731,304	**$24,134,391**
	107	IA	522	0.941	11/1/1992	$6,500,000	8293	$7,122,443	$158,059	$1,164,520	**$8,445,022**
	108	GA	301	0.913	9/27/1989	$1,297,000	4606	$2,637,316	$56,725	$731,304	**$3,425,345**
	109	GA	317	0.806	8/25/1988	$2,800,000	4542	$6,540,226	$32,580	$528,984	**$7,101,790**
	110	PA	183	0.978	4/1/1995	$7,000,000	5432	$11,267,208			**$11,267,208**
	111	PA	159	0.965	6/1/1991	$5,300,000	4818	$9,747,622	$67,812		**$9,815,434**
	112	AZ	853	0.895	8/1/2008	$35,000,000	8293	$40,322,760			**$40,322,760**
	113	PA	179	0.943	6/1/1993	$10,500,000	5260	$18,101,258	$74,247		**$18,175,506**
	114	AR	729	0.798	6/1/2003	$2,591,266	6709	$4,138,741	$24,492		**$4,163,233**
	115	CT	063	1.067	6/1/2005	$20,000,000	7415	$21,615,801		$1,034,704	**$22,650,505**
	116	FL	323	0.813	6/1/2002	$3,841,200	6532	$6,185,105		$456,788	**$6,641,893**

Table J.2. Construction Costs

Process	#	State	Utility Zip Code	R.S. Means Location Factor	Date of Construction	Raw Construction Cost ($)	ENR Construction Cost Index (CCI)	Adjusted Construction Cost with ENR Index and Location Factor	Filtration Cost	UV Cost	Total Construction Cost
	117	FL	323	0.813	6/1/2005	$1,632,000	7415	$2,314,917	$27,254		**$2,342,170**
	118	GA	308	0.805	6/1/2003	$2,602,650	6709	$4,120,776	$56,725		**$4,177,501**
	119	NC	285	0.681	6/1/2000	$1,482,357	6238	$2,983,851			**$2,983,851**
	120	TN	378	0.799	6/1/2000	$654,000	6238	$1,122,025	$18,712	$456,788	**$1,597,525**
	121	WV	254	0.901	6/1/2007	$23,102,000	7939	$27,616,961	$56,725	$731,304	**$28,404,991**
	122	NC	284	0.773	6/1/1999	$5,752,633	6039	$10,537,536			**$10,537,536**
	123	AR	170	0.996	7/10/1991	$1,493,242	4854	$2,641,119	$9062		**$2,650,181**
B.3) OD	124	FL	338	0.860	6/1/2001		6318				
	125	PA	189	1.058	1/22/1993	$2,572,048	5071	$4,099,366	$52,140		**$4,151,506**
	126	FL	327	0.919	7/1/1991	$12,308,555	4854	$23,594,387	$171,959		**$23,766,346**
	127	AR	726	0.740	6/1/2005	$933,760	7415	$1,455,155			**$1,455,155**
	128	AZ	856	0.872	4/1/1993	$3,000,000	5106	$5,761,570	$65,633	$781,370	**$6,608,573**
	129	FL	327	0.919	1/1/1984	$2,800,000	4109	$6,340,497	$56,725	$731,304	**$7,128,526**
	130	CA	934	1.054	11/20/2003	$21,534,000	6794	$25,714,345			**$25,714,345**
	131	MI	483	1.009	7/1/1986	$5,339,000	4332	$10,444,730	$46,166		**$10,490,896**
	132	FL	338	0.860	12/31/1985	$3,472,000	4208	$8,203,939	$94,794	$923,297	**$9,222,030**
	133	FL	348	0.833	3/2/1993	$3,900,000	5106	$7,840,716	$56,271		**$7,896,987**
	134	GA	348	0.833	8/1/1989	$13,500,000	4606	$30,087,198			**$30,087,198**
	135	FL	320	0.864	6/1/2008	$4,422,000	8185	$5,346,914			**$5,346,914**
	136	NC	275	0.788	6/1/2008	$1,213,027	8185	$1,608,209	$20,195		**$1,628,404**
	137	TN	377	0.799	6/1/2006	$3,819,175	7700	$5,308,221	$27,254	$504,576	**$5,840,050**
	138	TN	377	0.799	6/1/2005	$1,135,700	7415	$1,639,165	$63,083	$767,436	**$2,469,684**
	139	TN	377	0.799	6/1/2004	$1,615,000	7108	$2,431,617	$15,653	$435,711	**$2,882,982**
	140	FL	341	0.822	6/1/1999	$4,752,000	6039	$8,185,713	$118,067		**$8,303,780**
	141	NC	275	0.788	6/1/2003	$3,873,458	6709	$6,265,155	$78,460		**$6,343,615**
	142	CA	955	1.038	2/1/1988	$13,250,000	4473	$24,402,624	$47,451	$584,325	**$25,034,401**
	143	WI	531	1.024	7/1/1986	$6,000,000	4332	$11,565,909	$88,352	$894,263	**$12,548,524**
B.4) Biological Filtration	144	OR	971	1.058	11/1/2002	$691,000	6578	$849,015			**$849,015**
	145	OR	970	1.058	2/1/2007	$997,000	7903	$1,019,611			**$1,019,611**
	146	AR	727	0.718	6/1/2001	$1,300,000	6318	$2,450,508			**$2,450,508**

Table J.2. Construction Costs

Process	#	State	Utility Zip Code	R.S. Means Location Factor	Date of Construction	Raw Construction Cost ($)	ENR Construction Cost Index (CCI)	Adjusted Construction Cost with ENR Index and Location Factor	Filtration Cost	UV Cost	Total Construction Cost
C.1) MBR	147	CO	801	0.969	6/1/2004	$2,000,000	7108	$2,482,994			**$2,482,994**
	148	NC	275	0.788	8/1/2008	$4,800,000	8293	$6,280,877			**$6,280,877**
	149	MA	012	1.048	6/1/2005	$2,200,000	7415	$2,420,846			**$2,420,846**
	150	MO	633	0.957	4/1/2004	$1,300,000	7017	$1,655,377			**$1,655,377**
	151	MA	781	0.837	6/30/1999	$4,500,000	6039	$7,612,704			**$7,612,704**
	152	WA	980	1.059	5/1/2006	$11,600,000	7691	$12,178,565			**$12,178,565**
	153	WA	981	1.059	5/19/2006	$12,790,000	7691	$13,427,918			**$13,427,918**
	154	FL	330	0.917	6/30/1997	$3,000,000	5860	$4,773,877			**$4,773,877**
	155	CA	953	1.173	2/1/2004	$6,250,000	6825	$6,675,691			**$6,675,691**
	156	CA	954	1.121	6/1/1999	$12,000,000	6039	$15,157,498			**$15,157,498**
	157	CA	922	1.032	2/1/2004	$6,350,000	6825	$7,709,182			**$7,709,182**
	158	AZ	853	0.895	12/1/2002	$4,800,000	6538	$7,014,395			**$7,014,395**
	159	CA	953	1.173	1/31/2007	$26,967,471	7880	$24,947,837			**$24,947,837**
	160	CA	953	1.173	12/1/2003	$9,320,000	6678	$10,174,684			**$10,174,684**
	161	WA	980	1.059	12/1/2004	$9,000,000	7115	$10,213,828			**$10,213,828**
	162	WA	985	1.019	12/1/2004	$13,600,000	7115	$16,040,087			**$16,040,087**
	163	GA	301	0.913	1/1/2005	$7,500,000	7297	$9,626,381			**$9,626,381**
	164	GA	301	0.913	1/1/2003	$13,500,000	6581	$17,784,299			**$17,784,299**
	165	GA	301	0.913	1/1/2008	$13,000,000	8090	$15,050,155			**$15,050,155**
	166	CA	928	1.086	6/30/2000	$9,000,000	6238	$11,360,154			**$11,360,154**
	167	CA	945	1.148	6/1/1999	$15,500,000	6039	$19,117,966			**$19,117,966**
	168	GA	300	1.000	6/1/2001	$15,000,000	6319	$20,298,307			**$20,298,307**
	169	CA	344	0.810	12/1/2003	$20,950,000	6678	$33,120,892			**$33,120,892**
	170	CA	954	1.121	8/1/2006	$29,300,000	7722	$28,943,371			**$28,943,371**
D.1) Pond	171	CA	954	1.121	1/1/2003	$6,025,679	6581	$6,984,341	$56,725	$731,304	**$7,772,370**
	172	CA	933	1.066	5/1/1996	$2,544,100	5572	$3,662,478	$10,183	$388,855	**$4,061,516**
	173	GA	310	0.811	6/1/2006	$5,052,600	7700	$6,918,632	$45,064	$576,396	**$7,540,092**
	174	CA	954	1.121	6/1/2004	$4,100,965	7108	$4,400,985			**$4,400,985**
	175	GA	317	0.806	6/1/2005	$5,589,750	7415	$7,997,663	$21,651	$474,763	**$8,494,077**
	176	GA	301	0.913	6/1/2003	$9,500,000	6709	$13,262,089	$98,765	$940,659	**$14,301,512**

Table J.2. Construction Costs

Process	#	State	Utility Zip Code	R.S. Means Location Factor	Date of Construction	Raw Construction Cost ($)	ENR Construction Cost Index (CCI)	Adjusted Construction Cost with ENR Index and Location Factor	Filtration Cost	UV Cost	Total Construction Cost
	177	GA	315	0.761	6/1/2001		6318				
	178	AR	724	0.778	6/1/2005	$196,400	7415	$291,117	$2481	$267,608	**$561,206**
	179	AR	724	0.778	6/1/2005	$1,920,500	7415	$2,846,692	$13,420		**$2,860,112**
	180	AR	724	0.778	6/1/2005	$1,920,500	7415	$2,846,692	$5974		**$2,852,666**
	181	GA	306	0.806	6/1/2007	$1,673,377	7939	$2,236,196	$8990	$376,245	**$2,621,431**
D.2) Lagoon	182	AZ	864	0.836	1/31/2001	$1,718,500	6281	$2,798,539	$14,388	$426,100	**$3,239,027**
	183	NV	894	0.998	3/8/2008	$2,378,330	8109	$2,512,992	$2481	$267,608	**$2,783,081**
	184	CA	936	1.087	6/1/1991	$3,170,000	4818	$5,175,828	$56,725	$731,304	**$5,963,857**
	185	CA	936	1.087	6/1/2001	$438,000	6,318	$545,358	$32,058	$526,726	**$1,104,142**
	186	CA	936	1.087	6/1/1997		5860				
	187	NC	285	0.681	6/1/1994		5408				
	188	TN	385	0.756	6/1/1992		4973				
	189	WV	261	0.982	6/1/2007		7,939				
	190	CA	932	1.066	6/1/1997	$1,749,800	5860	$2,395,248	$14,067		**$2,409,315**
	191	CA	932	1.066	6/1/1975	$228,853	2393	$767,138	$8990		**$776,129**
	192	AR	721	0.826	6/1/2005	$170,000	7415	$237,342		$379,382	**$616,724**
	193	NC	283	0.780	6/1/2000	$603,000	6238	$1,059,728		$501,059	**$1,560,787**
	194	TN	380	0.893	6/1/2008	$635,000	8185	$742,883	$18,111	$452,857	**$1,213,852**
	195	WV	255	0.969	6/1/2007	$817,000	7939	$908,133	$10,402	$391,051	**$1,309,586**
	196	GA	305	0.781	6/1/2008	$1,700,000	8185	$2,274,030	$24,492	$490,512	**$2,789,034**
	197	NC	278	0.690	6/1/1999	$517,895	6039	$1,062,783	$4319		**$1,067,102**
	198	TN	384	0.773	6/1/2007	$600,000	7939	$836,032	$45,064	$576,396	**$1,457,492**
	199	TN	385	0.756	6/1/2002		6532				
D.3) Wetland	200	MN	564	1.000	6/1/2000	$381,189	6238	$522,531	$1022	$211,655	**$735,208**
	201	MN	560	1.006	6/1/2000	$657,133	6238	$895,420	$1429	$231,273	**$1,128,122**
	202	MN	557	1.090	6/1/2001	$247,331	6318	$307,107	$1308	$225,891	**$534,305**
	203	MN	563	1.103	6/1/2001	$304,819	6318	$374,028	$1338	$227,281	**$602,647**
	204	MN	557	1.090	6/1/2001	$704,263	6318	$874,471	$1055	$213,419	**$1,088,946**
	205	MN	553	1.138	6/1/2003	$419,405	6709	$469,732	$2032	$253,848	**$725,612**
	206	MN	561	0.885	6/1/2003	$410,048	6709	$590,542	$923	$206,004	**$797,468**

Table J.2. Construction Costs

Process	#	State	Utility Zip Code	R.S. Means Location Factor	Date of Construction	Raw Construction Cost ($)	ENR Construction Cost Index (CCI)	Adjusted Construction Cost with ENR Index and Location Factor	Filtration Cost	UV Cost	Total Construction Cost
	207	MN	553	1.138	6/1/2004	$618,054	7108	$653,362	$1338	$227,281	**$881,981**
	208	WI	550	1.126	6/1/2004	$2,996,500	7108	$3,201,440	$6472	$344,901	**$3,552,813**
	209	MN	562	0.913	6/1/2004	$1,281,762	7108	$1,688,908	$5526	$330,773	**$2,025,207**
	210	MN	563	1.103	6/1/2005	$349,743	7415	$365,662	$2383	$264,778	**$632,822**
	211	MN	550	1.126	6/1/2005	$406,281	7415	$416,096	$1459	$232,548	**$650,104**
	212	CA	955	1.039	4/1/2008	$3,309,596	8019	$3,396,692	$56,680	$612,461	**$4,065,833**
	213	AZ	859	0.848	6/1/1998	$561,975	5852	$968,386	$56,725	$731,304	**$1,756,416**
	214	SD	574	0.806	6/1/1998	$580,000	5852	$1,051,527	$20,488	$467,879	**$1,539,895**
	215	SD	570	0.822	6/1/1998	$52,048	5852	$92,525	$5164	$324,895	**$422,583**
	216	SD	573	0.764	6/1/1998	$117,048	5852	$223,871	$7142	$354,015	**$585,028**
	217	SD	573	0.764	6/1/1998	$124,364	5852	$237,864	$8990	$376,245	**$623,099**
	218	SD	570	0.822	6/1/1998	$63,536	5852	$112,947	$6370	$343,451	**$462,767**
	219	AL	360	0.838	6/1/1998	$487,009	5852	$849,220	$18,111	$452,857	**$1,320,189**
	220	SD	570	0.822	6/1/1998	$136,908	5852	$243,380	$8990	$376,245	**$628,615**
	221	OR	971	1.058	6/1/1998	$785,424	5852	$1,084,791	$41,666	$564,563	**$1,691,021**
	222	CO	814	0.911	6/1/1998	$1,224,768	5852	$1,964,550	$56,725	$731,304	**$2,752,579**
	223	WY	825	0.783	6/1/1998	$116,769	5852	$217,919	$25,051	$493,446	**$736,416**
	224	MD	210	0.943	6/1/1998	$98,923	5852	$153,290	$14,388	$426,100	**$593,778**
	225	MD	207	0.908	6/1/1998	$38,604	5852	$62,126	$4319	$309,904	**$376,349**
	226	MI	490	0.921	6/1/1998	$677,580	5852	$1,075,050	$5974	$337,680	**$1,418,704**
	227	CA	955	1.038	6/1/1982	$3,309,596	4290	$6,355,317	$64,756	$776,614	**$7,196,688**
	228	SD	571	0.822	6/1/1998	$1,332,204	5852	$2,368,244	$8990	$376,245	**$2,753,479**
E.1) LM	229	MD	217	0.910	5/1/2000	$1,077,777	6223	$1,627,439		$309,904	**$1,937,342**
	230	VT	054	0.902	5/1/2000	$1,710,280	6223	$2,605,420		$358,885	**$2,964,305**
	231	VT	054	0.902	5/1/2000	$10,457,542	6223	$15,930,895		$731,304	**$16,662,199**
	232	MD	217	0.910	5/1/2000	$985,391	6223	$1,487,936		$309,904	**$1,797,840**
	233	VT	054	0.902	5/1/2000	$1,570,246	6223	$2,392,094		$358,885	**$2,750,979**
	234	VT	054	0.902	5/1/2000	$9,232,257	6223	$14,064,311		$731,304	**$14,795,615**

Note: ENR Construction Cost Index in 12/2008 = 8551

Table J.3. O&M Costs - Material Costs

Process	#	Current Annual O&M Cost	Testing Costs	Chemical Costs	Materials (Supplies)	Maintenance Material Cost	Sludge Costs	Total Material Costs	ENR Material Price Index	Adjusted Material Cost with ENR Material Price Index and Location Factor
A.1) Activated Sludge	1									
	2									
	3									
	4	$81,395		$81,760		$65,700		$228,855	1371	$569,765
	5	$1,245,149		$27,442		$25,162		$1,297,753	1689	$2,270,700
	6	$468,515				$106,135		$574,650	1639	$1,004,069
	7									
	8									
	9									
	10									
	11									
	12				$25,385	$8008		$33,393	2572	$39,462
	13									
	14									
	15									
	16					$74,640	$35,000	$109,640	2585	$136,859
	17		$4829	$9646	$1922	$19,292		$35,689	2698	$40,205
	18					$5400		$5400	2120	$8792
	19					$23,000		$23,000	2698	$29,423
	20					$13,000		$13,000	2070	$19,759
	21									
	22					$16,800		$16,800	2698	$19,591
	23					$6000		$6000	2585	$8061
	24		$5000		$12,000			$17,000	2492	$22,012
	25									
	26		$5835	$2163		$1700	$3000	$12,698	2572	$12,697
A.2) Extended Aeration	27						$2,013,000	$2,013,000	2585	$1,882,367
	28		$3478	$1847		$4532		$9857	2572	$9977
	29		$1600			$4000		$5600	2572	$5151

Table J.3. O&M Costs - Material Costs

Process	#	Current Annual O&M Cost	Testing Costs	Chemical Costs	Materials (Supplies)	Maintenance Material Cost	Sludge Costs	Total Material Costs	ENR Material Price Index	Adjusted Material Cost with ENR Material Price Index and Location Factor
	30			$2500	$7500		$2500	$12,500	2698	$17,540
	31		$3000		$1000	$7500		$11,500	2572	$15,076
	32				$10,143	$7351	$2869	$20,363	2572	$29,932
	33		$2328	$2000	$1000	$6500		$11,828	2293	$18,518
	34			$7000		$42,000		$49,000	2157	$81,551
	35				$26,000			$26,000	2157	$37,924
	36				$5000	$10,000		$15,000	1987	$26,219
	37			$12,000				$12,000	2572	$17,663
	38		$2000	$500	$1000	$9000	$4000	$16,500	2070	$26,877
	39				$4414			$4414	2070	$7351
	40			$3800		$8000		$11,800	2070	$21,552
	41		$30,000					$30,000	2572	$40,258
	42			$20,000	$46,150			$66,150	2178	$102,533
	43					$51,972		$51,972	2028	$63,439
A.3) Intermittent Aeration	44									
A.4) A/O	45			$14,000		$6000	$95,000	$115,000	1686	$181,825
	46	$766,500		$32,850		$16,425		$815,775	1708	$1,200,539
	47	$912,500		$36,500		$21,900		$970,900	1718	$1,938,500
	48									
A.5) A2/O	49									
A.6) Bardenpho	50	$59,003		$49,039				$108,042	2219	$140,450
	51									
	52									
	53	$1,099,380		$138,700		$75,920		$1,314,000	1642	$2,364,937
	54									
	55									
	56	$59,003		$49,039				$108,042	1633	$192,451
	57					$65,000		$65,000	1547	$139,470
	58	$346,750		$7300				$354,050	1708	$522,934

Table J.3. O&M Costs - Material Costs

Process	#	Current Annual O&M Cost	Testing Costs	Chemical Costs	Materials (Supplies)	Maintenance Material Cost	Sludge Costs	Total Material Costs	ENR Material Price Index	Adjusted Material Cost with ENR Material Price Index and Location Factor
	59									
A.7) BNR	60									
	61									
	62									
	63									
	64									
	65			$13,593		$77,672		$91,265	1,499	$234,006
	66			$7738		$69,642		$77,380	1,351	$220,140
A.8) MLE	67									
	68									
	69									
	70									
	71									
A.9) Schreiber N&D	72	$529,250		$11,863				$541,113	1698	$940,773
A.10) In-Channel Denitrification	73									
A.11) ICEAS	74			$31,000		$295,000		$326,000	1714	$567,527
	75									
	76									
	77	$300,000		$3200			$22,000	$325,200	2031	$456,658
	78	$500,000		$1000			$15,000	$516,000	1699	$809,596
	79			$39,600				$39,600	1999	$81,080
	80	$159,700		$3000		$4200		$166,900	1681	$295,304
A.12) Trickling Filter	81									
	82				$4100	$5500		$9,600	1787	$18,658
A.13) RBC	83		$5149			$32,676		$37,825	2070	$58,689
B.1) Package Plant	84					$20,000		$20,000	2572	$30,054
	85	$250,000	$20,000					$270,000	2083	$306,648
	86		$6500			$3000	$12,000	$21,500	2698	$28,099

Table J.3. O&M Costs - Material Costs

Process	#	Current Annual O&M Cost	Testing Costs	Chemical Costs	Materials (Supplies)	Maintenance Material Cost	Sludge Costs	Total Material Costs	ENR Material Price Index	Adjusted Material Cost with ENR Material Price Index and Location Factor
	87									
	88		$3300	$761		$150	$1643	$5854	2219	$8513
	89					$3400		$3400	2083	$4603
B.2) SBR	90			$21,855	$68,699			$90,554	2120	$144,199
	91									
	92	$48,100		$8500				$56,600	2109	$81,392
	93									
	94			$2000			$8000	$10,000	1686	$16,986
	95									
	96			$1000			$8000	$9000	1655	$14,956
	97									
	98	$55,765		$500		$5192		$61,457	1,523	$134,106
	99									
	100	$80,000	$15,000	$20,000				$115,000	2178	$160,484
	101	$80,000	$3000					$83,000	2219	$124,159
	102									
	103									
	104									
	105									
	106									
	107			$10,000				$10,000	1777	$16,595
	108									
	109	$29,490		$6800				$36,290	1708	$73,153
	110									
	111	$147,240		$40,000				$187,240	1691	$318,413
	112	$2,121,337	$45,000	$100,000				$2,266,337	2823	$2,489,164
	113			$40,000				$40,000	2092	$56,266
	114									
	115									
	116		$4000		$22,000	$3000	$10,000	$39,000	2070	$64,308

Table J.3. O&M Costs - Material Costs

Process	#	Current Annual O&M Cost	Testing Costs	Chemical Costs	Materials (Supplies)	Maintenance Material Cost	Sludge Costs	Total Material Costs	ENR Material Price Index	Adjusted Material Cost with ENR Material Price Index and Location Factor
	117									
	118				$13,113			$13,113	2572	$17,575
	119			$5200		$14,900	$7300	$27,400	2120	$52,666
	120									
	121									
	122					$7500		$7500	2120	$12,700
	123	$97,210						$97,210	1708	$158,572
B.3) OD	124									
	125			$18,978				$18,978	1807	$27,547
	126									
	127					$28,822		$28,822	2572	$42,023
	128									
	129	$119,711						$119,711	1622	$222,859
	130									
	131	$542,500		$13,480		$35,300		$591,280	1643	$989,754
	132	$54,894		$21,729		$29,111		$105,734	1611	$211,779
	133									
	134			$8464				$8,464	1706	$16,528
	135		$18,000	$4000		$32,500		$54,500	2570	$68,110
	136				$182	$256,212		$256,394	2578	$350,237
	137									
	138					$40,000		$40,000	2492	$55,748
	139				$4968	$2707		$7675	2572	$10,364
	140									
	141		$7684	$30,363	$56,945	$76,140	$87,835	$258,967	1961	$465,054
	142			$67,160		$61,320		$128,480	1686	$203,725
	143	$549,000		$0		$10,000		$559,000	1643	$922,013
B.4) Biological Filtration	144									
	145									
	146									

Table J.3. O&M Costs - Material Costs

Process	#	Current Annual O&M Cost	Testing Costs	Chemical Costs	Materials (Supplies)	Maintenance Material Cost	Sludge Costs	Total Material Costs	ENR Material Price Index	Adjusted Material Cost with ENR Material Price Index and Location Factor
C.1) MBR	147	$120,405	$7825					$128,230	2345	$156,597
	148								2823	$0
	149									
	150									
	151									
	152									
	153									
	154									
	155									
	156									
	157									
	158									
	159									
	160									
	161									
	162									
	163	$80,000	$15,000	$1800				$96,800	2402	$122,488
	164	$80,000	$15,000	$20,000				$115,000	2578	$135,584
	165	$100,000	$15,000	$48,000				$163,000	2578	$192,175
	166									
	167									
	168		$35,000	$178,000		$10,000	$53,000	$276,000	2063	$371,255
	169									
	170									
D.1) Pond	171									
	172									
	173		$10,000			$15,000		$25,000	2585	$33,092
	174									
	175				$3000	$3000		$6000	2492	$8290
	176	$100,000	$15,000	$48,000				$163,000	2578	$192,175

Table J.3. O&M Costs - Material Costs

Process	#	Current Annual O&M Cost	Testing Costs	Chemical Costs	Materials (Supplies)	Maintenance Material Cost	Sludge Costs	Total Material Costs	ENR Material Price Index	Adjusted Material Cost with ENR Material Price Index and Location Factor
	177		$6000	$8400	$8300			$22,700	2120	$39,045
	178					$5000		$5000	2585	$6899
	179									
	180					$15,000		$15,000	2345	$22,816
	181		$2000	$1026	$1038			$4064	2345	$5967
D.2) Lagoon	182									
	183									
	184									
	185					$3500		$3500	2219	$4027
	186					$2214		$2214	2293	$2465
	187		$4000	$5673	$930	$4650		$15,253	2083	$29,839
	188			$3000		$15,000		$18,000	1787	$36,973
	189						$83,360	$83,360	2572	$91,588
	190									
	191									
	192				$2370			$2370	2492	$3195
	193			$27,700	$9600	$46,900	$20,000	$104,200	2157	$171,864
	194									
	195						$5588	$5588	2572	$6222
	196				$13,500	$37,500		$51,000	2698	$67,165
	197		$2251	$2500		$7600		$12,351	2492	$19,933
	198				$30,423	$33,654	$3562	$67,639	2572	$94,408
	199			$2300		$12,600		$14,900	2070	$26,421
D.3) Wetland	200									
	201									
	202									
	203									
	204									
	205									
	206									

Table J.3. O&M Costs - Material Costs

Process	#	Current Annual O&M Cost	Testing Costs	Chemical Costs	Materials (Supplies)	Maintenance Material Cost	Sludge Costs	Total Material Costs	ENR Material Price Index	Adjusted Material Cost with ENR Material Price Index and Location Factor
	207									
	208									
	209									
	210									
	211									
	212									
	213									
	214									
	215									
	216									
	217									
	218									
	219									
	220									
	221									
	222									
	223									
	224									
	225									
	226									
	227		$39,000	$8564				$47,564	2572	$49,440
	228									
E.1) LM	229					$10,248	$4375	$14,623	2241	$19,898
	230					$14,325	$8750	$23,075	2241	$31,678
	231					$105,949	$54,112	$160,061	2241	$219,735
	232					$9025	$4375	$13,400	2241	$18,234
	233					$12,626	$8750	$21,376	2241	$29,345
	234					$93,674	$54,112	$147,786	2241	$202,884

Note: ENR Material Price Index in 12/2008 =2775

Table J.4. O&M Costs - Electricity Costs and Labor Costs

Process	#	Electricity Costs	Average Price of Electricity ($)	Adjusted Electricity Cost with Average Prices and Location Factor	Total Labor Costs	ENR Skilled Labor Index	Adjusted Labor Cost with ENR Labor Index and Location Factor	Date for O&M	Total O&M Cost
A.1) Activated Sludge	1							06/01/95	**$1,702,000**
	2							06/01/93	**$44,678**
	3							10/05/86	
	4	$121,545	1.70	$647,255	$106,580	$3077	$345,396	06/01/74	**$1,562,416**
	5	$191,944	4.70	$320,102	$1,715,434	$4122	$3,593,028	11/01/88	**$6,183,831**
	6	$59,130	4.93	$91,099	$192,540	$3933	$409,575	09/01/86	**$1,504,744**
	7							01/01/86	
	8							01/21/86	
	9	$102,140	3.70	$188,300	$81,710	$3454	$177,743	06/01/80	**$366,043**
	10	$130,334	4.30	$239,360	$114,395	$3525	$282,288	06/01/81	**$521,648**
	11							06/01/06	
	12	$51,716	6.51	$64,040	$489,098	$7579	$573,025	06/01/07	**$676,526**
	13				$450,800	$6981	$656,030	06/01/05	**$656,030**
	14							06/01/06	**$612,117**
	15							06/01/05	
	16	$55,500	6.41	$74,099	$688,109	$7213	$899,297	06/01/06	**$1,110,255**
	17	$14,475	7.42	$15,726	$124,834	$7818	$141,784	06/01/08	**$197,715**
	18	$2640	5.23	$4621	$176,684	$5948	$299,523	06/01/01	**$312,936**
	19	$50,250	7.42	$61,995	$158,215	$7818	$204,059	06/01/08	**$295,477**
	20	$40,000	5.03	$66,359	$651,184	$6166	$970,715	06/01/02	**$1,056,833**
	21	$23,000	5.23	$36,697	$77,385	$5948	$119,585	06/01/01	**$156,283**
	22	$21,700	7.42	$24,404	$484,883	$7818	$570,076	06/01/08	**$614,072**
	23	$7600	6.41	$10,922	$115,527	$7213	$162,510	06/01/06	**$181,493**
	24	$38,000	5.86	$55,496	$40,575	$6981	$54,790	06/01/05	**$132,299**
	25	$24,720	6.51	$30,611	$289,776	$7579	$339,500	06/01/07	**$370,111**
	26	$17,142	6.51	$17,961	$119,013	$7579	$117,983	06/01/07	**$148,642**
A.2) Extended Aeration	27							06/01/06	**$1,882,367**
	28	$17,468	6.51	$18,526	$92,608	$7579	$92,926	06/01/07	**$121,429**
	29	$8300	6.51	$8000	$302,519	$7579	$275,869	06/01/07	**$289,020**

Table J.4. O&M Costs - Electricity Costs and Labor Costs

Process	#	Electricity Costs	Average Price of Electricity ($)	Adjusted Electricity Cost with Average Prices and Location Factor	Total Labor Costs	ENR Skilled Labor Index	Adjusted Labor Cost with ENR Labor Index and Location Factor	Date for O&M	Total O&M Cost
	30	$28,300	7.75	$36,666	$12,660	$7818	$17,910	06/01/08	**$72,115**
	31	$13,700	6.51	$18,820	$184,564	$7579	$239,881	06/01/07	**$273,777**
	32	$78,567	6.51	$121,015	$383,891	$7579	$559,449	06/01/07	**$710,396**
	33	$12,300	4.53	$25,853	$54,310	$5203	$109,473	06/01/97	**$153,843**
	34				$444,050	$5521	$843,519	06/01/99	**$925,070**
	35	$48,000	4.43	$90,416	$232,315	$5521	$386,768	06/01/99	**$515,109**
	36	$20,000	4.66	$39,534	$71,259	$4909	$147,286	06/01/95	**$213,039**
	37	$18,000	6.51	$27,763	$223,337	$7579	$325,915	06/01/07	**$371,342**
	38	$14,500	5.03	$25,780	$67,200	$6166	$107,356	06/01/02	**$160,012**
	39				$345,045	$6166	$563,555	06/01/02	**$570,906**
	40	$21,000	5.03	$41,863	$145,431	$6166	$260,506	06/01/02	**$323,921**
	41	$101,500	6.51	$142,727	$1,000,744	$7579	$1,331,420	06/01/07	**$1,514,406**
	42	$27,000	4.48	$53,962	$185,971	$5345	$343,151	06/01/98	**$499,647**
	43	$100,663	4.60	$143,676	$1,659,206	$7579	$1,583,226	06/01/07	**$1,790,342**
A.3) Intermittent Aeration	44							06/01/70	
A.4) A/O	45	$110,000	4.70	$165,471	$114,500	$4122	$216,325	02/01/88	**$563,621**
	46	$186,150	4.72	$262,924	$251,850	$4224	$437,834	11/20/89	**$1,901,297**
	47	$197,100	4.74	$378,301	$204,400	$4387	$466,901	11/19/90	**$2,783,702**
	48							01/01/87	
A.5) A2/O	49							05/22/90	
A.6) Bardenpho	50	$152,457	4.64	$251,381	$526,517	$5735	$773,685	06/01/00	**$1,165,516**
	51							03/29/86	
	52							05/22/89	
	53							04/01/83	**$2,364,937**
	54							11/01/88	
	55							06/11/89	
	56	$152,457	4.93	$238,578	$526,517	$3933	$1,137,628	08/07/86	**$1,568,657**
	57	$95,000	5.00	$167,273	$100,000	$3600	$269,371	12/27/82	**$576,114**
	58	$142,350	4.83	$197,195	$131,400	$4475	$216,406	07/01/91	**$936,535**

Table J.4. O&M Costs - Electricity Costs and Labor Costs

Process	#	Electricity Costs	Average Price of Electricity ($)	Adjusted Electricity Cost with Average Prices and Location Factor	Total Labor Costs	ENR Skilled Labor Index	Adjusted Labor Cost with ENR Labor Index and Location Factor	Date for O&M	Total O&M Cost
	59							11/01/88	
A.7) BNR	60							06/04/03	
	61							04/03/97	
	62							09/30/04	
	63							01/26/00	
	64							08/03/95	
	65	$165,053	3.70	$454,739	$281,561	$3454	$915,320	02/01/80	**$1,604,065**
	66	$61,904	1.30	$485,418	$251,485	$3021	$934,726	05/01/73	**$1,640,284**
A.8) MLE	67							02/27/88	
	68							11/25/82	
	69							06/22/87	
	70							10/14/90	
	71							06/26/88	
A.9) Schreiber N&D	72	$43,800	4.70	$72,967	$84,863	$4122	$177,558	05/13/88	**$1,191,298**
A.10) In-Channel Denitrification	73							06/01/83	**$1,400,000**
A.11) ICEAS	74	$85,000	4.74	$141,917	$295,000	$4250	$605,077	04/01/90	**$1,314,521**
	75							06/01/88	
	76							03/08/94	
	77	$260,000	4.66	$422,039	$70,000	$4881	$119,491	01/05/95	**$998,188**
	78	$100,000	4.70	$150,428	$125,000	$4122	$236,163	06/30/88	**$1,196,187**
	79	$53,000	4.66	$123,463	$264,000	$4903	$643,832	04/20/95	**$848,376**
	80	$29,000	4.72	$48,468	$54,000	$4224	$111,083	04/01/89	**$454,855**
A.12) Trickling Filter	81				$285,650	$5735	$534,120	06/01/00	**$534,120**
	82	$12,000	4.83	$22,886	$162,552	$4558	$361,852	06/01/92	**$403,396**
A.13) RBC	83	$11,742	5.03	$19,886	$131,593	$6166	$200,251	06/01/02	**$278,826**
B.1) Package Plant	84	$28,000	6.51	$44,089	$80,688	$7579	$120,208	06/01/07	**$194,351**
	85	$92,000	4.77	$121,018	$288,320	$4806	$414,623	06/01/94	**$842,288**
	86				$10,500	$7818	$13,835	06/01/08	**$41,934**
	87							06/01/07	**$34,252**

Table J.4. O&M Costs - Electricity Costs and Labor Costs

Process	#	Electricity Costs	Average Price of Electricity ($)	Adjusted Electricity Cost with Average Prices and Location Factor	Total Labor Costs	ENR Skilled Labor Index	Adjusted Labor Cost with ENR Labor Index and Location Factor	Date for O&M	Total O&M Cost
	88	$4000	4.64	$7378	$23,260	$5735	$38,233	06/01/00	**$54,123**
	89	$12,719	4.77	$19,944	$36,706	$4806	$62,924	06/01/94	**$87,472**
B.2) SBR	90	$29,504	5.23	$50,511	$203,216	$5948	$336,958	06/01/01	**$531,668**
	91							10/01/04	**$269,119**
	92	$53,100	4.77	$89,543	$57,400	$4764	$106,753	03/01/94	**$277,688**
	93							03/01/93	
	94	$18,000	4.70	$29,089	$85,000	$4122	$172,523	01/12/88	**$218,598**
	95							04/01/93	
	96	$32,000	4.77	$48,935	$78,000	$4025	$155,703	04/15/87	**$219,594**
	97							10/01/90	
	98	$27,793	4.30	$56,972	$47,400	$3525	$130,555	08/24/81	**$321,632**
	99							12/01/07	**$135,400**
	100	$72,000	4.48	$129,557	$80,000	$5345	$132,902	06/01/98	**$140,981**
	101	$30,000	4.64	$56,921	$174,000	$5735	$294,218	06/01/00	**$475,298**
	102							08/01/92	
	103							10/01/87	
	104							05/01/95	
	105							01/01/87	
	106							07/01/93	
	107	$180,000	4.83	$291,483	$115,000	$4551	$217,702	11/01/92	**$525,780**
	108							09/27/89	
	109	$6000	4.70	$11,657	$69,306	$4122	$169,117	08/25/88	**$253,927**
	110							04/01/95	
	111	$72,000	4.83	$113,694	$93,760	$4443	$177,286	06/01/91	**$609,392**
	112	$500,000	7.61	$540,306	$405,816	$7861	$467,615	08/01/08	**$3,497,086**
	113				$51,000	$4662	$94,047	06/01/93	**$150,314**
	114							06/01/04	**$212,479**
	115							06/01/05	
	116	$23,000	5.03	$41,395	$60,000	$6166	$97,033	06/01/02	**$202,736**
	117				$258,089	$6698	$384,232	06/01/04	**$384,232**

Table J.4. O&M Costs - Electricity Costs and Labor Costs

Process	#	Electricity Costs	Average Price of Electricity ($)	Adjusted Electricity Cost with Average Prices and Location Factor	Total Labor Costs	ENR Skilled Labor Index	Adjusted Labor Cost with ENR Labor Index and Location Factor	Date for O&M	Total O&M Cost
	118				$254,944	$7579	$338,764	06/01/07	**$356,339**
	119	$8500	5.23	$17,565	$191,405	$5948	$383,085	06/01/01	**$453,316**
	120				$157,713	$5735	$279,028	06/01/00	**$279,028**
	121							06/01/07	**$6,122,462**
	122	$37,500	5.23	$68,270	$499,878	$5948	$881,401	06/01/01	**$962,371**
	123	$28,997	4.83	$44,363				07/10/91	**$202,935**
B.3) OD	124				$863,312	$5948	$1,368,228	06/01/01	**$1,368,228**
	125	$92,569	4.85	$132,775	$89,504	$4653	$147,395	01/22/93	**$307,717**
	126							07/01/91	**$770,198**
	127				$137,134	$7579	$198,226	06/01/07	**$240,249**
	128							04/01/93	
	129				$6000	$3759	$14,081	01/01/84	**$236,940**
	130							11/20/03	
	131	$81,000	4.93	$119,846	$230,370	$3933	$470,621	07/01/86	**$1,580,221**
	132	$71,329	4.97	$122,826	$165,958	$3844	$406,983	12/31/85	**$741,588**
	133							03/02/93	
	134	$37,807	4.72	$70,773	$140,508	$4224	$323,737	08/01/89	**$411,039**
	135	$40,900	6.41	$54,354	$145,600	$7213	$189,405	06/01/06	**$311,869**
	136	$17,443	6.51	$25,026	$1683	$7579	$2,285	06/01/07	**$377,547**
	137				$517,728	$7213	$728,281	06/01/06	**$728,281**
	138				$378,251	$6981	$549,763	06/01/05	**$605,511**
	139	$20,694	6.51	$29,282	$279,086	$7579	$373,628	06/01/07	**$413,274**
	140							06/02/07	
	141	$147,655	5.28	$261,196	$764,778	$6487	$1,212,901	06/01/03	**$1,939,151**
	142	$20,440	4.70	$30,836	$508,080	$4122	$962,691	02/01/88	**$1,197,252**
	143	$48,000	4.93	$69,980	$142,000	$3933	$285,841	07/01/86	**$1,277,834**
B.4) Biological Filtration	144							11/01/02	
	145							02/01/07	
	146							06/01/01	
C.1) MBR	147	$24,000	5.46	$33,387	$760			06/01/04	**$189,984**

Table J.4. O&M Costs - Electricity Costs and Labor Costs

Process	#	Electricity Costs	Average Price of Electricity ($)	Adjusted Electricity Cost with Average Prices and Location Factor	Total Labor Costs	ENR Skilled Labor Index	Adjusted Labor Cost with ENR Labor Index and Location Factor	Date for O&M	Total O&M Cost
	148		7.61	$0				08/01/08	
	149							06/01/05	
	150							04/01/04	
	151							06/30/99	
	152							05/01/06	
	153							05/19/06	
	154							06/30/97	
	155							02/01/04	
	156							06/01/99	
	157							02/01/04	
	158							12/01/02	
	159							01/31/07	
	160							12/01/03	
	161							12/01/04	
	162							12/01/04	
	163	$35,000	5.23	$53,948	$30,000	$6912	$38,540	01/01/05	**$71,659**
	164	$72,000	6.27	$92,570	$80,000	$7796	$91,119	01/01/03	**$106,424**
	165	$52,000	6.27	$66,856	$80,000	$7796	$91,119	01/01/08	**$175,075**
	166							06/30/00	
	167							06/01/99	
	168	$240,000	4.78	$369,540	$300,000	$6148	$395,592	06/01/01	**$1,136,387**
	169							12/01/03	
	170							08/01/06	
D.1) Pond	171							01/01/03	**$648,932**
	172							05/01/96	**$86,490**
	173	$38,700	6.41	$54,791	$499,847	$7213	$692,724	06/01/06	**$780,607**
	174				$648,932	$7213	$650,636	06/01/06	**$650,636**
	175	$27,000	5.86	$42,074	$251,612	$6981	$362,526	06/01/05	**$412,889**
	176	$52,000	6.27	$66,856	$80,000	$7796	$91,119	01/01/08	**$175,075**
	177	$12,000	5.23	$22,191	$46,050	$5948	$82,477	06/01/01	**$143,713**

Table J.4. O&M Costs - Electricity Costs and Labor Costs

Process	#	Electricity Costs	Average Price of Electricity ($)	Adjusted Electricity Cost with Average Prices and Location Factor	Total Labor Costs	ENR Skilled Labor Index	Adjusted Labor Cost with ENR Labor Index and Location Factor	Date for O&M	Total O&M Cost
	178	$2680	6.41	$3955	$20,040	$7213	$28,951	06/01/06	**$39,805**
	179							06/01/03	**$275,000**
	180	$9000	5.46	$15,594	$112,862	$6698	$175,583	06/01/04	**$213,993**
	181	$12,000	5.46	$20,069	$109,335	$6698	$164,187	06/01/04	**$190,223**
D.2) Lagoon	182							01/31/01	
	183							03/08/08	**$36,980**
	184							06/01/91	
	185	$9000	4.64	$13,133	$99,812	$5735	$129,802	06/01/00	**$146,961**
	186	$7682	4.53	$11,482	$48,420	$5203	$69,407	06/01/97	**$83,354**
	187	$26,040	4.77	$59,000	$120,342	$4806	$298,089	06/01/94	**$386,928**
	188	$22,000	4.83	$44,344	$79,791	$4558	$187,723	06/01/92	**$269,040**
	189				$182,971	$7579	$199,305	06/01/07	**$290,893**
	190				$206,220	$5203	$301,425	06/01/97	**$301,425**
	191				$66,388	$4909	$102,849	06/01/95	**$102,849**
	192	$2500	5.86	$3801	$18,435	$6981	$25,918	06/01/05	**$32,915**
	193	$31,200	4.43	$66,456	$374,625	$5521	$705,252	06/01/99	**$943,573**
	194							06/01/08	
	195				$91,116	$7213	$105,685	06/01/07	**$111,907**
	196	$37,500	7.42	$47,627	$904,603	$7818	$1,201,079	06/01/08	**$1,315,870**
	197	$2175	5.86	$3959	$88,926	$6981	$149,666	06/01/05	**$173,558**
	198	$22,625	6.51	$33,091	$191,689	$7579	$265,256	06/01/07	**$392,755**
	199	$41,300	5.03	$79,935	$233,366	$6166	$405,856	06/01/02	**$512,213**
D.3) Wetland	200							06/01/00	
	201							06/01/00	
	202							06/01/01	
	203							06/01/01	
	204							06/01/01	
	205							06/01/03	
	206							06/01/03	
	207							06/01/04	

Table J.4. O&M Costs - Electricity Costs and Labor Costs

Process	#	Electricity Costs	Average Price of Electricity ($)	Adjusted Electricity Cost with Average Prices and Location Factor	Total Labor Costs	ENR Skilled Labor Index	Adjusted Labor Cost with ENR Labor Index and Location Factor	Date for O&M	Total O&M Cost
	208							06/01/04	
	209							06/01/04	
	210							06/01/05	
	211							06/01/05	
	212							04/01/08	
	213							06/01/98	
	214							06/01/98	
	215							06/01/98	
	216							06/01/98	
	217							06/01/98	
	218							06/01/98	
	219							06/01/98	
	220							06/01/98	
	221							06/01/98	
	222							06/01/98	
	223							06/01/98	
	224							06/01/98	
	225							06/01/98	
	226							06/01/98	
	227	$47,259	6.51	$51,473				06/01/07	**$103,387**
	228							06/01/98	
E.1) LM	229	$13,847	4.64	$24,136	$23,400	$5714	$36,483	05/01/00	**$80,518**
	230	$21,955	4.64	$38,609	$46,800	$5714	$73,614	05/01/00	**$143,901**
	231	$145,796	4.64	$256,389	$174,720	$5714	$274,825	05/01/00	**$750,949**
	232	$12,117	4.64	$21,121	$23,400	$5714	$36,483	05/01/00	**$75,838**
	233	$18,455	4.64	$32,454	$46,800	$5714	$73,614	05/01/00	**$135,413**
	234	$102,046	4.64	$179,452	$174,720	$5714	$274,825	05/01/00	**$657,161**

Note: Electricity Price ($) in 12/2008 = $7.36; ENR Skilled Labor Index on 12/2008 =$8,107

Table J.5. Effluent Water Quality

Process	#	Effluent Water Quality				Removal Efficiency			
		Effluent BOD (mg/L)	Effluent TSS (mg/L)	Effluent TN (mg/L)	Effluent TP (mg/L)	Removal Efficiency -BOD	Removal Efficiency -TSS	Removal Efficiency -TN	Removal Efficiency -TP
A.1) Activated Sludge	1	26.9	30.0			85.0%	88.8%	100.0%	
	2								
	3								
	4	1.1	1.2	2.0	0.2	99.2%	99.5%	95.1%	97.0%
	5	1.0	0.4	1.8	0.2				
	6	30.0	30.0	17.5		89.1%	88.0%	41.7%	
	7								
	8	5.0	9.0	0.3		97.0%			
	9								
	10								
	11								
	12								
	13	20.0	20.0			91.3%	90.0%		
	14	20.0	20.0			91.3%	90.0%		
	15								
	16					100.0%	100.0%		
	17								
	18	30.0	30.0						
	19								
	20								
	21								
	22								
	23								
	24	25.0	25.0			90.0%	90.0%		
	25								
	26	10.0	15.0	9.0		96.7%	94.0%	82.0%	
A.2) Extended Aeration	27								
	28								
	29								

Table J.5. Effluent Water Quality

Process	#	Effluent Water Quality				Removal Efficiency			
		Effluent BOD (mg/L)	Effluent TSS (mg/L)	Effluent TN (mg/L)	Effluent TP (mg/L)	Removal Efficiency -BOD	Removal Efficiency -TSS	Removal Efficiency -TN	Removal Efficiency -TP
	30	10.0	15.0	4.0					
	31	30.0	30.0			88.0%	88.2%		
	32	8.0	30.0	1.5		96.8%	88.0%	94.0%	
	33								
	34	7.5	30.0						
	35								
	36								
	37								
	38								
	39	15.9	8.4	6.4		95.2%	96.4%		
	40								
	41								
	42								
	43								
A.3) Intermittent Aeration	44								
A.4) A/O	45	10.0	30.0	3.0		95.0%	85.0%	92.5%	
	46	7.5	7.5	1.5	0.5	97.1%	97.0%	96.3%	95.0%
	47	7.5	7.5	1.5	0.5	97.2%	96.7%	96.3%	95.0%
	48	5.0	5.0	1.0	1.0	97.2%	96.9%	95.7%	89.1%
A.5) A2/O	49								
A.6) Bardenpho	50								
	51								
	52								
	53	1.5	1.5	1.0	0.6				
	54								
	55								
	56								
	57			1.2					
	58	2.0	1.0	5.0		99.2%	99.3%	86.5%	

Table J.5. Effluent Water Quality

Process	#	Effluent Water Quality				Removal Efficiency			
		Effluent BOD (mg/L)	Effluent TSS (mg/L)	Effluent TN (mg/L)	Effluent TP (mg/L)	Removal Efficiency -BOD	Removal Efficiency -TSS	Removal Efficiency -TN	Removal Efficiency -TP
	59								
A.7) BNR	60			0.9					
	61								
	62								
	63								
	64								
	65	2.2	10.5	0.2		98.1%	93.3%	98.9%	
	66	1.9	6.6	1.1		98.4%	96.6%	90.4%	
A.8) MLE	67								
	68								
	69								
	70								
	71								
A.9) Schreiber N&D	72	3.6	3.9	0.1	0.7	98.7%	98.6%	98.3%	84.9%
A.10) In-Channel Denitrification	73	3.7	1.8	2.9	1.5				
A.11) ICEAS	74	2.8	3.2	0.4		98.2%	97.8%	97.9%	
	75								
	76								
	77	13.0	18.0	0.1		91.8%	94.3%	93.0%	
	78	2.7	14.0	3.6		97.8%	94.8%	86.5%	
	79	3.8	2.9	1.3		98.4%	98.2%	93.5%	
	80	3.8	2.9	1.3		98.4%	98.2%	93.5%	
A.12) Trickling Filter	81								
	82								
A.13) RBC	83	16	21	16					
B.1) Package Plant	84	10.0	15.0						
	85	3.6				98.9%			
	86								
	87								

Table J.5. Effluent Water Quality

Process	#	Effluent Water Quality				Removal Efficiency			
		Effluent BOD (mg/L)	Effluent TSS (mg/L)	Effluent TN (mg/L)	Effluent TP (mg/L)	Removal Efficiency -BOD	Removal Efficiency -TSS	Removal Efficiency -TN	Removal Efficiency -TP
	88								
	89								
	90								
	91								
	92	10.0	10.0	5.0	1.0	96.0%	95.0%	87.5%	90.0%
	93								
	94	5.0	7.0	0.5	0.6	95.0%	93.0%	96.7%	92.5%
	95								
	96	10.0	10.0	0.6	0.6	94.2%	94.4%	97.6%	90.3%
	97								
	98	2.6	5.4	0.8		98.3%	97.1%	94.6%	
	99								
	100	5.0	5.0			98.6%	98.6%		
	101	15.0	18.4			94.6%	95.6%	100.0%	
	102								
B.2) SBR	103	10.0	20.0	1.0	2.0	95.6%	91.1%	96.0%	83.3%
	104								
	105								
	106	10.0	10.0	3.0	3.0	97.8%	97.7%	97.6%	80.0%
	107	10.0	15.0			91.1%	90.5%		
	108	6.2	17.2	0.1		95.3%	92.1%		
	109								
	110				5.0	100.0%	100.0%	100.0%	58.3%
	111	3.0	7.3	0.2	1.3	98.7%	92.8%	99.5%	56.7%
	112	6.0	1.0			97.9%	99.5%		
	113	10.0	30.0	1.0	1.0	95.5%	86.4%	96.0%	87.5%
	114	15.0	20.0	10.0		94.0%	92.0%		
	115								
	116	20.0	20.0			92.1%	93.3%		
	117			10.0		100.0%	100.0%	50.0%	

Table J.5. Effluent Water Quality

Process	#	Effluent Water Quality				Removal Efficiency			
		Effluent BOD (mg/L)	Effluent TSS (mg/L)	Effluent TN (mg/L)	Effluent TP (mg/L)	Removal Efficiency -BOD	Removal Efficiency -TSS	Removal Efficiency -TN	Removal Efficiency -TP
	118	30.0	30.0	30.0		91.0%	87.2%		
	119	5.0	30.0	2.0					
	120								
	121	10.0	30.0			96.3%	87.5%		
	122	5.0	5.0			98.0%	98.0%		
	123	5.0	6.8			94.7%	96.5%		
B.3) OD	124	10.0	30.00	5					
	125	10.0	15.0	6.0		96.7%	95.0%	85.0%	
	126	30.0	30.0		1.0	83.3%	86.4%	100.0%	
	127	20.0	22.5						
	128								
	129	10.0	15.0			95.0%	92.5%	100.0%	
	130								
	131	2.6	3.1	0.3	0.2	98.4%	97.8%	98.4%	93.7%
	132	1.0	0.7	0.6		99.1%	99.5%	98.6%	
	133	18.0	15.0	12.0	1.0	91.0%	91.7%	65.7%	90.0%
	134	3.4	3.9	0.3		98.0%	97.7%	98.6%	
	135	5.0	5.0	3.0					
	136	16.0	30.0	12.0					
	137								
	138								
	139								
	140								
	141	16.0	30.0						
	142	1.5	1.5	0.3	0.2	99.6%	99.5%	99.3%	97.0%
	143	3.6	3.8	3.2		98.0%	97.6%	86.2%	
B.4) Biological Filtration	144								
	145								
	146								
C.1) MBR	147	4.5	4.5			98.7%	98.1%		

Table J.5. Effluent Water Quality

Process	#	Effluent Water Quality				Removal Efficiency			
		Effluent BOD (mg/L)	Effluent TSS (mg/L)	Effluent TN (mg/L)	Effluent TP (mg/L)	Removal Efficiency -BOD	Removal Efficiency -TSS	Removal Efficiency -TN	Removal Efficiency -TP
	148	4.5	1.5			98.2%	99.5%	100.0%	100.0%
	149								
	150								
	151								
	152								
	153								
	154								
	155								
	156								
	157								
	158								
	159								
	160								
	161								
	162								
	163								
	164	5.0	5.0			98.6%	98.6%		
	165	50.0	90.0			85.7%	74.3%		
	166								
	167								
	168								
	169								
	170								
D.1) Pond	171								
	172								
	173	30.0	30.0						
	174								
	175	50.0	90.0	15.0	6.0	75.0%	55.0%	40.0%	25.0%
	176	5.0	5.0			98.6%	98.6%		
	177	29.5	37.0						

Table J.5. Effluent Water Quality

Process	#	Effluent Water Quality				Removal Efficiency			
		Effluent BOD (mg/L)	**Effluent TSS (mg/L)**	**Effluent TN (mg/L)**	**Effluent TP (mg/L)**	**Removal Efficiency -BOD**	**Removal Efficiency -TSS**	**Removal Efficiency -TN**	**Removal Efficiency -TP**
	178								
	179								
	180	30.0	90.0						
	181	20.0	20.0						
D.2) Lagoon	182								
	183								
	184								
	185	35.0				68.5%			
	186	40.0				64.0%			
	187	11.0	30.0	5.0					
	188								
	189	30.0	30.0						
	190								
	191	93.0	93.0			59.0%	56.7%		
	192								
	193	30.0	90.0						
	194								
	195								
	196								
	197								
	198								
	199								
D.3) Wetland	200								
	201								
	202								
	203								
	204								
	205								
	206								
	207								

Table J.5. Effluent Water Quality

Process	#	Effluent Water Quality				Removal Efficiency			
		Effluent BOD (mg/L)	Effluent TSS (mg/L)	Effluent TN (mg/L)	Effluent TP (mg/L)	Removal Efficiency -BOD	Removal Efficiency -TSS	Removal Efficiency -TN	Removal Efficiency -TP
	208								
	209								
	210								
	211								
	212								
	213								
	214								
	215								
	216								
	217								
	218								
	219								
	220								
	221								
	222								
	223								
	224								
	225								
	226								
	227	35.0	36.0			87.2%	82.0%		
	228								
E.1) LM	229								
	230	5.9	5.3	5.6	2.0	97.4%	97.5%	80.9%	66.7%
	231								
	232	4.0	2.0	11.0	6.0	98.3%	99.5%	75.0%	45.5%
	233								
	234								

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