
CHAPTER 4

Water Reuse Regulations and Guidelines in the U.S.

Most reuse programs operate within a framework of regulations that must be addressed in the earliest stages of planning. A thorough understanding of all applicable regulations is required to plan the most effective design and operation of a water reuse program and to streamline implementation.

Regulations refer to actual rules that have been enacted and are enforceable by government agencies. Guidelines, on the other hand, are not enforceable but can be used in the development of a reuse program. Currently, there are no federal regulations directly governing water reuse practices in the U.S. Water reuse regulations and guidelines have, however, been developed by many individual states. As of November 2002, 25 states had adopted regulations regarding the reuse of reclaimed water, 16 states had guidelines or design standards, and 9 states had no regulations or guidelines. In states with no specific regulations or guidelines on water reclamation and reuse, programs may still be permitted on a case-by-case basis.

Regulations and guidelines vary considerably from state to state. States such as Arizona, California, Colorado, Florida, Georgia, Hawaii, Massachusetts, Nevada, New Jersey, New Mexico, North Carolina, Ohio, Oregon, Texas, Utah, Washington, and Wyoming have developed regulations or guidelines that strongly encourage water reuse as a water resources conservation strategy. These states have developed comprehensive regulations or guidelines specifying water quality requirements, treatment processes, or both, for the full spectrum of reuse applications. The objective in these states is to derive the maximum resource benefits of the reclaimed water while protecting the environment and public health. Other states have developed water reuse regulations with the primary intent of providing a disposal alternative to discharge to surface waters, without considering the management of reclaimed water as a resource.

This section provides an inventory of the various state water reuse regulations throughout the U.S. and updates

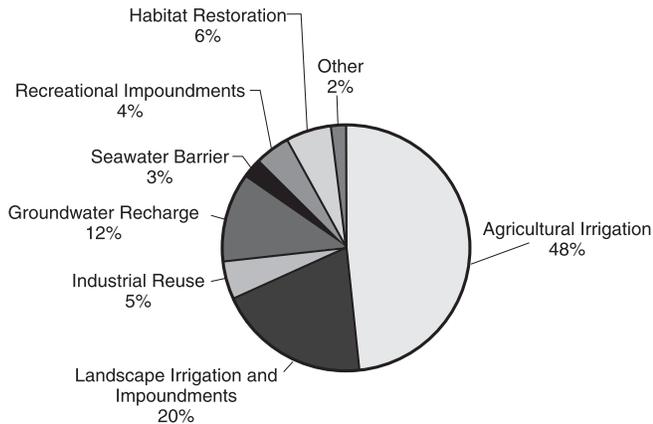
recommended guidelines that may aid in the development of more comprehensive state or even federal standards for water reuse. Water reuse outside the U.S. is discussed in Chapter 8.

4.1 Inventory of Existing State Regulations and Guidelines

The following inventory of state reuse regulations and guidelines is based on a survey of all states conducted specifically for this document. Regulatory agencies in all 50 states were contacted and information was obtained concerning their regulations governing water reuse. All of the information presented in this section is considered current as of November 2002.

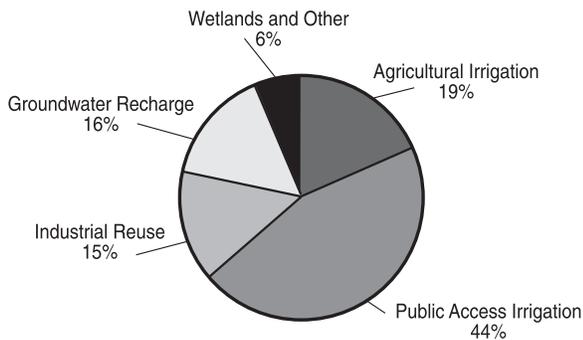
California and Florida compile comprehensive inventories of reuse projects by type of reuse application. These inventories are compiled by the California Water Resources Control Board (CWRCB) in Sacramento and the Florida Department of Environmental Protection (FDEP) in Tallahassee, respectively. The inventories are available for viewing or downloading from each agency's website. Florida's 2001 Reuse Inventory shows a total of 461 domestic wastewater treatment facilities with permitted capacities of 0.1 mgd (4.4 l/s) or more that produce reclaimed water. These treatment facilities serve 431 reuse systems and provide 584 mgd (25,600 l/s) of reclaimed water for beneficial purposes. The total reuse capacity associated with these systems is 1,151 mgd (50,400 l/s) (FDEP, 2002). California's May 2000 Municipal Wastewater Reclamation Survey, estimated a total of 358 mgd (14,800 l/s) treated municipal wastewater was being reused. This represents a 50 percent increase from the survey undertaken by CWRCB in 1987. The wastewater is treated at 234 treatment plants and is being reused at approximately 4,840 sites (CWRCB, 2000). **Figures 4-1 and 4-2** show the types of reuse occurring in California and Florida, respectively.

Figure 4-1. California Water Reuse by Type (Total 358 mgd)



Source: Adapted from California Environmental Protection Agency

Figure 4-2. Florida Water Reuse by Type (Total 584 mgd)



Source: 2001 Florida Water Reuse Inventory

Every 5 years, the U.S. Geological Survey (USGS) compiles an estimate of national reclaimed water use that is entered in a national database system and publishes its findings in a national circular, *Estimated Use of Water in the United States*. The 1995 publication estimated that approximately 983 mgd (43,060 l/s) of the effluent discharged in the U.S. was released for beneficial reuse, an increase of 55 mgd (2,410 l/s) from the 1990 estimate (Perlman *et al.*, 1998). More current estimates were not available from the USGS at the time of this update, but it is anticipated that the 2000 publication will be available at the time these guidelines are published.

Most states do not have regulations that cover all potential uses of reclaimed water. Arizona, California, Colorado, Florida, Hawaii, Nevada, New Jersey, Oregon, Texas, Utah, and Washington have extensive regulations or guidelines that prescribe requirements for a wide range of end uses of the reclaimed water. Other states have regulations or guidelines that focus upon land treatment of wastewater effluent, emphasizing additional treatment or effluent disposal rather than beneficial reuse, even though the effluent may be used for irrigation of agricultural sites, golf courses, or public access lands.

Based on the inventory, current regulations and guidelines may be divided into the following reuse categories:

- Unrestricted urban reuse – irrigation of areas in which public access is not restricted, such as parks, playgrounds, school yards, and residences; toilet flushing, air conditioning, fire protection, construction, ornamental fountains, and aesthetic impoundments.
- Restricted urban reuse – irrigation of areas in which public access can be controlled, such as golf courses, cemeteries, and highway medians.
- Agricultural reuse on food crops – irrigation of food crops which are intended for direct human consumption, often further classified as to whether the food crop is to be processed or consumed raw.
- Agricultural reuse on non-food crops – irrigation of fodder, fiber, and seed crops, pasture land, commercial nurseries, and sod farms.
- Unrestricted recreational reuse – an impoundment of water in which no limitations are imposed on body-contact water recreation activities.
- Restricted recreational reuse – an impoundment of reclaimed water in which recreation is limited to fishing, boating, and other non-contact recreational activities.
- Environmental reuse – reclaimed water used to create manmade wetlands, enhance natural wetlands, and sustain or augment stream flows.
- Industrial reuse – reclaimed water used in industrial facilities primarily for cooling system make-up water, boiler-feed water, process water, and general washdown.

- Groundwater recharge – using either infiltration basins, percolation ponds, or injection wells to recharge aquifers.
- Indirect potable reuse – the intentional discharge of highly treated reclaimed water into surface waters or groundwater that are or will be used as a source of potable water.

Table 4-1 (on the following page) provides an overview of the current water reuse regulations and guidelines by state and by reuse category. The table identifies those states that have regulations, those with guidelines, and those states that currently do not have either. Regulations refer to actual rules that have been enacted and are enforceable by government agencies. Guidelines, on the other hand, are not enforceable but can be used in the development of a reuse program.

The majority of current state regulations and guidelines pertain to the use of reclaimed water for urban and agricultural irrigation. At the time of the survey, the only states that had specific regulations or guidelines regarding the use of reclaimed water for purposes other than irrigation were Arizona, California, Colorado, Florida, Hawaii, Massachusetts, Nevada, New Jersey, North Carolina, Oregon, South Dakota, Texas, Utah, and Washington. The 1995 Substitute Senate Bill 5605, “Reclaimed Water Act,” passed in the State of Washington, states that reclaimed water is no longer considered wastewater (Van Riper *et al.*, 1998).

Table 4-2 shows the number of states with regulations or guidelines for each type of reuse. The category of unrestricted urban reuse has been subdivided to indicate the number of states that have regulations pertaining to urban reuse not involving irrigation.

States with regulations or guidelines pertaining to the use of reclaimed water for the following unrestricted urban reuse categories are:

- Toilet Flushing – Arizona, California, Florida, Hawaii, Massachusetts, New Jersey, North Carolina, Texas, Utah, and Washington
- Fire Protection – Arizona, California, Florida, Hawaii, New Jersey, North Carolina, Texas, Utah, and Washington
- Construction Purposes – Arizona, California, Florida, Hawaii, New Jersey, North Carolina, Oregon, Utah, and Washington
- Landscape or Aesthetic Impoundments – Arizona, California, Colorado, Florida, Hawaii, Nevada, New Jersey, North Carolina, Oregon, Texas, and Washington
- Street Cleaning – Arizona, California, Florida, Hawaii, North Carolina, and Washington

Table 4-2. Number of States with Regulations or Guidelines for Each Type of Reuse Application

Type of Reuse	Number of States
Unrestricted Urban	28
Irrigation	28
Toilet Flushing	10
Fire Protection	9
Construction	9
Landscape Impoundment	11
Street Cleaning	6
Restricted Urban	34
Agricultural (Food Crops)	21
Agricultural (Non-food Crops)	40
Unrestricted Recreational	7
Restricted Recreational	9
Environmental (Wetlands)	3
Industrial	9
Groundwater Recharge (Nonpotable Aquifer)	5
Indirect Potable Reuse	5

Table 4-1. Summary of State Reuse Regulations and Guidelines

State	Regulations	Guidelines	No Regulations or Guidelines ⁽¹⁾	Change from 1992 Guidelines for Water Reuse ⁽²⁾	Unrestricted Urban Reuse	Restricted Urban Reuse	Agricultural Reuse Food Crops	Agricultural Reuse Non-Food Crops	Unrestricted Recreational Reuse	Restricted Recreational Reuse	Environmental Reuse	Industrial Reuse	Groundwater Recharge	Indirect Potable Reuse
Alabama		•		N		•		•						
Alaska	•			NR				•						
Arizona	•			U	•	•	•	•		•				
Arkansas		•		N	•	•	•	•						
California ⁽³⁾	•			U	•	•	•	•	•	•		•	•	•
Colorado	• ⁽⁴⁾			GR	•	•	•	•	•	•				
Connecticut			•	N										
Delaware	•			GR	•	•		•						
Florida	•			U	•	•	•	•			•	•	•	•
Georgia		•		U	•	•		•						
Hawaii		•		U	•	•	•	•		•		•	•	•
Idaho	•			N	•	•	•	•						
Illinois	•			U	•	•		•						
Indiana	•			U	•	•	•	•						
Iowa	•			NR		•		•						
Kansas		•		N	•	•	•	•						
Kentucky			•	N										
Louisiana			•	N										
Maine			•	N										
Maryland		•		N		•		•						
Massachusetts		•		NG	•	•		•					•	•
Michigan	•			N			•	•					•	•
Minnesota			•	N										
Mississippi			•	N										
Missouri	•			N		•		•						
Montana	•			GR	•	•	•	•						
Nebraska	•			GR		•		•						
Nevada	•			GR	•	•	•	•	•	•				
New Hampshire			•	N										
New Jersey		•		RG	•	•	•	•				•		
New Mexico		•		N	•	•	•	•						
New York		•		N				•						
North Carolina	•			U	•	•						•		
North Dakota		•		U	•	•		•						
Ohio		•		NG	•	•		•						
Oklahoma	•			GR		•	•	•						
Oregon	•			N	•	•	•	•	•	•		•		
Pennsylvania		•		NG				•						
Rhode Island			•	N										
South Carolina	•			GR	•	•		•						
South Dakota		•		N	•	•		•			•			
Tennessee	•			N	•	•		•						
Texas	•			U	•	•	•	•	•	•		•		
Utah	•			U	•	•	•	•	•	•		•		
Vermont	•			N				•						
Virginia			•	N										
Washington		•		U	•	•	•	•	•	•	•	•	•	•
West Virginia	•			N			•	•						
Wisconsin	•			N				•						
Wyoming	•			U	•	•	•	•						

- (1) Specific regulations on reuse not adopted: however, reclamation may be approved on a case-by-case basis
- (2) N - no change
 U - updated guidelines or regulations
 NR - no guidelines or regulations to regulations
 NG - no guidelines or regulations to guidelines
 GR - guidelines to regulations
 RG - regulations to guidelines
- (3) Has regulations for landscape irrigation excluding residential irrigation; guidelines cover all other uses

It is important to understand that because a state does not have specific guidelines or regulations for a particular type of reuse as defined in this chapter, it does not mean that the state does not allow that type of reuse under other uses. Also, some states allow consideration of reuse options that are not addressed within their existing guidelines or regulations. For example, Florida's rules governing water reuse enable the state to permit other uses, if the applicant demonstrates that public health will be protected.

4.1.1 Reclaimed Water Quality and Treatment Requirements

Requirements for water quality and treatment receive the most attention in state reuse regulations. States that have water reuse regulations or guidelines have set standards for reclaimed water quality and/or specified minimum treatment requirements. Generally, where unrestricted public exposure is likely in the reuse application, wastewater must be treated to a high degree prior to its application. Where exposure is not likely, however, a lower level of treatment is usually accepted. The most common parameters for which water quality limits are imposed are biochemical oxygen demand (BOD), total suspended solids (TSS), and total or fecal coliform counts. Total and fecal coliform counts are generally used as indicators to determine the degree of disinfection. A

limit on turbidity is usually specified to monitor the performance of the treatment facility.

This discussion on reclaimed water quality and treatment requirements is based on the regulations from the following states: Arizona, California, Florida, Hawaii, Nevada, Texas, and Washington. These regulations were chosen because these states provide a collective wisdom of successful reuse programs and long-term experience.

4.1.1.1 Unrestricted Urban Reuse

Unrestricted urban reuse involves the use of reclaimed water where public exposure is likely in the reuse application, thereby necessitating a high degree of treatment. In general, all states that specify a treatment process require a minimum of secondary treatment and treatment with disinfection prior to unrestricted urban reuse. However, the majority of states require additional levels of treatment that may include oxidation, coagulation, and filtration. Texas does not specify the type of treatment processes required and only sets limits on the reclaimed water quality. **Table 4-3** shows the reclaimed water quality and treatment requirements for unrestricted urban reuse.

Where specified, limits on BOD range from 5 mg/l to 30 mg/l. Texas requires that BOD not exceed 5 mg/l (monthly

Table 4-3. Unrestricted Urban Reuse

	Arizona	California	Florida	Hawaii	Nevada	Texas	Washington
Treatment	Secondary treatment, filtration, and disinfection	Oxidized, coagulated, filtered, and disinfected	Secondary treatment, filtration, and high-level disinfection	Oxidized, filtered, and disinfected	Secondary treatment and disinfection	NS ⁽¹⁾	Oxidized, coagulated, filtered, and disinfected
BOD₅	NS	NS	20 mg/l CBOD ₅	NS	30 mg/l	5 mg/l	30 mg/l
TSS	NS	NS	5.0 mg/l	NS	NS	NS	30 mg/l
Turbidity	2 NTU (Avg)	2 NTU (Avg)	NS	2 NTU (Max)	NS	3 NTU	2 NTU (Avg)
	5 NTU (Max)	5 NTU (Max)					5 NTU (Max)
Coliform	Fecal	Total	Fecal	Fecal	Fecal	Fecal	Total
	None detectable (Avg)	2.2/100 ml (Avg)	75% of samples below detection	2.2/100 ml (Avg)	2.2/100 ml (Avg)	20/100 ml (Avg)	2.2/100 ml (Avg)
	23/100 ml (Max)	23/100 ml (Max in 30 days)	25/100 ml (Max)	23/100 ml (Max in 30 days)	23/100 ml (Max)	75/100 ml (Max)	23/100 ml (Max)

⁽¹⁾ NS - Not specified by state regulations

average) except when reclaimed water is used for landscape impoundments. In that case, BOD is limited to 10 mg/l. Nevada, on the other hand, requires that BOD not exceed 30 mg/l prior to unrestricted urban reuse. Limits on TSS vary from 5 mg/l to 30 mg/l. Florida requires a TSS limit of 5.0 mg/l prior to disinfection and Washington requires that TSS not exceed 30 mg/l.

Average fecal and total coliform limits range from non-detectable to 20/100 ml. Higher single sample fecal and total coliform limits are allowed in several state regulations. Florida requires that 75 percent of the fecal coliform samples taken over a 30-day period be below detectable levels, with no single sample in excess of 25/100 ml, while Texas requires that no single fecal coliform count exceed 75/100 ml.

In general and where specified, limits on turbidity range from 2 to 5 NTU. Most of the states require an average turbidity limit of 2 NTU and a not-to-exceed limit of 5 NTU, although Hawaii's guidelines identify a not-to-exceed limit of 2 NTU. Florida requires continuous on-line monitoring of turbidity as an indicator that the TSS limit of 5.0 mg/l is being met. No limit is specified but turbidity setpoints used in Florida generally range from 2 to 2.5 NTU. California specifies different turbidity requirements for wastewater that has been coagulated and passed through natural and undisturbed soils or a bed of filter media, as well as wastewater passed through membranes. For the first, turbidity is not to exceed 5 NTU for

more than 5 percent of the time within a 24-hour period and not to exceed 10 NTU at any time. For the latter, turbidity is not to exceed 0.2 NTU more than 5 percent of the time within a 24-hour period and not to exceed 0.5 NTU at any time.

At this time, no states have set limits on certain pathogenic organisms for unrestricted urban reuse. However, Florida does require monitoring of *Giardia* and *Cryptosporidium* with sampling frequency based on treatment plant capacity. For systems less than 1 mgd (44 l/s), sampling is required one time during each 5-year period. For systems equal to or greater than 1 mgd (44 l/s), sampling is required one time during each 2-year period. Samples are to be taken following the disinfection process.

4.1.1.2 Restricted Urban Reuse

Restricted urban reuse involves the use of reclaimed water where public exposure to the reclaimed water is controlled; therefore, treatment requirements may not be as strict as for unrestricted urban reuse. Six states, which regulate both unrestricted and restricted urban reuse, adjusted requirements downward for the restricted category. Florida imposes the same requirements on both unrestricted and restricted urban access reuse. **Table 4-4** shows the reclaimed water quality and treatment requirements for restricted urban reuse.

Table 4-4. Restricted Urban Reuse

	Arizona	California	Florida	Hawaii	Nevada	Texas	Washington
Treatment	Secondary treatment and disinfection	Secondary – 23, oxidized, and disinfected	Secondary treatment, filtration, and high-level disinfection	Oxidized and disinfected	Secondary treatment and disinfection	NS ⁽¹⁾	Oxidized and disinfected
BOD₅	NS	NS	20 mg/l CBOD ₅	NS	30 mg/l	20 mg/l	30 mg/l
TSS	NS	NS	5 mg/l	NS	NS	NS	30 mg/l
Turbidity	NS	NS	NS	2 NTU (Max)	NS	3 NTU	2 NTU (Avg)
							5 NTU (Max)
Coliform	Fecal	Total	Fecal	Fecal	Fecal	Fecal	Total
	200/100 ml (Avg)	23/100 ml (Avg)	75% of samples below detection	23/100 ml (Avg)	23/100 ml (Avg)	200/100 ml (Avg)	23/100 ml (Avg)
	800/100 ml (Max)	240/100 ml (Max in 30 days)	25/100 ml (Max)	200/100 ml (Max)	240/100 ml (Max)	800/100 ml (Max)	240/100 ml (Max)

⁽¹⁾ NS - Not specified by state regulations

Table 4-5. Agricultural Reuse - Food Crops

	Arizona	California	Florida	Haw aii	Nevada	Texas	Washington
Treatment	Secondary treatment, filtration, and disinfection	Oxidized, coagulated, filtered, and disinfected	Secondary treatment, filtration, and high-level disinfection	Oxidized, filtered, and disinfected	Secondary treatment and disinfection	NS (1)	Oxidized, coagulated, filtered, and disinfected
BOD5	NS	NS	20 mg/l CBOD ₅	NS	30 mg/l	5 mg/l	30 mg/l
TSS	NS	NS	5 mg/l	NS	NS	NS	30 mg/l
Turbidity	2 NTU (Avg)	2 NTU (Avg)	NS	2 NTU (Max)	NS	3 NTU	2 NTU (Avg)
	5 NTU (Max)	5 NTU (Max)					5 NTU (Max)
Coliform	Fecal	Total	Fecal	Fecal	Fecal	Fecal	Total
	None detectable (Avg)	2.2/100 ml (Avg)	75% of samples below detection	2.2/100 ml (Avg)	200/100 ml (Avg)	20/100 ml (Avg)	2.2/100 ml (Avg)
	23/100 ml (Max)	23/100 ml (Max in 30 days)	25/100 ml (Max)	23/100 ml (Max in 30 days)	400/100 ml (Max)	75/100 ml (Max)	23/100 ml (Max)

(1) NS - Not specified by state regulations

In general, the states require a minimum of secondary or biological treatment followed by disinfection prior to restricted urban reuse. Florida requires additional levels of treatment with filtration and possibly coagulation prior to restricted urban reuse. As in unrestricted urban reuse, Texas does not specify the type of treatment processes required and only sets limits on the reclaimed water quality.

Where specified, limits on average BOD range from 20 mg/l to 30 mg/l. Florida and Texas require that BOD not exceed 20 mg/l, while Nevada and Washington require that BOD not exceed 30 mg/l prior to restricted urban reuse. Limits on TSS vary from 5 mg/l to 30 mg/l. Florida requires that TSS not exceed 5.0 mg/l, while Washington requires that TSS not exceed 30 mg/l. As in unrestricted urban reuse, for those states that do not specify limitations on BOD or TSS, a particular level of treatment is usually specified.

Average fecal coliform limits range from non-detectable to 200/100 ml, with some states allowing higher single sample fecal coliform limits. As for unrestricted urban reuse, Florida requires that 75 percent of the fecal coliform samples taken over a 30-day period be below detectable levels, with no single sample in excess of 25/100 ml. Arizona and Texas require that no single fecal coliform count exceed 800/100 ml.

Washington is the only state that sets a limit on turbidity for restricted urban reuse with an average turbidity limit of 2 NTU and a not-to-exceed at any time limit of 5 NTU.

At this time, no states have set limits on certain pathogenic organisms for restricted urban reuse. However, Florida does require monitoring of *Giardia* and *Cryptosporidium* with sampling frequency as noted in Section 4.1.1.1.

4.1.1.3 Agricultural Reuse - Food Crops

The use of reclaimed water for irrigation of food crops is prohibited in some states, while others allow irrigation of food crops with reclaimed water only if the crop is to be processed and not eaten raw. Nevada allows only surface irrigation of fruit or nut bearing trees. Treatment requirements range from secondary treatment in Nevada for irrigation of processed food crops, to oxidation, coagulation, filtration, and disinfection in Arizona, California, Florida, Hawaii, and Washington. **Table 4-5** shows the reclaimed water quality and treatment requirements for irrigation of food crops.

Most states require a high level of treatment when reclaimed water is used for edible crops, especially those that are to be consumed raw. As in other reuse applications, however, existing regulations on treatment and

water quality requirements vary from state to state and depend largely on the type of irrigation employed and the type of food crop being irrigated. For example, for foods consumed raw, Washington requires that the reclaimed water be oxidized and disinfected when surface irrigation is used, with the mean total coliform count not to exceed 2.2/100 ml. When spray irrigation is utilized, Washington requires that the reclaimed water be oxidized, coagulated, filtered, and disinfected, with the mean total coliform count not to exceed 2.2/100 ml. For processed foods, Washington requires only oxidation and disinfection regardless of the type of irrigation, with a 7-day mean total coliform count of 240/100 ml.

Where specified, limits on BOD range from 5 mg/l to 30 mg/l. Texas requires a monthly average BOD limit of 5 mg/l when reclaimed water will be used to irrigate unprocessed food crops. In Texas, spray irrigation is not permitted on foods that may be consumed raw, and only irrigation types that avoid reclaimed water contact with edible portions of food crops are acceptable. Florida requires that the annual average CBOD not exceed 20 mg/l after secondary treatment with filtration and high-level disinfection, while Texas requires that the BOD not exceed 30 mg/l (monthly average) when the reclaimed water is treated using a pond system and is to be used to irrigate food crops undergoing processing.

Limits on TSS vary from 5 mg/l to 30 mg/l. Florida requires that TSS not exceed 5.0 mg/l in any one sample prior to disinfection, while Washington requires that the TSS not exceed 30 mg/l (monthly average). In Florida, direct contact (spray) irrigation of edible crops that will not be peeled, skinned, cooked, or thermally-processed before consumption is not allowed except for tobacco and citrus. Indirect contact methods (ridge and furrow, drip, subsurface application system) can be used on any type of edible crop. California allows for direct contact irrigation with the edible portion of the crop.

Average fecal and total coliform limits range from non-detectable to 200/100 ml. Arizona requires no detectable limit for fecal coliform when reclaimed water will be used for spray irrigation of food crops. Florida requires that 75 percent of the fecal coliform samples taken over a 30-day period be below detectable levels, with no single sample in excess of 25/100 ml. Conversely, Nevada requires a maximum fecal coliform count of less than 400/100 ml with only surface irrigation of fruit and nut bearing trees. Again, some states allow higher single sample coliform counts.

Limits on turbidity range from 2 to 10 NTU. For example, California requires that turbidity not exceed 2 NTU within a 24-hour period, not exceed 5 NTU more than 5 per-

cent of the time, and not exceed a maximum of 10 NTU at any time for reclaimed water that has been coagulated and passed through natural undisturbed soils or a bed of filter media and is irrigated on food crops to be consumed raw. California requires that the turbidity not exceed 0.2 NTU more than 5 percent of the time and not exceed a maximum of 0.5 NTU at any time for reclaimed water that has been passed through a membrane and is irrigated on food crops to be consumed raw. Hawaii requires that the detectable turbidity not exceed 5 NTU for more than 15 minutes and never exceed 10 NTU prior to filtration for reclaimed water used for spray irrigation of food crops.

At this time, no states have set limits on certain pathogenic organisms for agricultural reuse on food crops. Florida does require monitoring of *Giardia* and *Cryptosporidium* with sampling frequency as noted in Section 4.1.1.1.

4.1.1.4 Agricultural Reuse – Non-food Crops

The use of reclaimed water for agricultural irrigation of non-food crops presents a reduced opportunity of human exposure to the water, resulting in less stringent treatment and water quality requirements than other forms of reuse. In the majority of the states, secondary treatment followed by disinfection is required, although Hawaii also requires filtration. **Table 4-6** shows the reclaimed water quality and treatment requirements for irrigation of non-food crops.

Where specified, limits on BOD range from 5 mg/l to 30 mg/l. Texas requires that BOD not exceed 5 mg/l (monthly average) except when reclaimed water is used for landscape impoundments, in which case BOD is limited to 10 mg/l. Florida requires that the annual average CBOD not exceed 20 mg/l after secondary treatment and basic disinfection. Washington and Nevada require that BOD not exceed 30 mg/l as a monthly average. Limits on TSS vary from 20 mg/l to 30 mg/l. Florida requires that the annual average TSS not exceed 20 mg/l except when a subsurface application is used, in which case the single sample TSS limit is 10 mg/l. Washington requires a monthly mean of 30 mg/l TSS.

Average fecal and total coliform limits range from 2.2/100 ml for Hawaii to 200/100 ml for Arizona and Florida. There are several states that do not require disinfection if certain buffer requirements are met. For example, Nevada requires no disinfection with a minimum buffer zone of 800 feet for spray irrigation of non-food crops. Some states allow higher single sample coliform counts. For example, Arizona requires that no single fecal coliform count ex-

Table 4-6. Agricultural Reuse - Non-Food Crops

	Arizona	California	Florida	Hawaii	Nevada	Texas	Washington
Treatment	Secondary treatment and disinfection	Secondary-23, Oxidized, and disinfected	Secondary treatment, basic disinfection	Oxidized, filtered, and disinfected	Secondary treatment and disinfection	NS ⁽¹⁾	Oxidized and disinfected
BOD₅	NS	NS	20 mg/l CBOD ₅	NS	30 mg/l	5 mg/l	30 mg/l
TSS	NS	NS	20 mg/l	NS	NS	NS	30 mg/l
Turbidity	NS	NS	NS	2 NTU (Max)	NS	3 NTU	2 NTU (Avg)
							5 NTU (Max)
Coliform	Fecal	Total	Fecal	Fecal	Fecal	Fecal	Total
	200/100 ml (Avg)	23/100 ml (Avg)	200/100 ml (Avg)	2.2/100 ml (Avg)	200/100 ml (Avg)	20/100 ml (Avg)	23/100 ml (Avg)
	800/100 ml (Max)	240/100 ml (Max in 30 days)	800/100 ml (Max)	23/100 ml (Max)	400/100 ml (Max)	75/100 ml (Max)	240/100 ml (Max)

⁽¹⁾ NS - Not specified by state regulations

ceed 4,000/100 ml when reclaimed water will be used for irrigation of pasture for non-dairy animals.

At this time, Hawaii, Texas, and Washington require limits on turbidity for reclaimed water used for agricultural reuse on non-food crops. Washington requires that the turbidity not exceed 2 NTU as an average and not exceed 5 NTU at any time. Texas requires a turbidity limit of 3 NTU for reclaimed water that will be used for irrigation of pastures for milking animals. Hawaii, on the other hand, requires the detectable turbidity not exceed 5 NTU for more than 15 minutes and never exceed 10 NTU prior to filtration for reclaimed water used for spray irrigation of pastures for milking and other animals.

At this time, no states have set limits on certain pathogenic organisms for agricultural reuse on non-food crops.

4.1.1.5 Unrestricted Recreational Reuse

As with unrestricted urban reuse, unrestricted recreational reuse involves the use of reclaimed water where public exposure is likely, thereby necessitating a high degree of treatment. Only 4 of the 7 states (California, Nevada, Texas, and Washington) have regulations or guidelines pertaining to unrestricted recreational reuse. **Table 4-7** shows the reclaimed water quality and treatment requirements for unrestricted recreational reuse.

Nevada requires secondary treatment with disinfection, while California requires oxidation, coagulation, clarification, filtration, and disinfection. Where specified, limits on BOD range from 5 mg/l to 30 mg/l. Texas requires that BOD not exceed 5 mg/l as a monthly average, while Washington requires that BOD not exceed 30 mg/l prior to unrestricted recreational reuse. Washington is the only state to set a limit on TSS and requires 30 mg/l or less as a monthly average. All states, except Texas, require that the median total coliform count not exceed 2.2/100 ml, with no single sample to exceed 23/100 ml. Texas requires that the median fecal coliform count not exceed 20/100 ml, with no single sample to exceed 75/100 ml.

Limits on turbidity generally range from 2 NTU to 5 NTU. Most of the states require an average turbidity limit of 2 NTU and a not-to-exceed limit of 5 NTU. California specifies different turbidity requirements for wastewater that has been coagulated and passed through natural and undisturbed soils or a bed of filter media as well as wastewater passed through membranes. For the first, turbidity is not to exceed 5 NTU for more than 5 percent of the time within a 24-hour period and not to exceed 10 NTU at any time. For the latter, turbidity is not to exceed 0.2 NTU more than 5 percent of the time within a 24-hour period and not to exceed 0.5 NTU at any time. Texas requires a turbidity limit of 3 NTU, and Nevada does not specify a limit on turbidity.

Table 4-7. Unrestricted Recreational Reuse

	Arizona	California	Florida	Hawaii	Nevada	Texas	Washington
Treatment	NR ⁽¹⁾	Oxidized, coagulated, clarified, filtered, and disinfected	NR	NR	Secondary treatment and disinfection	NS	Oxidized, coagulated, filtered, and disinfected
BOD₅	NR	NS ⁽²⁾	NR	NR	30 mg/l	5 mg/l	30 mg/l
TSS	NR	NS	NR	NR	NS	NS	30 mg/l
Turbidity	NR	2 NTU (Avg)	NR	NR	NS	3 NTU	2 NTU (Avg)
		5 NTU (Max)					5 NTU (Max)
Coliform	NR	Total	NR	NR	Fecal	Fecal	Fecal
		2.2/100 ml (Avg)			2.2/100 ml (Avg)	20/100 ml (Avg)	2.2/100 ml (Avg)
		23/100 ml (Max in 30 days)			23/100 ml (Max)	75/100 ml (Max)	23/100 ml (Max)

(1) NR - Not regulated by the state

(2) NS - Not specified by state regulations

Table 4-8. Restricted Recreational Reuse

	Arizona	California	Florida	Hawaii	Nevada	Texas	Washington
Treatment	Secondary treatment, filtration, and disinfection	Secondary-23, oxidized, and disinfected	NR ⁽¹⁾	Oxidized, filtered, and disinfected	Secondary treatment and disinfection	NS	Oxidized and disinfected
BOD₅	NS ⁽²⁾	NS	NR	NS	30 mg/l	20 mg/l	30 mg/l
TSS	NS	NS	NR	NS	NS	NS	30 mg/l
Turbidity	2 NTU (Avg)	NS	NR	2 NTU (Max)	NS	NS	2 NTU (Avg)
	5 NTU (Max)						5 NTU (Max)
Coliform	Fecal	Total	NR	Fecal	Fecal	Fecal	Total
	None detectable (Avg)	2.2/100 ml (Avg)		2.2/100 ml (Avg)	200/100 ml (Avg)	200/100 ml (Avg)	2.2/100 ml (Avg)
	23/100 ml (Max)	23/100 ml (Max in 30 days)		23/100 ml (Max)	23/100 ml (Max)	800/100 ml (Max)	23/100 ml (Max)

(1) NR - Not regulated by the state

(2) NS - Not specified by state regulations

At this time, no states have set limits on certain pathogenic organisms for unrestricted recreational reuse.

4.1.1.6 Restricted Recreational Reuse

State regulations and guidelines regarding treatment and water quality requirements for restricted recreational reuse are generally less stringent than for unrestricted rec-

reational reuse since the public exposure to the reclaimed water is less likely. Six of the 7 states (Arizona, California, Hawaii, Nevada, Texas, and Washington) have regulations pertaining to restricted recreational reuse. With the exception of Arizona and Hawaii, which require filtration, the remaining states require secondary treatment with disinfection. Texas does not specify treatment process requirements. **Table 4-8** shows the reclaimed wa-

ter quality and treatment requirements for restricted recreational reuse.

Nevada, Texas, and Washington have set limits on BOD ranging from 20 mg/l to 30 mg/l as a monthly average. Only Washington has set limits on TSS of 30 mg/l as a monthly average. Arizona requires no detectable fecal coliform in 4 of the last 7 daily samples and a single sample maximum of 23/100 ml. California, Hawaii, Nevada, and Washington require that the median total coliform count not exceed 2.2/100 ml. Texas, on the other hand, requires that the median fecal coliform count not exceed 200/100 ml and that a single sample not exceed 800/100 ml.

Limits on turbidity are specified for Arizona, Hawaii, and Washington. Arizona and Washington require a turbidity of less than 2 NTU as an average and a not-to-exceed maximum of 5 NTU. Hawaii specifies an effluent turbidity requirement of 2 NTU. California, Nevada, and Texas have not specified turbidity requirements for restricted recreational reuse.

At this time, no states have set limits on certain pathogenic organisms for restricted recreational reuse.

4.1.1.7 Environmental - Wetlands

A review of existing reuse regulations shows only 2 of the 7 states (Florida and Washington) have regulations

pertaining to the use of reclaimed water for creation of artificial wetlands and/or the enhancement of natural wetlands. **Table 4-9** shows the reclaimed water quality and treatment requirements for environmental reuse.

Florida has comprehensive and complex rules governing the discharge of reclaimed water to wetlands. Treatment and disinfection levels are established for different types of wetlands, different types of uses, and the degree of public access. Most wetland systems in Florida are used for tertiary wastewater treatment; and wetland creation, restoration, and enhancement projects can be considered reuse. Washington also specifies different treatment requirements for different types of wetlands and based on the degree of public access. General compliance requirements of 20 mg/l BOD and TSS, 3 mg/l total Kjeldahl nitrogen (TKN), and 1 mg/l total phosphorus must be met for all categories.

4.1.1.8 Industrial Reuse

Five of the 7 states (California, Florida, Hawaii, Texas, and Washington) have regulations or guidelines pertaining to industrial reuse of reclaimed water. **Table 4-10** shows the reclaimed water quality and treatment requirements for industrial reuse.

Reclaimed water quality and treatment requirements vary based on the final use of the reclaimed water and exposure potential (see Appendix A, Table A-8 for a sum-

Table 4-9. Environmental Reuse - Wetlands

	Arizona	California	Florida ⁽¹⁾	Hawaii	Nevada	Texas	Washington
Treatment	NR ⁽²⁾	NR	Advanced treatment	NR	NR	NR	Oxidized, coagulated, and disinfected
BOD₅	NR	NR	5 mg/l CBOD ₅	NR	NR	NR	20 mg/l
TSS	NR	NR	5 mg/l	NR	NR	NR	20 mg/l
Coliform	NR	NR	NS ⁽³⁾	NR	NR	NR	Fecal
							2.2/100 ml (Avg)
							23/100 ml (Max)
Total Ammonia	NR	NR	2 mg/l	NR	NR	NR	Not to exceed chronic standards for freshwater
Total Phosphorus	NR	NR	1 mg/l	NR	NR	NR	1 mg/l

(1) Florida requirements are for discharge of reclaimed water to receiving wetlands

(2) NR - Not regulated by the state

(3) NS - Not specified by state regulations

Table 4-10. Industrial Reuse⁽¹⁾

	Arizona	California	Florida	Hawaii	Nevada	Texas	Washington
Treatment	NR ⁽²⁾	Oxidized and disinfected	Secondary treatment and basic disinfection	Oxidized and disinfected	NR	NS	Oxidized and disinfected
BOD₅	NR	NS ⁽³⁾	20 mg/l	NS	NR	20 mg/l	NS
TSS	NR	NS	20 mg/l	NS	NR	---	NS
Turbidity	NR	NS	NS	NS	NR	3 NTU	NS
Coliform	NR	Total	Fecal	Fecal	NR	Fecal	Total
		23/100 ml (Avg)	200/100 ml (Avg)	23/100 ml (Avg)		200/100 ml (Avg)	23/100 ml (Avg)
		240/100 ml (Max in 30 days)	800/100 ml (Max)	200/100 ml (Max)		800/100 ml (Avg)	240/100 ml (Avg)

(1) All state requirements are minimum values. Additional treatment may be required depending on expected public exposure. Additional regulations for industrial systems are contained in Appendix A.

(2) NR - Not regulated by the state

(3) NS - Not specified by state regulations

mary of each state’s regulations). For example, California has different requirements for the use of reclaimed water as cooling water, based on whether or not a mist is created. If a mist is created, oxidation, coagulation, filtration, and disinfection are required and total coliform limits of 2.2/100 ml as a weekly median must be met. If a mist is not created, only oxidation and disinfection are required and total coliform limits of 23/100 ml as a weekly median must be met.

4.1.1.9 Groundwater Recharge

Spreading basins, percolation ponds, and infiltration basins have a long history of providing both effluent disposal and groundwater recharge. Most state regulations allow for the use of relatively low quality water (i.e., secondary treatment with basic disinfection) based on the fact that these systems have a proven ability to provide additional treatment. Traditionally, potable water supplies have been protected by requiring a minimum separation between the point of application and any potable supply wells. These groundwater systems are also typically located so that their impacts to potable water withdrawal points are minimized. While such groundwater recharge systems may ultimately augment potable aquifers,

that is not their primary intent and experience suggests current practices are protective of raw water supplies.

Based on a review of the existing reuse regulations and guidelines, California, Florida, Hawaii, and Washington have regulations or guidelines for reuse with the specific intent of groundwater recharge of aquifers. **Table 4-11** shows reclaimed water quality and treatment requirements for groundwater recharge via rapid-rate application systems.

For groundwater recharge, California and Hawaii do not specify required treatment processes and determine requirements on a case-by-case basis. The California and Hawaii Departments of Health Services base the evaluation on all relevant aspects of each project including treatment provided, effluent quality and quantity, effluent or application spreading area operation, soil characteristics, hydrogeology, residence time, and distance to withdrawal. Hawaii does require a groundwater monitoring program.

Washington has extensive guidelines for the use of reclaimed water for direct groundwater recharge of nonpotable aquifers. It requires Class A reclaimed wa-

Table 4-11. Groundwater Recharge ⁽¹⁾

	Arizona	California ⁽²⁾	Florida	Hawaii	Nevada	Texas	Washington
Treatment	NR ⁽³⁾	Case-by-case basis	Secondary treatment and basic disinfection	Case-by-case basis	NR	NR	Oxidized, coagulated, filtered, and disinfected
BOD₅	NR		NS ⁽⁴⁾		NR	NR	5 mg/l
TSS	NR		10.0 mg/l		NR	NR	5 mg/l
Turbidity	NR		NS		NR	NR	2 NTU (Avg) 5 NTU (Max)
Coliform	NR		NS		NR	NR	Total 2.2/100 ml (Avg) 23/100 ml (Max)
Total Nitrogen	NR		12 mg/l		NR	NR	NS

- (1) All state requirements are for groundwater recharge via rapid-rate application systems. Additional regulations for recharge of potable aquifers are contained in Section 4.1.1.10 and Appendix A.
- (2) Groundwater recharge in California and Hawaii is determined on a case-by-case basis
- (3) NR - Not regulated by the state
- (4) NS - Not specified by state regulations

ter defined as oxidized, coagulated, filtered, and disinfected. Total coliform is not to exceed 2.2/100 ml as a 7-day median and 23/100 ml in any sample. Weekly average BOD and TSS limits are set at 5 mg/l. Turbidity is not to exceed 2 NTU as a monthly average and 5 NTU in any sample. Additionally, groundwater monitoring is required and is based on reclaimed water quality and quantity, site-specific soil and hydrogeologic characteristics, and other considerations. Washington also specifies that reclaimed water withdrawn for nonpotable purposes can be withdrawn at any distance from the point of injection and at any time after direct recharge.

Florida requires that TSS not exceed 5.0 mg/l in any sample, be achieved prior to disinfection, and that the total nitrogen in the reclaimed water be less than 12 mg/l. Florida also requires continuous on-line monitoring of turbidity; however, no limit is specified.

4.1.1.10 Indirect Potable Reuse

Indirect potable reuse involves the use of reclaimed water to augment surface water sources that are used or will be used for public water supplies or to recharge groundwater used as a source of domestic water supply. Unplanned indirect potable water reuse is occurring in many

river systems today. Many domestic wastewater treatment plants discharge treated effluent to surface waters upstream of intakes for domestic water supply treatment plants. Additionally, many types of beneficial reuse projects inadvertently contribute to groundwater augmentation as an unintended result of the primary activity. For example, irrigation can replenish groundwater sources that will eventually be withdrawn for use as a potable water supply. Indirect potable reuse systems, as defined here, are distinguished from typical groundwater recharge systems and surface water discharges by both intent and proximity to subsequent withdrawal points for potable water use. Indirect potable reuse involves the intentional introduction of reclaimed water into the raw water supply for the purposes of increasing the total volume of water available for potable use. In order to accomplish this objective, the point at which reclaimed water is introduced into the environment must be selected to ensure it will flow to the point of withdrawal. Typically the design of these systems assumes there will be little to no additional treatment in the environment after discharge, and all applicable water quality requirements are met prior to release of the reclaimed water.

Based on a review of the existing reuse regulations and guidelines, 4 of the 7 states (California, Florida, Hawaii,

and Washington) have regulations or guidelines pertaining to indirect potable reuse. For groundwater recharge of potable aquifers, most of the states require a pretreatment program, public hearing requirements prior to project approval, and a groundwater monitoring program. Florida and Washington require pilot plant studies to be performed. In general, all the states that specify treatment processes require secondary treatment with filtration and disinfection. Washington is the only state that specifies the wastewater must be treated by reverse osmosis. California and Hawaii do not specify the type of treatment processes required and determine requirements on a case-by-case basis.

Most states specify reclaimed water quality limitations for TSS, nitrogen, total organic carbon (TOC), turbidity, and total coliform. Florida requires that TSS not exceed 5.0 mg/l in any sample and be achieved prior to disinfection. Florida and Washington require the total nitrogen in the reclaimed water to be less than 10 mg/l. Washington has a limit of 1 mg/l for TOC, while Florida's limit is set at 3 mg/l as a monthly average. Florida also requires an average limit of 0.2 mg/l for total organic halides (TOX). Turbidity limits vary greatly where specified. For example, Washington specifies a limit of 0.1 NTU as a monthly average and 0.5 NTU as a maximum at any time. Florida requires continuous on-line monitoring of turbidity; however, no limit is specified. Fecal coliform limits also vary greatly from state to state. Washington requires a limit of 1/100 ml for total coliform as a weekly median and a not to exceed limit of 5/100 ml in any one sample for direct injection into a potable aquifer. The states that specify reclaimed water quality limitations require the reclaimed water to meet drinking water standards.

Most states specify a minimum time the reclaimed water must be retained underground prior to being withdrawn as a source of drinking water. Washington requires that reclaimed water be retained underground for a minimum of 12 months prior to being withdrawn as a drinking water supply. Several states also specify minimum separation distances between a point of recharge and the point of withdrawal as a source of drinking water. Florida requires a 500-foot (150-meter) separation distance between the zone of discharge and potable water supply well. Washington requires the minimum horizontal separation distance between the point of direct recharge and point of withdrawal as a source of drinking water supply to be 2,000 feet (610 meters). **Table 4-12** shows the reclaimed water quality and treatment requirements for indirect potable reuse.

Florida includes discharges to Class I surface waters (public water supplies) as indirect potable reuse. Discharges less than 24 hours travel time upstream from

Class I waters are also considered as indirect potable reuse. Surface water discharges located more than 24 hours travel time to Class I waters are not considered indirect potable reuse. For discharge to Class I surface waters or water contiguous to or tributary to Class I waters (defined as a discharge located less than or equal to 4 hours travel time from the point of discharge to arrival at the boundary of the Class I water), secondary treatment with filtration, high-level disinfection, and any additional treatment required to meet TOC and TOX limits is required. The reclaimed water must meet primary and secondary drinking water standards, except for asbestos, prior to discharge. TSS must not exceed 5.0 mg/l in any sample prior to disinfection and total nitrogen cannot exceed 10 mg/l as an annual average. The reclaimed water must also meet TOC limitations of 3 mg/l as a monthly average and 5 mg/l in any single sample. Outfalls for surface water discharges are not to be located within 500 feet (150 meters) of existing or approved potable water intakes within Class I surface waters.

4.1.2 Reclaimed Water Monitoring Requirements

Reclaimed water monitoring requirements vary greatly from state to state and again depend on the type of reuse. For unrestricted urban reuse, Oregon requires sampling for coliform daily, while for agricultural reuse of non-food crops, sampling for total coliform is only required once a week. Oregon also requires hourly monitoring of turbidity when a limit on turbidity is specified.

For unrestricted and restricted urban reuse, as well as agricultural reuse on food crops, Florida requires the continuous on-line monitoring of turbidity and chlorine residual. Even though no limits on turbidity are specified in Florida, continuous monitoring serves as an on-line surrogate for suspended solids. In addition, Florida requires that the TSS limit be achieved prior to disinfection and has a minimum schedule for sampling and testing flow, pH, chlorine residual, dissolved oxygen, TSS, CBOD, nutrients, and fecal coliform based on system capacity. Florida also requires an annual analysis of primary and secondary drinking water standards for reclaimed water used in irrigation for facilities greater than 100,000 gpd (4.4 l/s). Monitoring for *Giardia* and *Cryptosporidium* must also be performed with frequency dependent on system capacity. Other states determine monitoring requirements on a case-by-case basis depending on the type of reuse.

4.1.3 Treatment Facility Reliability

Some states have adopted facility reliability regulations or guidelines in place of, or in addition to, water quality

Table 4-12. Indirect Potable Reuse ⁽¹⁾

	Arizona	California ⁽²⁾	Florida	Hawaii	Nevada	Texas	Washington	
Treatment	NR ⁽³⁾	Case-by-case basis	Advanced treatment, filtration, and high-level disinfection	Case-by-case basis	NR	NR	Oxidized, coagulated, filtered, reverse-osmosis treated, and disinfected	
BOD₅	NR		20 mg/l		NR	NR	5 mg/l	
TSS	NR		5.0 mg/l		NR	NR	5 mg/l	
Turbidity	NR		NS ⁽⁴⁾		NR	NR	0.1 NTU (Avg) 0.5 NTU (Max)	
Coliform	NR		Total		All samples less than detection	NR	NR	Total
								1/100 ml (Avg)
								5/100 ml (Max)
Total Nitrogen	NR		10 mg/l		NR	NR	10 mg/l	
TOC	NR		3 mg/l (Avg)		NR	NR	1.0 mg/l	
			5 mg/l (Max)					
Primary and Secondary Standards	NR	Compliance with most primary and secondary	NR	NR	Compliance with most primary and secondary			

(1) Florida requirements are for the planned use of reclaimed water to augment surface water sources that will be used as a source of domestic water supply

(2) Indirect potable reuse in California and Hawaii is determined on a case-by-case basis

(3) NR - Not regulated by the state

(4) NS - Not specified by state regulations

requirements. Generally, requirements consist of alarms warning of power failure or failure of essential unit processes, automatic standby power sources, emergency storage, and the provision that each treatment process be equipped with multiple units or a back-up unit.

Articles 8, 9, and 10 of California’s Title 22 regulations provide design and operational considerations covering alarms, power supply, emergency storage and disposal, treatment processes, and chemical supply, storage, and feed facilities. For treatment processes, a variety of reliability features are acceptable in California. For example, for all biological treatment processes, one of the following is required:

- Alarm (failure and power loss) and multiple units capable of producing biologically oxidized wastewater with one unit not in operation

- Alarm (failure and power loss) and short-term (24-hour) storage or disposal provisions and standby replacement equipment

- Alarm (failure and power loss) and long-term (20-day) storage or disposal provisions

Florida requires Class I reliability of treatment facilities when reclaimed water is used for irrigation of food crops and for restricted and unrestricted urban reuse. Class I reliability requires multiple treatment units or back-up units and a secondary power source. In addition, a minimum of 1 day of reject water storage is required to store reclaimed water of unacceptable quality for additional treatment. Florida also requires staffing at the water reclamation facility 24 hours/day, 7 days/week or 6 hours/day, 7 days/week. The minimum staffing requirement may be reduced to 6 hours/day, 7 days/week if reclaimed water

is delivered to the reuse system only during periods when a qualified operator is present, or if additional reliability features are provided.

Florida has also established minimum system sizes for treatment facilities to aid in assuring the continuous production of high-quality reclaimed water. Minimum system size for unrestricted and restricted urban reuse and for use on edible crops is 0.1 mgd (4.4 l/s). A minimum system size is not required if reclaimed water will be used only for toilet flushing and fire protection uses.

Other states that have regulations or guidelines regarding treatment facility reliability include Georgia, Hawaii, Indiana, Massachusetts, North Carolina, Oregon, Utah, Washington, and Wyoming. Washington's guidelines pertaining to treatment facility reliability are similar to California's regulations. Georgia, Massachusetts, North Carolina, Oregon, and Wyoming require that multiple treatment units be provided for all essential treatment processes and a secondary or back-up power source be supplied.

4.1.4 Reclaimed Water Storage

Current regulations and guidelines regarding storage requirements are primarily based upon the need to limit or prevent surface water discharge and are not related to storage required to meet diurnal or seasonal variations in supply and demand. Storage requirements vary from state to state and are generally dependent upon geographic location and site conditions. For example, Florida requires a minimum storage volume equal to 3 days of the average design flow, while South Dakota requires a minimum storage volume of 210 days of the average design flow. The large difference in time is primarily due to the high number of non-irrigation days due to freezing temperatures in the northern states. In addition to the minimum storage requirement, Florida also requires that a water balance be performed based on a 1-in-10 year rainfall recurrence interval and a minimum of 20 years of climatic data to determine if additional storage is required beyond the minimum requirement of 3 days.

Most states that specify storage requirements do not differentiate between operational and seasonal storage, with the exception of Delaware, Georgia, and Ohio, which require that both operational and wet weather storage be considered. The majority of states that have storage requirements in their regulations or guidelines require that a water balance be performed on the reuse system, taking into account all inputs and outputs of water to the system based on a specified rainfall recurrence interval.

Presently, Florida is the only state with regulations or guidelines for aquifer storage and recovery (ASR) of reclaimed water. ASR systems using reclaimed water are required to meet the technical and permitting requirements of Florida's Department of Environmental Protection underground injection control program and obtain an underground injection control construction and operation permit in addition to the domestic wastewater permit. Water recovered from the ASR system must meet the performance standards for fecal coliform as specified for high-level disinfection. Specifically, the fecal coliform limits require 75 percent of samples to be below detection limits, and any single sample is not to exceed 25/100 ml before use in a reuse system. Preapplication treatment and disinfection requirements vary depending on the class of groundwater receiving injected reclaimed water, but may be as stringent as to require that reclaimed water meet primary and secondary drinking water standards and TOC and TOX limits prior to injection. Monitoring of the reclaimed water prior to injection and after recovery from the ASR system is required. In addition, a groundwater monitoring plan must be implemented before placing the ASR system into operation. The monitoring plan must be designed to verify compliance with the groundwater standards and to monitor the performance of the ASR system. As part of the monitoring plan, a measure of inorganics concentration (such as chlorides or total dissolved solids) and specific conductance of the water being injected, the groundwater, and the recovered water are required to be monitored. In some cases, an extended zone of discharge for the secondary drinking water standards and for sodium can be approved.

Injection wells and recovery wells used for ASR are to be located at least 500 feet from any potable water supply well. For potable water supply wells that are not public water supply wells, a smaller setback distance may be approved if it can be demonstrated that confinement exists such that the system will not adversely affect the quantity or quality of the water withdrawn from the potable water supply well. If the ASR well is located in the same aquifer as a public supply well, the permitting agencies may require a detailed analysis of the potential for reclaimed water entry into the public supply well.

4.1.5 Application Rates

When regulations specify application or hydraulic loading rates, the regulations generally pertain to land application systems that are used primarily for additional wastewater treatment for disposal rather than reuse. When systems are developed chiefly for the purpose of land treatment and/or disposal, the objective is often to dispose of as much effluent on as little land as possible;

thus, application rates are often far greater than irrigation demands and limits are set for the maximum hydraulic loading. On the other hand, when the reclaimed water is managed as a valuable resource, the objective is to apply the water according to irrigation needs rather than maximum hydraulic loading, and application limits are rarely specified.

Many states do not have any specific requirements regarding reclaimed water irrigation application rates, as these are generally based on site conditions; however, most states emphasizing beneficial reuse recommend a maximum hydraulic loading rate of no more than 2 inches per week (5.1 cm per week). Delaware's regulations require that the maximum design wastewater loading be limited to 2.5 inches per week (6.4 cm per week). Florida recommends a maximum annual average of 2 inches per week (5.1 cm per week). Those states emphasizing land treatment or disposal may recommend a hydraulic loading rate of up to 4 inches per week (10.2 cm per week).

In addition to hydraulic loading rates, some states also have limits on nitrogen loading. For example, Alabama, Arkansas, and Tennessee all require that the effluent from the reuse system have a nitrate-nitrogen concentration of 10 mg/l or less, while Missouri and Nebraska both require that the nitrogen loading not exceed the nitrogen uptake of the crop.

4.1.6 Groundwater Monitoring

Groundwater monitoring programs associated with reclaimed water irrigation generally focus on water quality in the surficial aquifer and are required by Alabama, Arkansas, Delaware, Florida, Hawaii, Illinois, Iowa, Massachusetts, Missouri, New York, Ohio, Pennsylvania, South Carolina, South Dakota, Tennessee, West Virginia, and Wisconsin. In general, these groundwater monitoring programs require that 1 well be placed hydraulically upgradient of the reuse site to assess background and incoming groundwater conditions within the aquifer in question. In addition 2 wells must be placed hydraulically downgradient of the reuse site to monitor compliance. Florida normally requires a minimum of 3 monitoring wells at each reuse site. For reuse projects involving multiple sites, Florida may allow monitoring at selected example sites. Some states also require that a well be placed within each reuse site. South Carolina's guidelines suggest that a minimum of 9 wells be placed in golf courses (18 holes) that irrigate with reclaimed water. Sampling parameters and frequency of sampling are generally considered on a case-by-case basis.

4.1.7 Setback Distances for Irrigation

Many states have established setback distances or buffer zones between reuse irrigation sites and various facilities such as potable water supply wells, property lines, residential areas, and roadways. Setback distances vary depending on the quality of reclaimed water and the method of application. For example, Nevada requires a 400- to 800-foot (120- to 240-meter) buffer, depending on disinfection level, for a spray irrigation system, but when surface irrigation is used as the application method, no buffer is required. For restricted and unrestricted urban reuse and irrigation of food crops, Florida requires a 75-foot (23-meter) setback to potable water supply wells; but for agricultural reuse on non-food crops, Florida requires a 500-foot (150-meter) setback to potable water supply wells and a 100-foot (30-meter) setback to property lines. Florida will allow reduced setback distances for agricultural reuse on non-food crops if additional disinfection and reliability are provided or if alternative application techniques are used. Colorado recommends a 500-foot (150-meter) setback distance to domestic supply wells and a 100-foot (30-meter) setback to any irrigation well regardless of the quality of the reclaimed water.

Due to the high degree of treatment required, Oregon and Nevada do not require setback distances when reclaimed water is used for unrestricted urban reuse or irrigation of food crops. However, setback distances are required for irrigation of non-food crops and restricted urban reuse. In Nevada, the quality requirements for reclaimed water are based not only on the type of reuse, but also on the setback distance. For example, for restricted urban reuse and a 100-foot (30-meter) buffer zone, Nevada requires that the reclaimed water have a mean fecal coliform count of no more than 23/100 ml and not exceed a maximum daily number of 240/100 ml. However, with no buffer zone, the reclaimed water must have a mean fecal coliform count of no more than 2.2/100 ml and not exceed a maximum daily number of 23/100 ml.

4.2 Suggested Guidelines for Water Reuse

Table 4-13 presents suggested wastewater treatment processes, reclaimed water quality, monitoring, and setback distances for various types of water reuse. Suggested guidelines are presented for the following categories:

- Urban Reuse
- Restricted Access Area Irrigation

- Agricultural Reuse - Food Crops
 - Food crops not commercially processed
 - Commercially processed food crops and surface irrigation of orchards and vineyards
- Agricultural Reuse – Non-Food Crops
 - Pasture for milking animals and fodder, fiber, and seed crops
- Recreational Impoundments
- Landscape Impoundments
- Construction Uses
- Industrial Reuse
- Environmental Reuse
- Groundwater Recharge
 - Spreading or injection into aquifers not used for public water supply
- Indirect Potable Reuse
 - Spreading into potable aquifers
 - Injection into potable aquifers
 - Augmentation of surface supplies

These guidelines apply to domestic wastewater from municipal or other wastewater treatment facilities having a limited input of industrial waste. The suggested guidelines are predicated principally on water reclamation and reuse information from the U.S. and are intended to apply to reclamation and reuse facilities in the U.S. Local social, economic, regulatory, technological, and other conditions may limit the applicability of these guidelines in some countries (see Chapter 8). It is explicitly stated that the direct application of these suggested guidelines will not be used by the United States Agency for International Development (USAID) as strict criteria for funding.

The suggested treatment processes, reclaimed water quality, monitoring frequency, and setback distances are based on:

- Water reuse experience in the U.S. and elsewhere
- Research and pilot plant or demonstration study data
- Technical material from the literature
- Various states' reuse regulations, policies, or guidelines (see Appendix A)

- Attainability
- Sound engineering practice

These guidelines are not intended to be used as definitive water reclamation and reuse criteria. They are intended to provide reasonable guidance for water reuse opportunities, particularly in states that have not developed their own criteria or guidelines.

Adverse health consequences associated with the reuse of raw or improperly treated wastewater are well documented. As a consequence, water reuse regulations and guidelines are principally directed at public health protection and generally are based on the control of pathogenic microorganisms for nonpotable reuse applications and control of both health significant microorganisms and chemical contaminants for indirect potable reuse applications. These guidelines address health protection via suggested wastewater treatment unit processes, reclaimed water quality limits, and other controls (setback distances, etc.).

Both treatment processes and water quality limits are recommended for the following reasons:

- Water quality criteria that include the use of surrogate parameters may not adequately characterize reclaimed water quality.
- A combination of treatment and quality requirements known to produce reclaimed water of acceptable quality obviate the need to monitor the finished water for certain constituents, e.g., some health-significant chemical constituents or pathogenic microorganisms.
- Expensive, time-consuming, and, in some cases, questionable monitoring for pathogenic organisms, such as viruses, is eliminated without compromising health protection.
- Treatment reliability is enhanced.

It would be impractical to monitor reclaimed water for all of the chemical constituents and pathogenic organisms of concern, and surrogate parameters are universally accepted. In the U.S., total and fecal coliforms are the most commonly used indicator organisms in reclaimed water as a measure of disinfection efficiency. While coliforms are adequate indicator organisms for many bacterial pathogens, they are, by themselves, poor indicators of parasites and viruses. The total coliform analysis includes enumeration of organisms of both fecal and nonfecal origin, while the fecal coliform analysis is spe-

Table 4-13. Suggested Guidelines for Water Reuse ¹

Types of Reuse	Treatment	Reclaimed Water Quality ²	Reclaimed Water Monitoring	Setback Distances ³	Comments
<p><i>Urban Reuse</i></p> <p>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</p>	<ul style="list-style-type: none"> • Secondary ⁴ • Filtration ⁵ • Disinfection ⁶ 	<ul style="list-style-type: none"> • pH = 6-9 • ≤ 10 mg/l BOD ⁷ • ≤ 2 NTU ⁸ • No detectable fecal coli/100 ml ^{9,10} • 1 mg/l Cl₂ residual (minimum) ¹¹ 	<ul style="list-style-type: none"> • pH - weekly • BOD - weekly • Turbidity - continuous • Coliform - daily • Cl₂ residual - continuous 	<ul style="list-style-type: none"> • 50 ft (15 m) to potable water supply wells 	<ul style="list-style-type: none"> • See Table 2-7 for other recommended limits. • 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. ¹² • Reclaimed water should be clear and odorless. • A higher chlorine residual and/or a longer contact time may be necessary to assure 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. • See Section 3.4.3. for recommended treatment reliability.
<p><i>Restricted Access Area Irrigation</i></p> <p>Sod farms, silviculture sites, and other areas where public access is prohibited, restricted or infrequent</p>	<ul style="list-style-type: none"> • Secondary ⁴ • Disinfection ⁶ 	<ul style="list-style-type: none"> • pH = 6-9 • ≤ 30 mg/l BOD ⁷ • ≤ 30 mg/l TSS • ≤ 200 fecal coli/100 ml ^{9,13,14} • 1 mg/l Cl₂ residual (minimum) ¹¹ 	<ul style="list-style-type: none"> • pH - weekly • BOD - weekly • TSS - daily • Coliform - daily • Cl₂ residual - continuous 	<ul style="list-style-type: none"> • 300 ft (90 m) to potable water supply wells • 100 ft (30 m) to areas accessible to the public (if spray irrigation) 	<ul style="list-style-type: none"> • See Table 2-7 for other recommended limits. • If spray irrigation, TSS less than 30 mg/l may be necessary to avoid clogging of sprinkler heads. • See Section 3.4.3 for recommended treatment reliability.
<p><i>Agricultural Reuse – Food Crops Not Commercially Processed ¹⁵</i></p> <p>Surface or spray irrigation of any food crop, including crops eaten raw.</p>	<ul style="list-style-type: none"> • Secondary ⁴ • Filtration ⁵ • Disinfection ⁶ 	<ul style="list-style-type: none"> • pH = 6-9 • ≤ 10 mg/l BOD ⁷ • ≤ 2 NTU ⁸ • No detectable fecal coli/100 ml ^{9,10} • 1 mg/l Cl₂ residual (minimum) ¹¹ 	<ul style="list-style-type: none"> • pH - weekly • BOD - weekly • Turbidity - continuous • Coliform - daily • Cl₂ residual - continuous 	<ul style="list-style-type: none"> • 50 ft (15 m) to potable water supply wells 	<ul style="list-style-type: none"> • See Table 2-7 for other recommended limits. • 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 assure that viruses and parasites are inactivated or destroyed. • High nutrient levels may adversely affect some crops during certain growth stages. • See Section 3.4.3 for recommended treatment reliability.
<p><i>Agricultural Reuse – Food Crops Commercially Processed ¹⁵</i></p> <p>Surface Irrigation of Orchards and Vineyards</p>	<ul style="list-style-type: none"> • Secondary ⁴ • Disinfection ⁶ 	<ul style="list-style-type: none"> • pH = 6-9 • ≤ 30 mg/l BOD ⁷ • ≤ 30 mg/l TSS • < 200 fecal coli/100 ml ^{9,13,14} • 1 mg/l Cl₂ residual (minimum) ¹¹ 	<ul style="list-style-type: none"> • pH - weekly • BOD - weekly • TSS - daily • Coliform - daily • Cl₂ residual - continuous 	<ul style="list-style-type: none"> • 300 ft (90 m) to potable water supply wells • 100 ft (30 m) to areas accessible to the public (if spray irrigation) 	<ul style="list-style-type: none"> • See Table 2-7 for other recommended limits. • 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. • See Section 3.4.3 for recommended treatment reliability.
<p><i>Agricultural Reuse – Non-food Crops</i></p> <p>Pasture for milking animals; fodder, fiber, and seed crops</p>	<ul style="list-style-type: none"> • Secondary ⁴ • Disinfection ⁶ 	<ul style="list-style-type: none"> • pH = 6-9 • ≤ 30 mg/l BOD ⁷ • ≤ 30 mg/l TSS • < 200 fecal coli/100 ml ^{9,13,14} • 1 mg/l Cl₂ residual (minimum) ¹¹ 	<ul style="list-style-type: none"> • pH - weekly • BOD - weekly • TSS - daily • Coliform - daily • Cl₂ residual - continuous 	<ul style="list-style-type: none"> • 300 ft (90 m) to potable water supply wells • 100 ft (30 m) to areas accessible to the public (if spray irrigation) 	<ul style="list-style-type: none"> • See Table 2-7 for other recommended limits. • 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 adhered to. • See Section 3.4.3 for recommended treatment reliability.

Table 4-13. Suggested Guidelines for Water Reuse ¹

Types of Reuse	Treatment	Reclaimed Water Quality ²	Reclaimed Water Monitoring	Setback Distances ³	Comments
<p><i>Recreational Impoundments</i></p> <p>Incidental contact (e.g., fishing and boating) and full body contact with reclaimed water allowed</p>	<ul style="list-style-type: none"> • Secondary ⁴ • Filtration ⁵ • Disinfection ⁶ 	<ul style="list-style-type: none"> • pH = 6-9 • ≤ 10 mg/l BOD ⁷ • ≤ 2 NTU ⁸ • No detectable fecal coli/100 ml ^{9,10} • 1 mg/l Cl₂ residual (minimum) ¹¹ 	<ul style="list-style-type: none"> • pH - weekly • BOD - weekly • Turbidity - continuous • Coliform - daily • Cl₂ residual - continuous 	<ul style="list-style-type: none"> • 500 ft (150 m) to potable water supply wells (minimum) if bottom not sealed 	<ul style="list-style-type: none"> • Dechlorination may be necessary to protect aquatic species of flora and fauna. • Reclaimed water should be non-irritating to skin and eyes. • Reclaimed water should be clear and odorless. • Nutrient removal may be necessary to avoid algae 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 assure that viruses and parasites are inactivated or destroyed. • Fish caught in impoundments can be consumed. • See Section 3.4.3. for recommended treatment reliability.
<p><i>Landscape Impoundments</i></p> <p>Aesthetic impoundment where public contact with reclaimed water is not allowed</p>	<ul style="list-style-type: none"> • Secondary ⁴ • Disinfection ⁶ 	<ul style="list-style-type: none"> • ≤ 30 mg/l BOD ⁷ • ≤ 30 mg/l TSS • ≤ 200 fecal coli/100 ml ^{9,13,14} • 1 mg/l Cl₂ residual (minimum) ¹¹ 	<ul style="list-style-type: none"> • pH - weekly • TSS - daily • Coliform - daily • Cl₂ residual - continuous 	<ul style="list-style-type: none"> • 500 ft (150 m) to potable water supply wells (minimum) if bottom not sealed 	<ul style="list-style-type: none"> • Nutrient removal may be necessary to avoid algae growth in impoundments. • Dechlorination may be necessary to protect aquatic species of flora and fauna. • See Section 3.4.3 for recommended treatment reliability.
<p><i>Construction Use</i></p> <p>Soil compaction, dust control, washing aggregate, making concrete</p>	<ul style="list-style-type: none"> • Secondary ⁴ • Disinfection ⁶ 	<ul style="list-style-type: none"> • ≤ 30 mg/l BOD ⁷ • ≤ 30 mg/l TSS • ≤ 200 fecal coli/100 ml ^{9,13,14} • 1 mg/l Cl₂ residual (minimum) ¹¹ 	<ul style="list-style-type: none"> • BOD - weekly • TSS - daily • Coliform - daily • Cl₂ residual - continuous 		<ul style="list-style-type: none"> • 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. • See Section 3.4.3 for recommended treatment reliability.
<p><i>Industrial Reuse</i></p> <p>Once-through cooling</p>	<ul style="list-style-type: none"> • Secondary ⁴ • Disinfection ⁶ 	<ul style="list-style-type: none"> • pH = 6-9 • ≤ 30 mg/l BOD ⁷ • ≤ 30 mg/l TSS • ≤ 200 fecal coli/100 ml ^{9,13,14} • 1 mg/l Cl₂ residual (minimum) ¹¹ 	<ul style="list-style-type: none"> • pH - weekly • BOD - weekly • TSS - daily • Coliform - daily • Cl₂ residual - continuous 	<ul style="list-style-type: none"> • 300 ft (90 m) to areas accessible to the public 	<ul style="list-style-type: none"> • Windblown spray should not reach areas accessible to workers or the public.
<p>Recirculating cooling towers</p>	<ul style="list-style-type: none"> • Secondary ⁴ • Disinfection ⁶ (chemical coagulation and filtration ⁵ may be needed) 	<ul style="list-style-type: none"> • Variable depends on recirculation ratio (see Section 2.2.1) pH = 6-9 • ≤ 30 mg/l BOD ⁷ • ≤ 30 mg/l TSS • ≤ 200 fecal coli/100 ml ^{9,13,14} • 1 mg/l Cl₂ residual (minimum) ¹¹ 	<ul style="list-style-type: none"> • pH - weekly • BOD - weekly • TSS - daily • Coliform - daily • Cl₂ residual - continuous 	<ul style="list-style-type: none"> • 300 ft (90 m) to areas accessible to the public. May be reduced or eliminated if high level of disinfection is provided. 	<ul style="list-style-type: none"> • Windblown spray should not reach areas accessible to workers or the public. • Additional treatment by user is usually provided to prevent scaling, corrosion, biological growths, fouling and foaming. • See Section 3.4.3 for recommended treatment reliability.
Other Industrial Uses	Depends on site specific uses (See Section 2.2.3)				
<p><i>Environmental Reuse</i></p> <p>Wetlands, marshes, wildlife habitat, stream augmentation</p>	<ul style="list-style-type: none"> • Variable • Secondary ⁴ and disinfection ⁶ (minimum) 	<ul style="list-style-type: none"> • Variable, but not to exceed: • ≤ 30 mg/l BOD ⁷ • ≤ 30 mg/l TSS • ≤ 200 fecal coli/100 ml ^{9,13,14} 	<ul style="list-style-type: none"> • BOD - weekly • TSS - daily • Coliform - daily • Cl₂ residual - continuous 		<ul style="list-style-type: none"> • 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. • See Section 3.4.3 for recommended treatment reliability.

Table 4-13. Suggested Guidelines for Water Reuse ¹

Types of Reuse	Treatment	Reclaimed Water Quality ²	Reclaimed Water Monitoring	Setback Distances ³	Comments
<p><i>Groundwater Recharge</i></p> <p>By spreading or injection into aquifers not used for public water supply</p>	<ul style="list-style-type: none"> Site-specific and use dependent Primary (minimum) for spreading Secondary ⁴ (minimum) for injection 	<ul style="list-style-type: none"> Site-specific and use dependent 	<ul style="list-style-type: none"> Depends on treatment and use 	<ul style="list-style-type: none"> Site-specific 	<ul style="list-style-type: none"> Facility should be designed to ensure that no reclaimed water reaches potable water supply aquifers See Section 2.5 for more information. For spreading projects, secondary treatment may be needed to prevent clogging. For injection projects, filtration and disinfection may be needed to prevent clogging. See Section 3.4.3 for recommended treatment reliability.
<p><i>Indirect Potable Reuse</i></p> <p>Groundwater recharge by spreading into potable aquifers</p>	<ul style="list-style-type: none"> Secondary ⁴ Disinfection ⁶ May also need filtration ⁵ and/or advanced wastewater treatment ¹⁶ 	<ul style="list-style-type: none"> Secondary ⁴ Disinfection ⁶ Meet drinking water standards after percolation through vadose zone 	<p>Includes, but not limited to, the following:</p> <ul style="list-style-type: none"> pH - daily Coliform - daily Cl₂ residual - continuous Drinking water standards - quarterly Other ¹⁷ - depends on constituent BOD - weekly Turbidity - continuous 	<ul style="list-style-type: none"> 500 ft (150 m) to extraction wells. May vary depending on treatment provided and site-specific conditions. 	<ul style="list-style-type: none"> The depth to groundwater (i.e., thickness to the vadose zone) should be at least 6 feet (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. See Sections 2.5 and 2.6 for more information. The reclaimed water should not contain measurable levels of viable pathogens after percolation through the vadose zone. ¹² See Section 3.4.3 for recommended treatment reliability.
<p><i>Indirect Potable Reuse</i></p> <p>Groundwater recharge by injection into potable aquifers</p>	<ul style="list-style-type: none"> Secondary ⁴ Filtration ⁵ Disinfection ⁶ Advanced wastewater treatment ¹⁶ 	<p>Includes, but not limited to, the following:</p> <ul style="list-style-type: none"> pH = 6.5 - 8.5 ≤ 2 NTU ⁸ No detectable total coli/100 ml ^{9,10} 1 mg/l Cl₂ residual (minimum) ¹¹ ≤ 3 mg/l TOC ≤ 0.2 mg/l TOX Meet drinking water standards 	<p>Includes, but not limited to, the following:</p> <ul style="list-style-type: none"> pH - daily Turbidity - continuous Total coliform - daily Cl₂ residual - continuous Drinking water standards - quarterly Other ¹⁷ - depends on constituent 	<ul style="list-style-type: none"> 2000 ft (600 m) to extraction wells. May vary depending on site-specific conditions. 	<ul style="list-style-type: none"> 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 See Sections 2.5 and 2.6 for more information. A higher chlorine residual and/or a longer contact time may be necessary to assure virus and protozoa inactivation. See Section 3.4.3 for recommended treatment reliability.
<p><i>Indirect Potable Reuse</i></p> <p>Augmentation of surface supplies</p>	<ul style="list-style-type: none"> Secondary ⁴ Filtration ⁵ Disinfection ⁶ Advanced wastewater treatment ¹⁶ 	<p>Includes, but not limited to, the following:</p> <ul style="list-style-type: none"> pH = 6.5 - 8.5 ≤ 2 NTU ⁸ No detectable total coli/100 ml ^{9,10} 1 mg/l Cl₂ residual (minimum) ¹¹ ≤ 3 mg/l TOC Meet drinking water standards 	<p>Includes, but not limited to, the following:</p> <ul style="list-style-type: none"> pH - daily Turbidity - continuous Total coliform - daily Cl₂ residual - continuous Drinking water standards - quarterly Other ¹⁷ - depends on constituent 	<ul style="list-style-type: none"> Site-specific 	<ul style="list-style-type: none"> Recommended level of treatment is site-specific and depends on factors such as receiving water quality, time and distance to point of withdrawal, dilution and subsequent treatment prior to distribution for potable uses. The reclaimed water should not contain measurable levels of viable pathogens. ¹² See Sections 2.6 for more information. A higher chlorine residual and/or a longer contact time may be necessary to assure virus and protozoa inactivation. See Section 3.4.3 for recommended treatment reliability.

Footnotes

1. These guidelines are based on water reclamation and reuse practices in the U.S., 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 U.S., local conditions may limit the applicability of the guidelines in some countries (see Chapter 8). 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.
4. Secondary treatment processes include activated sludge processes, trickling filters, rotating biological contractors, 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, 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 5-day BOD test.
8. The recommended turbidity limit should be met prior to disinfection. The average turbidity should be based on a 24-hour 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 minutes.
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, reverse osmosis and other membrane processes, air stripping, ultrafiltration, 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.

cific for coliform organisms of fecal origin. Therefore, fecal coliforms are better indicators of fecal contamination than total coliforms, and these guidelines use fecal coliform as the indicator organism. Either the multiple-tube fermentation technique or the membrane filter technique may be used to quantify the coliform levels in the reclaimed water.

The *Guidelines* suggest that, regardless of the type of reclaimed water use, some level of disinfection should be provided to avoid adverse health consequences from inadvertent contact or accidental or intentional misuse of a water reuse system. For nonpotable uses of reclaimed water, 2 levels of disinfection are recommended. Reclaimed water used for applications where no direct public or worker contact with the water is expected should be disinfected to achieve an average fecal coliform concentration not exceeding 200/100 ml because:

- Most bacterial pathogens will be destroyed or reduced to low or insignificant levels in the water
- The concentration of viable viruses will be reduced somewhat
- Disinfection of secondary effluent to this coliform level is readily achievable at minimal cost
- Significant health-related benefits associated with disinfection to lower, but not pathogen-free, levels are not obvious

For uses where direct or indirect contact with reclaimed water is likely or expected, and for dual water systems where there is a potential for cross-connections with potable water lines, disinfection to produce reclaimed water having no detectable fecal coliform organisms per 100 ml is recommended. This more restrictive disinfection level is intended for use in conjunction with tertiary treatment and other water quality limits, such as a turbidity less than or equal to 2 NTU in the wastewater prior to disinfection. This combination of treatment and use of water quality limits has been shown to produce reclaimed water that is essentially free of measurable levels of bacterial and viral pathogens.

For indirect potable uses of reclaimed water, where reclaimed water is intentionally introduced into the raw water supply for the purposes of increasing the total volume of water available for potable use, disinfection to produce reclaimed water having no detectable total coliform organisms per 100 ml is recommended. Total coliform is recommended, in lieu of fecal coliform, to be consistent with the Safe Drinking Water Act (SDWA) National Primary Drinking Water Regulations (NPDWR)

that regulate drinking water standards for producing potable drinking water.

These guidelines do not include suggested specific parasite or virus limits. Parasites have not been shown to be a problem at water reuse operations in the U.S. at the treatment and quality limits recommended in these guidelines, although there has been considerable interest in recent years regarding the occurrence and significance of *Giardia* and *Cryptosporidium* in reclaimed water. Viruses are of concern in reclaimed water, but virus limits are not recommended in these guidelines for the following reasons:

A significant body of information exists indicating that viruses are reduced or inactivated to low or immeasurable levels via appropriate wastewater treatment, including filtration and disinfection (Yanko, 1993).

- The identification and enumeration of viruses in wastewater are hampered by relatively low virus recovery rates, the complexity and high cost of laboratory procedures, and the limited number of facilities having the personnel and equipment necessary to perform the analyses.
- The laboratory culturing procedure to determine the presence or absence of viruses in a water sample takes about 14 days, and an additional 14 days are required to identify the viruses.
- While recombinant DNA technology provides new tools to rapidly detect viruses in water (e.g., nucleic acid probes and polymerase chain reaction technology), methods currently in use are not able to quantify viruses or differentiate between infective and non-infective virus particles.
- There is no consensus among virus experts regarding the health significance of low levels of viruses in reclaimed water.
- There have been no documented cases of viral disease resulting from the reuse of wastewater at any of the water reuse operations in the U.S.

The removal of suspended matter is related to the virus issue. Many pathogens are particulate-associated and that particulate matter can shield both bacteria and viruses from disinfectants such as chlorine and UV radiation. Also, organic matter consumes chlorine, thus making less of the disinfectant available for disinfection. There is general agreement that particulate matter should be reduced to low levels, e.g., 2 NTU or 5 mg/l TSS, prior to disinfection to ensure reliable destruction of patho-

genic microorganisms during the disinfection process. Suspended solids measurements are typically performed daily on a composite sample and only reflect an average value. Continuously monitored turbidity is superior to daily suspended solids measurements as an aid to treatment operation.

The need to remove organic matter is related to the type of reuse. Some of the adverse effects associated with organic substances are that they are aesthetically displeasing (may be malodorous and impart color), provide food for microorganisms, adversely affect disinfection processes, and consume oxygen. The recommended BOD limit is intended to indicate that the organic matter has been stabilized, is nonputrescible, and has been lowered to levels commensurate with anticipated types of reuse. TSS limits are suggested as a measure of organic and inorganic particulate matter in reclaimed water that has received secondary treatment. The recommended BOD and TSS limits are readily achievable at well operated water reclamation plants.

The suggested setback distances are somewhat subjective. They are intended to protect drinking water supplies from contamination and, where appropriate, to protect humans from exposure to the reclaimed water. While studies indicate the health risk associated with aerosols from spray irrigation sites using reclaimed water is low, the general practice is to limit, through design or operational controls, exposure to aerosols and wind-blown spray produced from reclaimed water that is not highly disinfected.

Unplanned or incidental indirect potable reuse occurs in many states in the U.S., while planned or intentional indirect potable reuse via groundwater recharge or augmentation of surface supplies is a less-widely accepted practice. Whereas the water quality requirements for nonpotable water uses are tractable and not likely to change significantly in the future, the number of water quality constituents to be monitored in drinking water (and, hence, reclaimed water intended for potable reuse) will increase and quality requirements will become more restrictive. Consequently, it would not be prudent to suggest a complete list of reclaimed water quality limits for all constituents of concern. Some general and specific information is provided in the guidelines to indicate the extensive treatment, water quality, and other requirements that are likely to be imposed where indirect potable reuse is contemplated.

4.3 Pathogens and Emerging Pollutants of Concern (EPOC)

As needs for alternative water supplies grow, reclaimed water will be used more in both direct nonpotable applications and indirect potable reuse projects. Future monitoring for pathogens and other EPOCs will likely be necessary to ensure that reclaimed water is a safe water source. For example, California regulations require monthly sampling and analysis for *Giardia*, enteric viruses, and *Cryptosporidium* for the use of reclaimed water for impoundments during the first year of operation (State of California, 2000). After the first year, the reclaimed water may be sampled and analyzed quarterly and monitoring may be discontinued after 2 years of operation with the approval of the California Department of Health Services (DHS). As previously discussed, Florida requires monitoring of *Giardia* and *Cryptosporidium* with sampling frequency based on treatment plant capacity for specific types of reuse.

The DHS updated the draft regulations for Groundwater Recharge Reuse in July 2003 to require monitoring of EPOCs. Each quarter, during the first year of operation, the reclaimed water shall be analyzed for: unregulated chemicals; priority toxic pollutants; chemicals with state action levels; and other chemicals that the DHS has specified (California DHS, 2003). Chemicals with state action levels are defined as chemicals that have been detected at least once in drinking water supplies or chemicals of interest for some specific reason. The other chemicals as specified by the DHS include N-Nitrosodiethylamine (NDEA) and N-Nitrosopyrrolidine.

The draft regulations also require annual monitoring of pharmaceuticals, endocrine disrupting chemicals, and other chemical indicators of municipal wastewater presence. The draft regulations state that these samples are being collected for information purposes, and there are no standards for the contaminants listed and no standards anticipated at this time (California DHS, 2003).

Although no illnesses to date have been directly connected to the use of reclaimed water, in order to better define pathogens and EPOCs contained in reclaimed water, it is recommended to continue with ongoing research and additional monitoring for *Giardia*, *Cryptosporidium*, and other EPOCs.

4.4 Pilot Testing

Because it is desirable to fully characterize the reclaimed water to be produced and to compare its quality to other water sources in the area, pilot testing should be conducted in support of some of the more sensitive types of

reuse, like groundwater recharge by injection and indirect potable reuse. Pilot testing can be used to demonstrate the ability of the selected unit processes to meet project objectives and to refine the design of sophisticated treatment trains. Pilot testing also can be used to demonstrate the ability of the treatment and disinfection units to effectively control pathogens and organic compounds. As part of this activity, the EPOCs, including pharmaceutically active substances, endocrine disruptors, and personal care products, can be evaluated. Ideally, pilot testing should build on previous work as opposed to repeating it.

4.5 References

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