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DISTRIBUTION OF COMMUNITY WATER SYSTEMS ACROSS THE UNITED STATES WITH EMPHASIS ON SIZE, WATER PRODUCTION, OWNERSHIP, AND TREATMENT

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ABSTRACT*

An understanding of the diversity of community water systems (CWS) in the United States is essential when evaluating the financial implications of the 1986 and subsequent amendments to the Safe Drinking Water Act (SDWA). This diversity, in terms of size, primary water source, ownership, and existing levels of treatment, shape the nature of the technical, institutional, and financial issues that must be confronted in moving these systems toward compliance with SDWA regulations. This report provides a descriptive summary of these operating and design characteristics of CWS's across the country.

The data are organized to help provide a typology of representative public water systems that can be examined to better understand the regional effects of policy implementation. The focus of the analysis is on small water systems, those most burdened by the expanded montoring and treatment regulations; much of the data are also provided for larger systems for purposes of comparison and completeness.

Emphasis is directed towards current water treatment objectives being pursued by CWS's and the treatment processes already in place. It is for those smaller systems that may require the addition of multiple water treatment processes that the financial implications are likely to be most severe.

As would be expected, there is a shortfall between the number of systems serving fewer than 10,000 people employing multiple treatment processes and the estimated number required. There are systems, however, that have demonstrated success with a number of multiple treatment processes, particularly in the small and medium-size categories. The experience gained by these systems would seem invaluable in efforts to accelerate the process of field testing and approval of technologies applicable to systems serving lower population levels.

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INTRODUCTION

As part of a comprehensive examination of the status of our nation's community water systems (CWS) and the financial implications of the 1986 Amendments to the Safe Drinking Water Act (SDWA), one must have a clear picture of the number and diversity of these systems both nationally and at the regional level. This diversity, particularly in terms of size, primary water source, ownership, and existing levels of treatment, shape the nature of the technical, institutional, and financial issues that must be confronted in moving the nation's many community water systems toward compliance with SDWA regulations.[1]

The purpose of this report is to provide a descriptive summary of these various operating and design characteristics of CWS's across the country. As such, the manuscript is one of the first in a series designed to provide a comprehensive look at the implications of the 1986 amendments. The objectives are modest relative to the scope of the overall research effort, but they are a necessary first step. Emphasis is focused on the policy implications that can be drawn from a careful analysis of the data. These data are also organized to help provide a typology of representative public water systems that can be examined to better understand the regional effects of policy implementation. The focus of the analysis is on small water systems, but much of the data is also provided for larger systems primarily for purposes of comparison and completeness.

Brief summaries of the size distribution of public water systems are already contained in two previous reports designed to assess the benefits and costs of the 1986 SDWA amendments, and the technical and economic capacity of states and public water systems for implementation of the 1986 amendments (Wade Miller Associates, 1990, and EPA, 1993). However, the assessments in these reports focused primarily at the national level, and there was little need to articulate differences in the distribution of systems regionally or by characteristics such as ownership, system capacity, and nature of the population served. At the time at least one of these studies was completed, many of the rules associated with various provisions of the 1986 amendments were at best in the early stages of development; few systems had yet to be confronted with the reality of compliance, so there was little need to focus on existing monitoring and treatment experience.

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[1] Passage of the 1996 amendments to the SDWA (PL-104-182) occurred during the development of this report. As such, the predominant focus of the report is directed towards the 1986 amendments, application is made to the 1996 amendments where appropriate. Given the descriptive nature of this report, this should be of little concern.

The issues surrounding the implementation of the 1986 amendments go well beyond those related to aggregate benefits and costs to society, which are the primary bases for justifying the regulations from a national perspective. Knowledge of the diversity of systems at a more disaggregate level is essential for the examination of these broader issues. For example, detailed information about public water systems at the regional level should be of interest in the design and location of regional centers for technical assistance as authorized in the 1996 amendments to the Safe Drinking Water Act. To the extent that the distribution of systems by type differs regionally, the cost of compliance relative to the benefits will differ as well. This could alter the financial implications for local governments, and in regions where the perceived benefit-cost ratios are lowest, the incentives for seeking exemptions could be quite high. The potential for viable restructuring could also be affected. Information concerning the proportion of systems owned privately and their size may be important to understand the effects of new legislative initiatives such as the unfunded mandate legislation passed recently by both the Senate and the House. This could be particularly true if, as some suspect, the availability of exemptions from full compliance would differ between public and private providers. Information about the type of population served by community water systems should enable one to make educated guesses about the income distribution in order to study the financial effects of amendments on individuals by income class.

The remainder of the report is divided into several sections. To provide a clear picture of what the data represent, we begin by reiterating the definition of a public water system. Since the data described in this report come primarily from the *FRDS-II Data Base*, we also discuss briefly how the data were organized to complete the analysis, and how potential problems associated with missing data in this large data base were handled. The focus then shifts to a discussion of the characteristics of water systems at the national level and their policy implications. The policy significance of the regional diversity of water systems is also highlighted.[2] Perhaps the most important section relates to the current treatment objectives and levels of treatment. This discussion helps to delineate the treatment needs, but it also provides a good indication of what financially feasible treatment strategies are being used currently by large and small systems. It should be invaluable in establishing priorities for further research. The final section summarizes the conclusions and implications for policy. Before proceeding, it is also important to emphasize that the nature of the analysis requires the presentation of a lot of data, particularly relating to the treatment strategies. This makes for

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[2] To facilitate this discussion of the regional data without adding unduly to the length of the text of the report, a detailed description of the regional diversity of water systems and the supporting data is included in an appendix. Its primary purpose is as a source document for those interested in the specific regional data.

some rather tedious reading at times, but we offer few apologies because this is very much a working document; much of the descriptive analysis is designed to help set priorities for further research.

PUBLIC WATER SYSTEMS DEFINED

A public water system (PWS), according to the definition used by the Federal government for policy purposes, is one that pipes water to the public for human consumption (EPA, 1993). To qualify as a PWS, a system must have at least 15 service connections, or regularly serve at least 25 individuals for two months or more during the year. By federal definition, PWS's are further divided into two groups: community water systems and non-community water systems. Non-community water systems are either transient or non-transient. Of the more than 200 thousand PWS's across the nation, nearly 30% are community water systems (CWS), just over 10% are non-transient, non-community systems (NTNC), and the remaining systems, nearly 60%, are transient, non-community systems (TNC).

In addition to being descriptive of the types of customers they serve, these classifications are important because the extent to which they must comply with the 1986 amendments differs. Historically, for example, all non-community water systems were required to meet only those standards designed to prevent short-term health problems such as bacteria, nitrates, and turbidity. This remains true for most transient, non-community systems (such as campgrounds, motels, and gas stations) which cater to transient customers in non-residential areas. The estimated 3% of these systems that rely on surface water supplies are also required to meet standards for filtration and disinfection (EPA, 1993).

On the other hand, non-transient non-community water systems must serve at least 25 people at least six months of the year and include schools, factories, hospitals and other institutions with their own water supplies. Subsequent to their passage, NTNC's are required to comply with the 1986 SDWA amendments. This is also true for community water systems (CWS), defined as public water systems which serve at least 15 service connections used by year-round residents or regularly serve at least 25 year-round residents. CWS's range from smaller units such as trailer parks and housing complexes to larger systems serving rural and suburban communities and large cities. Since the majority of systems which are potentially affected most seriously by the passage of the 1986 SDWA amendments are community water systems, the analysis here focuses on this group. This is consistent with the analysis in EPA's recent report to Congress on the technical and economic capacity of states and public water systems to implement drinking water regulations (EPA, 1993).

THE FEDERAL REPORTING DATA SYSTEM

The data on CWS's analyzed in this report come primarily from EPA's *FRDS-II Data Base* as of July 1, 1994. The data base is designed specifically to support the EPA's Office of Groundwater and Drinking Water (OGWDW) in monitoring compliance with the Safe Drinking Water Act of 1974. Water systems across the country are required to report information about their systems on an annual basis to their respective state agencies, who, in turn, forward it to the *FRDS* system maintained at EPA's computing center in North Carolina.

The *FRDS-II Data Base* is a complex data structure for public water systems arranged hierarchically in four levels and containing information relating to the operation, design, and treatment. There is detailed information on: population served, daily water production and design capacity, ownership, primary water sources, treatment objectives, treatment processes employed, the geographic areas served, on site visits and water sampling, violation and enforcement actions, and variance/exemption actions. As one moves deeper into the hierarchy of the system, it is necessary to maintain numerous records for each system. For example, the source/entry file in Level 2 contains individual records for each water source utilized by a particular CWS listed in the Level 1 file. The treatment data file, located in Level 3, contains separate records for each treatment process that is linked to each source record from Level 2. The location of the treatment (i.e., at the source, treatment plant, or entry point) is also attached to these records.[3]

This type of data structure lends itself well to retrieving complete data for one or a handful of systems. However, the structure presents a real challenge to anyone attempting to use such a data base for research purposes where detailed data on all systems must be summarized and analyzed. To our knowledge, no one has attempted such an analysis, and to this extent, much of the information in this report is not widely known.

This report relies primarily on the first-and second-level descriptive features of CWS's across the country relating to operation characteristics, production requirements, and treatment processes and objectives. Subsequent reports will concentrate more on types and frequencies of violation and enforcement actions and/or variances related to those violations.

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[3] Other data files exhibit a similar "branching" structure, such as the non-compliance file at Level 2 which branches first into the violation file at Level 3, and second into the file on enforcement action at Level 4. Put differently, a CWS listed in Level 1 may be flagged as being non-compliant at Level 2, with the one or more individual violations associated with non-compliance delineated at Level 3. Each of these records is finally linked to the one or more enforcement actions in Level 4 associated with the corresponding violation contained in Level 3 records.

In any data base of this size and where reporting is ultimately the responsibility of individuals at the system level, there are always some problems with the data. To facilitate the identification of these problems and the manipulation of the data, we converted the entire *FRDS-II Data Base* into SAS data files. For this analysis, we focused attention on systems located in the 50 states, ignoring, at least for the time being, about 700 systems in the several territories of the United States.

To obtain a usable data set for this analysis, it was also necessary to eliminate observations in which important pieces of data were either missing or obviously in error. To begin, we eliminated observations where some of the most basic information on population served, ownership, and treatment classification was missing. We also eliminated systems where the information was provided, but was obviously erroneous because of inconsistencies between population served, average daily production and design capacity. The result was a data set including information on about 45,600 community water systems.

Although this is a significant subset of the data (containing 80% of the community water systems around the country), we were concerned that inferences drawn from it may be biased if the subset turned out not to be representative of the population. To obtain some notion of the nature of any bias, we performed a number of statistical tests between the distribution of the subset of systems by size category and the entire population of water systems by size category as reported in the EPA's report to Congress on the technical and economic capacity of states and public water systems to implement drinking water regulations (EPA, 1993). The test for the similarity of distributions is the Kolmogorov-Smirnov test, and the results are reported in detail in appendix A.

Based on this test, there is reason to believe that the size distribution of the systems in the subset is representative of that for the entire population of combined ground and surface water systems. The same is true for ground water systems examined separately. For surface water systems, the size distributions appear identical, with the exception of those in the smallest size category. Here, there seemed to be a slightly higher proportion of small systems eliminated because of missing or inconsistent data. On this basis, it seems unlikely that the steps required to develop a useable set of data for the analysis lead to any serious bias in the results, particularly if one believes that the general characteristics of very small systems are likely to be more homogeneous than those of systems with retail service populations greater than 500.

A NATIONAL AND REGIONAL PERSPECTIVE

To obtain a picture of the diversity of community water systems from a national perspective, it is convenient to begin by examining the distribution of systems by size. Size, however, can be defined in a variety of ways, ranging from the size of the population served, to some measure of the average (or peak) daily flow or the system's design capacity. Measures of average daily flow or design capacity are most important for decisions regarding water system construction and water treatment, and are related to the population served, but not completely so. The demand for water also depends among other things on climate, the demographic makeup of the population, as well as the nature of the retail, industrial, and residential development in the service area.

For policy purposes and to facilitate the development of regulations, the EPA groups public water systems into 12 categories by size of population served if the information necessary to formulate the regulation is available at that level of detail (EPA, 1993). Where information is limited, the systems are recombined into five size categories which are simple aggregations of the initial 12. These categories are defined according to the population served, and are presented in table 1.

Classifying systems in this way for policy purposes is one way to focus attention on the potential resources that can be drawn on to meet the costs of compliance with the SDWA regulations. For example, it is generally believed that systems serving populations of 10,000 or more are large enough to take advantage of economies of size in production and management and sufficient resources to finance increased monitoring and treatment at a reasonable cost to customers. For systems serving fewer people, the possibilities for realizing economies of size in production, distribution, or planning are limited, and the ability to finance needed treatment and monitoring to comply with SDWA regulations is more problematic. Other characteristics such as ownership of the system and the primary water source affect the cost, as well as the resources available to comply with the regulations.

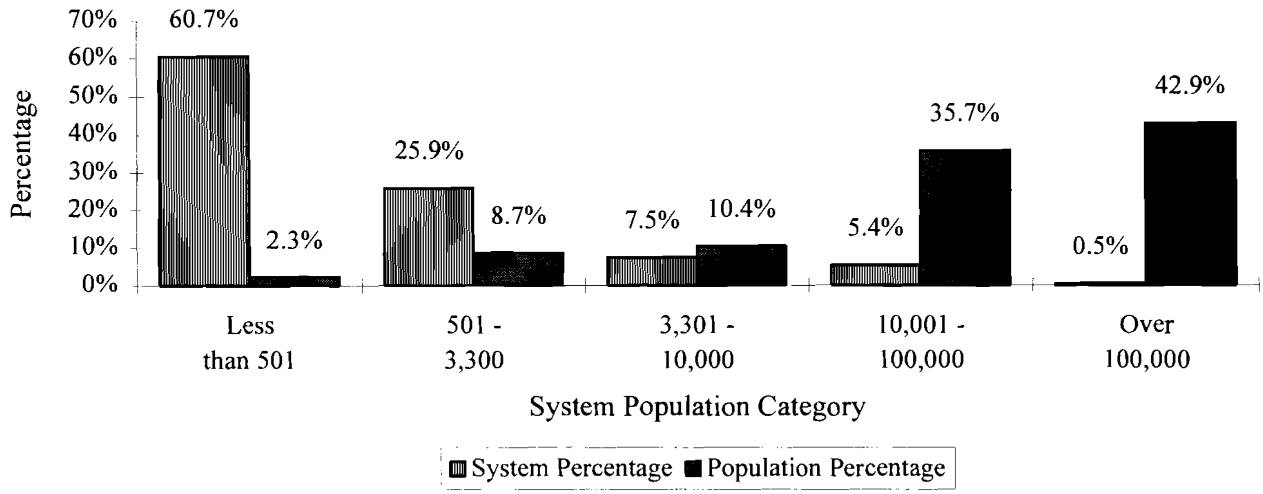
Distribution of CWS's by Population Served

Of the more than 57,000 community water systems nationwide, just over 18% of them rely on surface water as their primary water source, with the remaining 82% relying primarily on ground water. The data in table 1 provide a clear picture of the distribution of CWS's by population size category for all systems, as well as for groups differentiated by whether the system's primary water source is from ground or surface water. These data are easier to

Table 1. Distribution of Community Water Systems and Population Served by Ground and Surface Water Sources.

Population Category	Population Range	Population Classification	Ground and Surface Water Systems: Number	Ground and Surface Water Systems: Population Served	Ground Water Systems: Number	Ground Water Systems: Population Served	Surface Water Systems: Number	Surface Water Systems: Population Served
			%	%	%	%	%	%
A	< 101	Very Small	29.6	0.4	34.6	1.0	7.5	0.0
B	101 to 500	Very Small	31.0	1.9	33.6	4.1	19.6	0.4
C	501 to 1,000	Small	10.8	1.9	10.6	3.8	11.5	0.7
D	1,001 to 2,500	Small	12.0	4.6	10.4	8.3	19.0	2.3
E	2,501 to 3,300	Small	3.1	2.2	2.4	3.4	6.3	1.3
F	3,301 to 5,000	Medium	3.3	3.2	2.3	4.6	7.6	2.2
G	5,001 to 10,000	Medium	4.2	7.3	2.8	9.9	10.6	5.4
H	10,001 to 50,000	Large	4.7	24.7	2.8	29.3	13.6	21.6
I	50,001 to 75,000	Large	0.5	6.8	0.2	6.9	1.5	6.8
J	75,001 to 100,000	Large	0.2	4.2	0.1	4.5	0.7	4.0
K	> 100,000	Very Large	0.5	42.9	0.2	24.1	2.1	55.2

Figure 1. CWS Distribution by System and Population Served by Size Category.



visualize in figure 1. Very small systems, those serving retail populations of less than 500 people, account for the lion's share (over 60%) of all CWS's nationwide. Given their size, it is not surprising that they serve only an estimated 2% of the population. Small systems, those serving between 501 and 3,300 people, account for an additional 26% of all systems and serve just under 9% of the retail population. Medium-sized systems, serving retail populations between 3,301 and 10,000 people, constitute slightly more than 7% of all CWS's, and serve an additional 10% of the retail population. The remaining 80% of the population is served by only 6% of the CWS's, all of which have a service population of more than 10,000; within this group, over 40% of the population is served by the one-half of one percent of the CWS's with a service population over 100,000.

The fact that such a large percentage of the population is served by large systems with sufficient resources to take advantage of economies of size in water treatment and system administration tends to disguise the magnitude of the problems in achieving greater compliance with the 1986 amendments to the Safe Drinking Water Act. While only 10% of the population is affected, the unique problems facing small systems potentially affect about 50,000 CWS's and/or units of local government distributed across the country, somewhat differentially by region as is seen in the data from appendix B.

For example, the proportion of small and very small systems exceeds the national average significantly in New England and in the three EPA regions served by Dallas, Denver, and Seattle. The proportion of the population served by these systems in the Dallas region is more than double the national average. With the exception of the metropolitan areas surrounding the regional offices in these latter two regions, the small systems are scattered across the sparsely populated areas of the northern plains where population densities are among the lowest in the country. In New England, the rural populations served by these small systems are much more evenly distributed across the landscape. Thus, the problems facing small systems in these two diverse areas, and the potential for restructuring in terms of physical consolidation or administrative cooperation can be expected to be markedly different.

Perhaps one of the few bright spots about the nature of small water systems affecting their effort to expand water treatment is their relatively large reliance on ground water as the primary source of water. Nearly 92% of all ground water systems are in the small and very small categories, and they serve over 20% percent of the population receiving water from ground water sources (table 1). Part of the explanation lies in the fact that many of the areas served by these small systems have no proximity to a surface water source, and, in other cases, the source development costs could have been lower than that for surface water or the quality of the raw water could have been higher.[4]

Regardless of the reasons for this pattern, there are important implications for compliance with the SDWA regulations and modifications in them that might be anticipated in future reauthorization efforts. The most direct implication relates to the Surface Water Treatment Rule (SWTR). This rule was promulgated in June of 1989 and requires surface water sources to apply disinfection and may require filtration unless specific criteria are met. These requirements are designed to protect against the adverse health effects associated with various viruses, heterotrophic bacteria, and other pathogenic organisms (*54 FR 27486*).

With the exception of those ground water sources under the direct influence of surface water, none of these rules apply to small or very small systems whose primary source is ground water. Fortunately, according to the data in *FRDS-II*, fewer than two-tenths of one percent of the ground water systems are under the direct influence of surface water.

In addition, the Information Collection Rule (ICR) defines specific monitoring requirements based on a system's size. Systems subject to the SWTR and serving populations of more than 10,000 or ground water systems serving more than 50,000 are all affected by the ICR. All utilities serving more than 100,000 people must develop a formal sampling plan, including monthly monitoring requirements for coliphage viruses and Clostridium perfringens, as well as traditional coliforms, Giardia, and Cryptospiridium. The smaller systems will be

[4] Although small surface water systems serve less than 5% of the population receiving water from surface water sources, they still represent nearly 65% of all surface water systems.

required to monitor every two months; all subject to change relative to microbes to be tested and testing schedules. It is expected that monitoring for disinfection by-products (DBP) will proceed in a parallel fashion, with EPA looking for chemicals of concern related to chloramine, chlorine, dioxide, and ozone disinfection.

In additon to a more relaxed standard setting process from the 1996 amendments to the SDWA, small water system monitoring requirements will be limited to those contaminants likely to be detected in their drinking water. EPA must issue regulations for a monitoring program regarding unregulated contaminants. These regulations ensure that only a representative sample of small water systems witll be required to monitor for all regulated contaminants. States with primacy may provide interim monitoring relief for PWS's serving under 10,000 people. However, systems must provide to customers annual reports on existing contaminant levels and potential health effects.

Furthermore, where the raw water from a ground water source is of high quality, small water systems may benefit from a growing recognition that the list of potentially effective strategies for insuring the safety of our drinking water extend well beyond conventional treatment solutions, including a greater emphasis on watershed planning and the identification of methods for adequate source protection.

System Size as Measured by Flow or Design Capacity

Although for many purposes it makes sense to classify CWS's by the population served, measures of size that are more directly related to the actual volume of water produced are also important for planning purposes and projecting system costs. Classifying systems by these measures is less important for policy purposes, but given the availability of data on average daily flow and design capacity, it is useful to relate these three measures of size directly in a formal mathematical way. In so doing, we essentially are able to estimate two equations econometrically that provide estimates of conditional demands for water at the system level.[5] Demands can easily be put on a per capita basis.

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[5] We refer to conditional demand models in much the same way energy economists have used multivariate regression models with demographic characteristics, weather, and the stock of household appliances to estimate electricity consumption or appliance utilization rates (EPRI EA-3410, 1984, and Parti and Parti, 1980). In this case, however, the regression models are used to estimate average daily flow or design capacity as functions of population served, weather, and geographic location. These consumption estimates are conditional in the sense that the effect of price cannot be determined because of the lack of data. To the extent that there are systematic differences in price by region or in rural vs. urban areas, the dummy variables in the regression may reflect some of the price differentials.

These relationships will prove extremely useful in further research, but it should be pointed out that in working with the *FDRS-II Data Base* the quality of the data on a system's average daily flow and system design capacity was perhaps the most problematic. In many cases, only one of the two variables was reported, and in other cases both were missing. Therefore, in addition to their being useful in other research, these equations were necessary to estimate missing values for many systems in order to develop size distributions of CWS's using these variables as measures of size. To estimate the conditional demand relations, we used data from over 11,000 systems for which there was reliable data on these variables. The estimated equations are given in appendix C, along with a detailed discussion of the interpretation of the estimated coefficients.

As one would expect, both the average daily flow and the design capacity of water systems are positively related to the population served as well as the number of hookups. The design capacity is also positively related to the average daily flow, requiring that the two equations be estimated in a two-stage fashion. These equations are used to estimate the average daily flow and the design capacity for all the systems in the data set for which data were missing.

Based on these estimates, the mean average daily flow (production) (ADF) is about 700,000 gallons per day; the design capacity is just under 1.9 million gallons per day. This is about 2.7 times the average daily production, and the excess capacity is there partly to accommodate peak flows and to anticipate growth in demand or system expansion.

On a per capita basis, average daily flow is estimated at about 126 gallons per day (table 2). This figure is understandably larger than the per capita consumption implied by the 300-gallon per day estimate of household indoor use for a typical family of four (EPA, 1991). On a per capita basis, these estimated average daily flows are remarkably consistent across systems by population category. The many additional demands placed on a water system in urban areas for industrial, commercial, institutional, and emergency purposes certainly explains why per capita demands placed on the very large systems are nearly 40% higher than for the very small systems. The 138 gallon average daily flow per person for the smallest group is larger than for systems serving populations between 101 and 10,000, probably because of some need for systems to be of some minimum size to operate properly. Water needs for emergencies, etc. also constitute a disproportionate share of total production for these very small systems.

Table 2. Per Capita Average Daily Flow and Design Capacity by Population Category.

Population Category	Population Range	Average Daily Flow Per Capita		Design Capacity Per Capita	
		Mean	Std. Dev.	Mean	Std. Dev.
All Categories	A - K	126	113	789	692
A	< 101	138	111	1,232	786
B	101 to 500	118	123	774	652
C	501 to 1,000	113	114	551	486
D	1,001 to 2,500	119	112	480	411
E	2,501 to 3,300	123	104	440	403
F	3,301 to 5,000	127	107	408	339
G	5,001 to 10,000	130	108	391	310
H	10,001 to 50,000	139	76	379	292
I	50,001 to 75,000	155	62	385	250
J	75,001 to 100,000	164	62	431	288
K	> 100,000	181	77	431	277

Note: Average flow and capacity values are given in gallons per day per capita.

The variation around the mean in average daily flow is substantial for all systems, but is higher for the small and medium-size systems. The same pattern is evident in the variation in design capacity. This variation is certainly due in large measure to the socioeconomic and demographic characteristics of the service areas, and without detailed data on the demographic structure of the population and the diversity of the economic systems it is impossible to sort the differences out precisely.

However, by examining the coefficients on the dummy variables in the regression equations in appendix C, we do see part of the explanation. All else equal, the design capacity tends to be higher in the hot and semi-arid areas in the South and the West, and in urban areas. Compared with systems that serve non-residential areas, systems that serve residential and semi-residential areas design systems with smaller capacities for a given service population. Design capacities of private systems tend to be smaller than for those owned by the government. The capacity also tends to be smaller for systems that purchase water from other systems or rely primarily on surface rather than ground water. The story is about the same for the equation used to predict average daily flow. The two exceptions are: the average daily flow is higher for surface water systems than for ground water systems (table 3), and average daily flow is also higher if the system serves a semi-residential area. These trends are certainly evident in the regional data reported in appendix B.

Table 3. Per Capita Average Daily Flow and Design Capacity Distributions by Water Source and Population Classification.

Population Classification	Ground Water Systems				Surface Water Systems			
	Average Daily Flow		Design Capacity		Average Daily Flow		Design Capacity	
	Mean	Std. Dev.	Mean	Std. Dev	Mean	Std. Dev.	Mean	Std. Dev
All Populations	125	112	863	717	131	121	434	431
Very Small	128	116	1027	763	127	133	669	588
Small	115	109	542	471	122	121	398	337
Medium	124	86	437	326	134	130	349	312
Large	132	57	421	278	150	86	346	294
Very Large	171	73	506	318	185	79	399	252

Note: Average flow and capacity mean values are expressed in gallons per day per capita.

The explanation for why the design capacities of ground water systems tend to have larger design capacities but smaller average daily flows than for surface water systems is straightforward if viewed in terms of the financial and other requirements to expand or otherwise change the two types of systems. Increasing production for a given surface water system may, in many instances, require modest changes such as increasing intake flow rates from an established reservoir or impoundment. The situation, however, may be much more complicated for a ground water system. The physical and technical changes could very well include the drilling of additional wells, the installation of additional transmission mains, or increased storage capacity. Therefore, to allow for possible growth in demand and avoid the additional costs of increasing capacity in the future, it may be more cost effective to "oversize" the systems to some degree in the initial construction phase.

System Ownership

During the debate over re-authorization, it was clear that members of both Houses of Congress were keenly aware of the financial burden facing the owners of small water systems throughout the country as they make changes to comply with the SDWA, and it is their hope that this financial burden can be eased by careful relaxation of some requirements without seriously compromising water quality or health risk. The 1996 amendments to the SDWA provide additional federal funding for drinking water system improvements in the form of a state revolving loan fund (SRF), similar in form to the current SRF available in the Clean Water Act for waste water treatment improvements. The fund provides $9.6 billion in grant and loan funding, capitalized over the years of 1994 through 2003, for local water system facility improvments. To ease the burden further, the 1996 amendments provide to states up to 15% of annual funding for PWS's serving less than 10,000 people. In addition, states may use up to 30% of theire fund allocation for special assistance to small, disadvantaged systems.

The appropriateness of the size of this set aside turns not only on the size distribution of water systems across the country, but on the distribution of ownership as well. The importance of the size distribution is perhaps the most obvious. While 15% of the funds are earmarked for systems serving populations below 10,000, we know from the data above, that these community water systems constitute over 90% of the total and provide water to about 20% of the population (table 1). Clearly, funds are not being set aside in proportion to the number of systems or population served. It is unclear at this time whether the cost savings provided by the relief from some of the regulations are sufficient to offset the higher costs of compliance with the remaining provisions. It is well known that these small systems are unable to take advantage of the substantial economies of size in water supply and treatment (Boisvert and Tsao, 1995).

If it turns out that funds are insufficient, then the effects will be largest in EPA regions where the proportions of population served by systems of less than 10,000 are well above the national average (See table B2). These include regions whose regional offices are located in Dallas, Kansas City, Denver, and Seattle. The situation could well be exacerbated in these regions, as well as throughout the country if, as is suspected by many, the infrastructure of many small systems has been allowed to deteriorate. In such cases, EPA estimates that for every dollar spent on treatment there would be need for an additional dollar spent on rehabilitation and repair (EPA, 1993).

The implications of system ownership for the requirements for allocating money from the revolving funds are less clear until one remembers that money from these funds are earmarked primarily for public/governmental water systems, with some provisions for investor-owned (private) water systems. Public water systems not owned by a governmental or inter-governmental agency, a non-profit organization, an Indian tribe, or any combination thereof, may receive assistance from a state revolving fund; however it will be designated only to those systems having the greatest public health and financial needs. Granted, the specification here is vague and determining those systems with the "greatest" need may be obligatory, but, it is also clear that owners of private systems may be at a competitive disadvantage in applying for these loan funds.

This is unlikely to be a trivial problem because only 41% of all CWS's are owned by local governments, including authorities, commissions, districts, municipalities, cities, towns, and counties, while 53% are owned privately by various entities such as subdivisions, investors, trusts, cooperatives, and water associations (table 4).[6]

These ownership patterns are not overly surprising, based on the high proportion of small systems, most of which are located in smaller communities or mobile home parks and housing complexes. Over 96% of the systems serve primary residential areas, of which 17% of them serve mobile home parks. This is certainly reflected as well in the distribution of ownership by system size. About 73% of the very small systems are owned privately,

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[6] Ownership of the remaining CWS's is in the hands of the Federal government (1%), the state governments (1%), mixed public and private ownership (4%), and Native Americans (less than one-half of 1%). The Native American classification includes indian tribes and reservations and Alaskan remote villages.

Table 4. Ownership Type Percentage Distributions by Water Source and Population Classification.

Population Classification	Ground and Surface Water Systems		Ground Water Systems		Surface Water Systems	
	Private	Local Government	Private	Local Government	Private	Local Government
	%					
All Populations	52.6	41.2	59.7	33.9	20.3	66.4
Very Small	72.9	20.9	75.9	17.9	39.3	55.7
Small	25.4	67.7	28.5	64.6	16.4	76.6
Medium	12.5	81.7	15.4	78.1	8.7	86.3
Large	13.3	82.5	16.9	77.0	10.2	87.3
Very Large	20.1	78.3	21.6	73.0	19.4	80.6

Note: The percentage of systems not accounted for are owned by Federal and state governments, mixed public and private entities, and Native American villages.

dropping to just over 25% in the small system category. From a regional perspective, the proportion of private ownership is much higher than the national average in New England and in the EPA regions served by regional offices in New York, Philadelphia, and Atlanta (table B4). The predominance of private ownership in these regions is explained in part by the fact that they were the oldest developed areas of the country and by the fact that the desire for local control is as strong in New England and the Northeast as any where in the country. The nature of the retirement communities in Florida may also partially explain this trend in the Atlanta region.

One can only speculate on the average income levels of the people living in areas served by these small private water systems. In some cases where the systems serve exclusive developments and upper middle income multi-family housing developments, we know the answer. We probably also know the answer for those that serve mobile home parks and similar developments, and it is here where low-income people and others on fixed incomes will have the most difficulty absorbing the additional costs of treatment passed on by the owners of the private systems. The incomes of rural residents is generally lower than those of their suburban and urban counterparts as well (EPA, 1988; Boisvert and Ranney, 1991). How these considerations are factored into plans for allocating money from revolving funds have important implications for equity.

Again, the only bright spot in this scenario is that nearly 60% of the ground water systems are privately owned. In contrast, local governments own nearly 75% of the surface water systems, and to the extent that the treatment needs of these systems are likely to be more extensive than for ground water systems, there may be some justification for a disproportionate share of revolving fund loans to go to these systems.

Treatment Objectives

In attempting to deal with the particular problems facing smaller community water systems, the 1996 amendments to the SDWA also contain provisions for making the regulations more flexible and less costly for states and local governments, including relaxing the schedules for testing and monitoring for contaminants. Specifically, the amendments contain provisions for communities serving fewer than 10,000 people to use alternative, more affordable technologies to meet current and anticipated drinking water regulations. These alternatives, referred to as Best Available Affordable Technologies (BAAT), are to be designed by EPA and may include public education and notification. The BAAT's may not reduce contaminant levels to regulated MCL's, but the level of treatment is to be sufficient so as not to result in an unreasonable health risk.

An important step in understanding the effects of legislation is to know the treatment practices and treatment objectives currently in place in the Nation's medium-sized and small community water systems. This will provide a perspective of the seriousness of the remaining problems and also lend perspective on treatment practices that seem to be working for a selected number of systems. This will be a solid foundation for examining the economic feasibility of adapting these successful treatment scenarios to other systems.

Dealing with treatment objectives and the individual processes used to meet the various objectives is undoubtedly the most complex aspect of the *FRDS-II Data Base*. Exhibit 1 provides some perspective on the long list of the most relevant treatment processes and the corresponding treatment objectives that can be met by each. A comprehensive examination of these data is complicated by at least two factors. The first is rather mechanical, and relates to those systems for which treatment information is from the previous FRDS's data file (FRDS1.5). This indicates that treatment for these systems has not changed recently. It appears that the earlier version of *FRDS's* did not differentiate between treatment processes and objectives, and while one can infer treatment objectives from the process file, there is no way to obtain this information from the treatment objective file. Therefore, for our purposes these records are eliminated from initial consideration. As is seen below, this causes few problems.

The second complexity is a direct result of the fact that some water systems have more than one water source and/or plant. Since treatments can differ by source and plant, the treatment file can contain multiple records for an individual system. Developing a strategy for summarizing the data under these conditions was a challenge. It was extremely difficult to avoid double counting etc.

We were assisted in our efforts by a variable in *FRDS-II* that is generated by the program which classifies CWS's as treated, mixed, or untreated. A "treated" classification implies that all of a particular system's water sources are subjected to treatment; an "untreated" classification implies that none of a particular system's water sources are subjected to treatment. Obviously, a system is assigned a "mixed" treatment classification when systems with multiple water sources provide treatment for water from at least one source, but no treatment for water from at least one other source. Regardless of whether the system is classified as "treated" or "mixed", the treatment objectives for water at each source may well differ. Water can be treated at the source, at the treatment plant, or at the point of entry.

Exhibit 1. Combined Treatment Objective & Process Codes

	Treatment Objectives											
Treatment Process	DBP Control	Corrosion Control	Dis-infection	De-Chlorination	Iron	In-organics	Man-ganese	Organics	Par-ticulate	Radio-nuclides	Soften	Taste/ Ordor
Activated Alumina						X				X		
Activated Carbon, Granular	X			X		X		X		X		X
Activated Carbon, Powder	X							X				X
Aeration, Cascade	X			X	X			X		X		X
Aeration, Diffused	X			X	X			X		X		X
Aeration, Packed Tower	X			X	X			X		X		X
Aeration, Slat Tray	X			X	X			X		X		X
Aeration, Spray	X			X	X			X		X		X
Chlorine Dioxide	X		X									
Coagulation	X					X		X	X	X	X	
Distillation					X	X	X	X	X	X	X	
Electrodialysis						X				X		
Filtration, Cartridge									X			
Diatomaceous Earth									X			
Greensand					X		X					
Pressure Sand	X				X	X			X	X	X	
Rapid Sand	X				X	X		X	X	X	X	
Slow Sand			X						X			
Ultrafiltration									X			
Gas. Chlorination, Post			X									
Gas. Chlorination, Pre			X		X		X	X				X
Hypochlorination, Post			X									
Hypochlorination, Pre			X		X		X	X				X
Inhibitor		X										
Iodine			X									
Ion Exchange						X				X	X	
Lime - Soda Ash	X					X				X	X	
Microscreening									X			
Ozonation, Post	X		X									
Ozonation, Pre	X		X		X		X	X				X
Permanganate					X			X				X
Peroxide					X			X				X
Reducing Agents				X				X				
Reverse Osmosis	X				X	X	X	X		X	X	
Ultraviolet Radiation	X		X									
pH Adjustment	X	X			X	X		X	X	X	X	

According to this variable, over 60% of CWS's nationwide are classified as "treated" and, therefore, meet at least one treatment objective for each source. Of the remaining CWS's, 32% are classified as "untreated", while 7% are "mixed" (table B5 of appendix B). Put differently, nearly 70% of CWS's provide at least some treatment for their sources of water, and, irrespective of system size, more systems provide treatment than do not. For systems serving larger retail populations, there is a larger proportion of them in the "mixed" treatment category. This seems only logical, since as systems increase in size, the average number of water sources used increases, providing greater flexibility in treatment options. The fact that treatment may differ by source could reflect incremental investment in new sources of water to accommodate growth in demand.

As one would expect, the proportions of systems treating at least one of its water sources increases with system size: 97% of the very large systems are classified as "treated" or "mixed", while 91% and 87%, respectively, of the large and medium-size systems fall into these two categories. Given the heightened concern over the implications for smaller systems of the 1986 amendments to the SDWA it is perhaps somewhat surprising to see that over 50% of the small and very small systems are doing some type of treatment. It remains to be seen, the extent to which these treatment objectives are consistent with the requirements under the 1986 amendments. This can only be done by moving deeper into the details of the treatment files. In this way, we eventually hope to match treatment objectives with treatment processes as a way of identifying appropriate treatment technologies for meeting various combinations of treatment objectives.

The extent to which systems are currently treating water differs by primary water source as well. About 65% of ground water systems apply at least some treatment; this is significantly below the 80% of all surface water systems that treat at least some portion of their raw water. Although smaller ground water well systems are likely to apply no treatment, as systems serve larger populations, storage with at least some disinfection requirements may be needed; this is certainly one explanation of why this gap narrows between ground water and surface water systems as size increases. To provide further insight into the differences in current treatment practices, we need to examine specific treatment objectives and/or processes in use and delineate situations where systems are meeting more than one treatment objective. Multiple treatment objectives and/or treatment processes which address multiple contaminant regulations will have significant impacts on system and national cost-benefit analyses.

Treatment Objectives. Through the four panels of data in table 5, we obtain a first glimpse of the detailed information in the *FRDS-II Data Base*. Since there are some major differences in the level of treatment between ground water and surface water systems, we focus on these two subsets immediately. There are about 6,600 systems in the surface water subset and nearly 34,500 ground water systems.

The total of the two, about 41,100 systems, is about 4,500 fewer than our original sample for two reasons. First, about half of the removed observations had to be eliminated because of missing information. The other half of these systems are not in the data because they purchase water and the water is treated by the seller. Thus, this treatment is reflected in the data, but it is in the records for systems selling water.

For purposes of the analysis, it is also necessary to ignore systems whose treatment classification is still in terms of the old FRDS's system. We have no way to know what treatment is being applied to these systems. This leaves us with about 6,100 surface water systems and 30,600 ground water systems in the data set.

With these preliminaries out of the way, we can begin to examine the data. The first panel in table 5 contains those surface water systems that list a single treatment objective. There are 25% of these systems that have no treatment at all sources and water plants. Just over 14% of the systems only disinfect, while processes needed to remove particulates only are in use by about 3% of the systems.

For the ground water systems, nearly 39% have no treatment at any plant or source, while about 34% only disinfect, and less than 1% soften water, remove particulates and iron, and operate corrosion control indirectly. There are just a handful of systems that have other single treatment objectives.

While the data on single treatments are useful to gain perspective on the extent of treatment, the panels in table 5 containing data on multiple treatments are potentially more important for identifying the range of treatment options being used already by small systems. These data, however, need some explanation. To begin, the sum in the systems column is much greater than the total number of systems, because every individual water source and plant where a particular treatment objective is met is reported separately and individual sources or plants may contain more than one treatment objective. Thus, for example, the "no treatment" row contains all systems (61% of the total) which have at least one source or plant doing no treatment. Where these systems have other water sources or plants at which there is treatment,

Table 5. General Treatment Objectives of All Community Water Systems[a]

Treatment Objective	Obj. Code	Single Treatment Systems	Single Treatment Percentage	Multiple Treatments Systems	Multiple Treatments Percentage
Surface Water Systems[c]					
Additional Treatment Elsewhere	A	0	0.0	7	0.1
Disinfection By-Product Control	B	1	0.0	272	4.5
Corrosion Control	C	7	0.1	1,432	23.5
Disinfection	D	876	14.4	3,970	65.3
Dechlorination	E	0	0.0	11	0.2
Iron Removal	F	4	0.1	519	8.5
Inorganics Removal	I	0	0.0	224	3.7
Manganese Removal	M	0	0.0	152	2.5
No Treatment [b]	N	1,516	24.9	3,718	61.1
Organics Removal	O	1	0.0	384	6.3
Particulate Removal	P	153	2.5	3,137	51.6
Radionuclides Removal	R	0	0.0	60	1.0
Softening	S	7	0.1	597	9.8
Taste/Odor Control	T	1	0.0	916	15.1
Other (Process Fluoridation)	Z	5	0.1	1,068	17.6
Ground Water Systems[d]					
Additional Treatment Elsewhere	A	0	0.0	0	0.0
Disinfection By-Product Control	B	4	0.0	50	0.2
Corrosion Control	C	65	0.2	1,996	6.5
Disinfection	D	10,543	34.4	16,769	54.8
Dechlorination	E	1	0.0	14	0.0
Iron Removal	F	109	0.4	2,600	8.5
Inorganics Removal	I	13	0.0	221	0.7
Manganese Removal	M	7	0.0	667	2.2
No Treatment [b]	N	11,790	38.5	21,007	68.6
Organics Removal	O	7	0.0	423	1.4
Particulate Removal	P	79	0.3	887	2.9
Radionuclides Removal	R	7	0.0	65	0.2
Softening	S	124	0.4	1,183	3.9
Taste/Odor Control	T	40	0.1	1,146	3.7
Other (Process Fluoridation)	Z	85	0.3	2,212	7.2

[a] Frequencies exclude those system which apply no treatment themselves, but purchase treated water, since unable to tie specific treatment objective to water utilized; i.e. systems with treatment objective=N (no treatment) and treatment process = 996 (treatment applied by seller).

[b] For sole treatments, no treatment implies no treatment at all source or plant locations. For the general multiple classification, no treatment implies that the system applies no treatment to at least one source or plant location and may be in addition to other treatments.

[c] total systems = 6,083

[d] total systems = 30,624

they are reported separately under that particular objective. A system with two sources of water employing different objectives at each would be counted in both objective categories. The same result would occur for a system meeting two treatment objectives at a single source.

According to this interpretation of the data in table 5, there are just over 60% of the surface water systems around the country in which at least one water source or plant apply no water treatment whatsoever; the percentage (69%) is only slightly higher for ground water systems.[7] Similarly, about 65% of the surface water systems disinfect their water, while 52% remove particulates, and nearly a quarter control for corrosion. Another 10% soften their water; about 15% treat for taste and odor problems; and about 9% remove iron. Fewer than 5% of the surface water systems have processes in place that meet any of the other treatment objectives listed in the table. Although the percentage of ground water systems that have no treatment processes in place somewhere in the system is not substantially higher than for surface water systems, the multiple treatment strategies used seem to be less complex and focus mainly around disinfection (55%), iron removal (9%), and corrosion control (7%). Just under 4% of the systems soften their water and treat for taste and odor problems. Similar data for community water systems by size category are given in appendix D for completeness, but there is no need to discuss the data in detail.

To gain some perspective on what multiple treatment strategies can be used effectively and at affordable costs, it is helpful to look behind these numbers and delineate the number of these systems that meet more than one treatment objective. These objectives may or may not be accomplished through a single treatment process, and it is in the data in the treatment process files that we can shed some light on which combinations of processes seem to be working currently for small and very small systems. We examine the various combinations of treatment processes used by the community water systems in a subsequent section.

For completeness, we include a detailed list of the number of systems in EPA's five aggregate size categories that are meeting any possible combination of treatment objectives as an attachment to this report. However, as is evident from the attachment, there are an extremely large number of treatment objective combinations, many of which are given by fewer than 5 water systems. Therefore, to facilitate discussion, we limit our attention to those combinations of treatments given by at least 5 systems. (The percentages given in the tables are based on the whole sample, including systems where the combined treatment objectives are

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[7]Although this "no treatment" percentage is not overly meaningful, the percentages under the various treatment objectives do provide a benchmark measure for the extent to which various treatment objectives are met.

given by fewer than 5 systems.) The data for very small and small systems are in tables 6 and 7, because systems in these two groups are of primary interest to this analysis. Tables E1 through E3 in appendix E contain data for medium, large, and very large systems.

Somewhat surprisingly, the data in table 6 suggest that a significant number of very small systems are treating to meet a wide combination of treatment objectives, but as one would expect, the majority of the systems treat for a single objective. Nearly 73% of the ground water systems only disinfect, while 30% of the surface water systems do likewise. Another third of the surface water systems disinfect and treat for particulate removal, and about 3% combine some type of corrosion control. Nearly 12% of the surface water systems only treat for removal of particulates. Nearly 5% of the very small ground water systems disinfect and only apply some type of corrosion control, with an additional 1.3% adding an additional objective to disinfection and corrosion control. About 4% disinfect and remove iron. About 4% combine disinfection with either water softening or taste and odor control. Each of the many remaining combinations of treatment objectives in place are in at most 1% of the systems, and for most in much less than 1% of the systems.

The story is not terribly different for the small community water systems (table 7). The number of treatment objective combinations is somewhat higher primarily because a smaller proportion of systems do no treatment at all. In addition, there are fewer small surface and ground water systems that treat for only a single objective such as disinfection. Only 60% of these ground water systems solely disinfect, while this is true for only 26% of the surface water systems. An additional 34% of the ground water systems and 50% of the surface water systems combine disinfection with one or more additional treatment objectives.

Treatment Processes. In trying to understand the nature of current treatment strategies being used by CWS's across the country, we must look at the various treatment processes as well. Appendix F contains estimates of the percentages of systems by size category currently treating water through a variety of treatment processes. While it is important to include the information at this level of detail in this report, further discussion of it is probably unnecessary. What is needed is some way to relate the treatment objectives to treatment processes.

Perhaps the best way to do this is to compare these data with estimates of the proportions of CWS's that would need particular combinations of water treatment technologies to meet the 1986 amendments. These proportions were estimated by Miller (1990) and are based on probabilities of co-occurrence of various contaminants, and the ability of different processes to deal with the contaminants. The joint probabilities on which the estimates are

Table 6. Multiple Treatment Objectives Found in Very Small Community Water Systems

Treatment Objectives[a]	Ground Water Systems Number	Ground Water Systems Percent	Surface Water Systems Number	Surface Water Systems Percent
BD	10	0.10		
C	47	0.46		
CD	495	4.79	8	1.00
CDF	51	0.49		
CDFM	30	0.29		
CDFP	7	0.07		
CDFS	5	0.05		
CDI	9	0.09		
CDO	19	0.18		
CDP	6	0.06	26	3.25
CDPS			12	1.50
CDPT			8	1.00
CDS	14	0.14		
CDST	5	0.05		
CDT	5	0.05		
CF	6	0.06		
CPS			5	0.63
D	7506	72.70	237	29.66
DF	380	3.68	6	0.75
DFM	189	1.83		
DFMP	6	0.06		
DFMS	6	0.06		
DFP	33	0.32		
DFPS	6	0.06		
DFPT	14	0.14		
DFS	56	0.54		
DFT	20	0.19		
DI	25	0.24		
DIM	10	0.10		
DIS	5	0.05		
DM	64	0.62		
DO	16	0.16		
DOP			10	1.25
DOT	49	0.47	5	0.63
DP	109	1.06	262	32.79
DPS	14	0.14	23	2.88
DPT	10	0.10	10	1.25
DS	224	2.17		
DST	15	0.15		
DT	239	2.31	7	0.88
F	130	1.26		
FM	21	0.20		
FP	9	0.09		
FS	9	0.09		
I	15	0.15		
IRS	5	0.05		
M	19	0.18		
O	6	0.06		
P	81	0.78	93	11.64
R	7	0.07		
S	116	1.12		
T	32	0.31		

[a]Each letter in this column represents a particular treatment objective from table 5, e.g. CD is corrosion control combined with disinfection.

Table 7. Multiple Treatment Objectives Found in Small Community Water Systems

Treatment Objectives[a]	Ground Water Systems Number	Ground Water Systems Percent	Surface Water Systems Number	Surface Water Systems Percent
BDIOPRS			7	0.46
BDPS			15	0.99
C	25	0.48	10	0.66
CD	343	6.65	31	2.04
CDF	102	1.98		
CDFM	26	0.50		
CDFO	27	0.52		
CDFP	17	0.33	7	0.46
CDFPS	8	0.16		
CDFPT	7	0.14	11	0.72
CDFS	11	0.21		
CDFT	5	0.10		
CDI	7	0.14		
CDO	72	1.40		
CDP	6	0.12	130	8.55
CDPS	7	0.14	64	4.21
CDPST	10	0.19	10	0.66
CDS	14	0.27	5	0.33
CDST	5	0.10		
CDT	13	0.25		
D	3114	60.38	402	26.43
DF	375	7.27	9	0.59
DFI	5	0.10		
DFM	90	1.75	5	0.33
DFMP	5	0.10		
DFMS	5	0.10		
DFO	6	0.12		
DFP	39	0.76	12	0.79
DFPS	13	0.25	10	0.66
DFPT	11	0.21	26	1.71
DFS	110	2.13		
DFST	10	0.19		
DFT	24	0.47		
DIP	5	0.10	5	0.33
DM	15	0.29		
DO	16	0.31		
DOPT			11	0.72
DOT	11	0.21		
DP	35	0.68	298	19.59
DPS	8	0.16	50	3.29
DPST	13	0.25	7	0.46
DPT	15	0.29	47	3.09
DS	48	0.93	9	0.59
DST	14	0.27		
DT	189	3.66	12	0.79
F	65	1.26		
FM	8	0.16		
FS	7	0.14		
M	9	0.17		
P	6	0.12	123	8.09
S	44	0.85	7	0.46
T	8	0.16		

[a]Each letter in this column represents a particular treatment objective from table 5, e.g. CD is corrosion control combined with disinfection.

Table 6. Multiple Treatment Objectives Found in Very Small Community Water Systems				
Treatment	Ground Water Systems		Surface Water Systems	
Objectives[a]	Number	Percent	Number	Percent
BD	10	0.10		
C	47	0.46		
CD	495	4.79	8	1.00
CDF	51	0.49		
CDFM	30	0.29		
CDFP	7	0.07		
CDFS	5	0.05		
CDI	9	0.09		
CDO	19	0.18		
CDP	6	0.06	26	3.25
CDPS			12	1.50
CDPT			8	1.00
CDS	14	0.14		
CDST	5	0.05		
CDT	5	0.05		
CF	6	0.06		
CPS			5	0.63
D	7506	72.70	237	29.66
DF	380	3.68	6	0.75
DFM	189	1.83		
DFMP	6	0.06		
DFMS	6	0.06		
DFP	33	0.32		
DFPS	6	0.06		
DFPT	14	0.14		
DFS	56	0.54		
DFT	20	0.19		
DI	25	0.24		
DIM	10	0.10		
DIS	5	0.05		
DM	64	0.62		
DO	16	0.16		
DOP			10	1.25
DOT	49	0.47	5	0.63
DP	109	1.06	262	32.79
DPS	14	0.14	23	2.88
DPT	10	0.10	10	1.25
DS	224	2.17		
DST	15	0.15		
DT	239	2.31	7	0.88
F	130	1.26		
FM	21	0.20		
FP	9	0.09		
FS	9	0.09		
I	15	0.15		
IRS	5	0.05		
M	19	0.18		
O	6	0.06		
P	81	0.78	93	11.64
R	7	0.07		
S	116	1.12		
T	32	0.31		

[a]Each letter in this column represents a particular treatment objective from table 5, e.g. CD is corrosion control combined with disinfection.

Table 7. Multiple Treatment Objectives Found in Small Community Water Systems

Treatment Objectives[a]	Ground Water Systems Number	Ground Water Systems Percent	Surface Water Systems Number	Surface Water Systems Percent
BDIOPRS			7	0.46
BDPS			15	0.99
C	25	0.48	10	0.66
CD	343	6.65	31	2.04
CDF	102	1.98		
CDFM	26	0.50		
CDFO	27	0.52		
CDFP	17	0.33	7	0.46
CDFPS	8	0.16		
CDFPT	7	0.14	11	0.72
CDFS	11	0.21		
CDFT	5	0.10		
CDI	7	0.14		
CDO	72	1.40		
CDP	6	0.12	130	8.55
CDPS	7	0.14	64	4.21
CDPST	10	0.19	10	0.66
CDS	14	0.27	5	0.33
CDST	5	0.10		
CDT	13	0.25		
D	3114	60.38	402	26.43
DF	375	7.27	9	0.59
DFI	5	0.10		
DFM	90	1.75	5	0.33
DFMP	5	0.10		
DFMS	5	0.10		
DFO	6	0.12		
DFP	39	0.76	12	0.79
DFPS	13	0.25	10	0.66
DFPT	11	0.21	26	1.71
DFS	110	2.13		
DFST	10	0.19		
DFT	24	0.47		
DIP	5	0.10	5	0.33
DM	15	0.29		
DO	16	0.31		
DOPT			11	0.72
DOT	11	0.21		
DP	35	0.68	298	19.59
DPS	8	0.16	50	3.29
DPST	13	0.25	7	0.46
DPT	15	0.29	47	3.09
DS	48	0.93	9	0.59
DST	14	0.27		
DT	189	3.66	12	0.79
F	65	1.26		
FM	8	0.16		
FS	7	0.14		
M	9	0.17		
P	6	0.12	123	8.09
S	44	0.85	7	0.46
T	8	0.16		

[a]Each letter in this column represents a particular treatment objective from table 5, e.g. CD is corrosion control combined with disinfection.

based are first approximations. They are based on the best available data, and they were used in EPA's assessment of the technical and economic capacity of public water systems to comply with the 1986 SDWA amendments.[8]

To understand how these comparisons are made, we can look at the summary data in table 8. For example, Miller estimates that to comply with the 1986 amendments, 46% of the very small ground water systems would need to install multiple treatment processes, while 40% would need only a single process. About 14% would need no treatment at all. Based on the *FRDS's* data, however, 48% of the very small ground water systems currently treat none of their water, while 42% use a single treatment technology, and only 8% currently employ more than one treatment process.

Perhaps the most striking features of this table are the rather high estimates of the systems that require no treatment at all to meet the 1986 amendments to the SDWA, particularly for the medium to very large systems. This means that the proportion of systems that will need multiple treatments is correspondingly low. Miller (1990) comments on the relative size of these proportions and suggests that the probability of needing multiple treatments, particularly for the larger systems is too low. He argues that the results are driven by the underlying assumptions about contaminant occurrence, the decision trees built into the analysis, and the numbers of systems in the various size categories. Unfortunately, he provides too little information about the procedure for us to unravel the mystery, although we suspect much of the explanation for the underestimates has to do with the assumption of independence of co-occurrence of all contaminants. This assumption is hard to rationalize in built up areas served by large and very large water systems. The independence assumption is probably easier to justify in areas served by smaller systems. The magnitude of the underestimates of the need for multiple treatment in these cases is probably smaller. For this reason, one might regard Miller's (1990) estimates as lower bounds on the proportion of systems needing single or multiple treatments. The estimates provided by Miller may also be more appropriate for smaller systems since the recent 1996 amendments to the SDWA allow for more relaxed monitoring and treatment schedules by systems serving fewer than 10,000 people.

Detailed information about the particular combinations of processes on which table 8 was constructed is given in appendix G. In discussing these data, however, we are less interested in the percentages themselves than we are the short fall between what is needed and what is in place at the present time. This can be seen best by examining the relative

[8] As data from EPA's on-going needs survey of the Nation's public water systems becomes available, it will certainly be possible to refine these probability estimates.

Table 8. Estimated and Actual Treatment Combinations Used by Community Water Systems

Treatment	No. of	Very Small		Small		Medium		Large		Very Large	
Combination	Treatments	Estimated[a]	Actual[b]	Estimated	Actual	Estimated	Actual	Estimated	Actual	Estimated	Actual
		- - - - - - - - - - - -	- - - -	- - - -	- - - -	- - - - % - - - -	- - - -	- - - -	- - - -	- - - -	- - - -
Ground Water:											
No Treatment	0	14	48	22	21	24	14	25	7	33	1
Single Treatment	1	40	42	47	53	47	49	47	33	49	18
Multiple Treatment	2+	46	8	30	19	30	28	28	39	19	44
Surface Water:											
No Treatment	0	12	49	12	22	15	13	15	12	22	4
Single Treatment	1	45	25	45	27	46	27	47	23	50	28
Multiple Treatment	2+	41	25	42	48	39	58	38	63	28	67

Note: These data were calculated from Tables G1. and G2. by summing up the number of systems using no treatment, single treatment, and multiple treatments.

[a]Estimated percentages were calculated from EPA document, Benefits and Costs of the 1986 Amendments to the SDWA (Wade Miller, 1989).

[b]Actual percentages were obtained from FRDS multiple treatment data search results.

based are first approximations. They are based on the best available data, and they were used in EPA's assessment of the technical and economic capacity of public water systems to comply with the 1986 SDWA amendments.[8]

To understand how these comparisons are made, we can look at the summary data in table 8. For example, Miller estimates that to comply with the 1986 amendments, 46% of the very small ground water systems would need to install multiple treatment processes, while 40% would need only a single process. About 14% would need no treatment at all. Based on the *FRDS's* data, however, 48% of the very small ground water systems currently treat none of their water, while 42% use a single treatment technology, and only 8% currently employ more than one treatment process.

Perhaps the most striking features of this table are the rather high estimates of the systems that require no treatment at all to meet the 1986 amendments to the SDWA, particularly for the medium to very large systems. This means that the proportion of systems that will need multiple treatments is correspondingly low. Miller (1990) comments on the relative size of these proportions and suggests that the probability of needing multiple treatments, particularly for the larger systems is too low. He argues that the results are driven by the underlying assumptions about contaminant occurrence, the decision trees built into the analysis, and the numbers of systems in the various size categories. Unfortunately, he provides too little information about the procedure for us to unravel the mystery, although we suspect much of the explanation for the underestimates has to do with the assumption of independence of co-occurrence of all contaminants. This assumption is hard to rationalize in built up areas served by large and very large water systems. The independence assumption is probably easier to justify in areas served by smaller systems. The magnitude of the underestimates of the need for multiple treatment in these cases is probably smaller. For this reason, one might regard Miller's (1990) estimates as lower bounds on the proportion of systems needing single or multiple treatments. The estimates provided by Miller may also be more appropriate for smaller systems since the recent 1996 amendments to the SDWA allow for more relaxed monitoring and treatment schedules by systems serving fewer than 10,000 people.

Detailed information about the particular combinations of processes on which table 8 was constructed is given in appendix G. In discussing these data, however, we are less interested in the percentages themselves than we are the short fall between what is needed and what is in place at the present time. This can be seen best by examining the relative

[8] As data from EPA's on-going needs survey of the Nation's public water systems becomes available, it will certainly be possible to refine these probability estimates.

Table 8. Estimated and Actual Treatment Combinations Used by Community Water Systems

Treatment Combination	No. of Treatments	Very Small Estimated[a]	Very Small Actual[b]	Small Estimated	Small Actual	Medium Estimated	Medium Actual	Large Estimated	Large Actual	Very Large Estimated	Very Large Actual
		%									
Ground Water:											
No Treatment	0	14	48	22	21	24	14	25	7	33	1
Single Treatment	1	40	42	47	53	47	49	47	33	49	18
Multiple Treatment	2+	46	8	30	19	30	28	28	39	19	44
Surface Water:											
No Treatment	0	12	49	12	22	15	13	15	12	22	4
Single Treatment	1	45	25	45	27	46	27	47	23	50	28
Multiple Treatment	2+	41	25	42	48	39	58	38	63	28	67

Note: These data were calculated from Tables G1. and G2. by summing up the number of systems using no treatment, single treatment, and multiple treatments.
[a]Estimated percentages were calculated from EPA document, Benefits and Costs of the 1986 Amendments to the SDWA (Wade Miller, 1989).
[b]Actual percentages were obtained from FRDS multiple treatment data search results.

differences between the actual and the estimated percentages of single and multiple treatment needs (tables 9 and 10), although the conclusions drawn from the sign on these differences is somewhat ambiguous. For example, if this difference is positive, as is the case for the "no treatment" percentages, then a move toward more complete compliance would require a reduction in the actual percentage of systems not treating, while the percentage of systems employing single or multiple treatments could both rise. In this instance, the interpretation of the positive difference is straightforward. On the other hand, if the difference is positive for the single treatment case, it could mean that many of the systems are in compliance, but it could also imply that many of the systems now using a single treatment actually belong in multiple treatment category and, therefore, need to install additional treatment processes to be in compliance with the SDWA amendments.

Despite this ambiguity, when the difference between the actual and estimated percentage is negative, more systems belong in that category. Thus, we have a criterion for setting priorities for study of the economic and institutional feasibility of various combinations of treatments. Beginning in the multiple treatment category, we can place some priority on those combinations of processes where the short fall is negative. Highest priority should perhaps be given where the absolute value of this short fall is the largest. Next on the list of priorities would be an examination of the single treatments where the negative short fall is highest.

Although the data in tables 9 and 10 provide, in theory, a good criterion by which to set priorities for the development and evaluation of multiple treatment options, the data themselves are a bit disappointing. That is, in order to establish clear priorities, one would have hoped for more variation in the estimated short falls, across treatment combinations and system size categories. Most of the estimated short falls for the multiple treatment combinations for the three smallest size groups range between -1.0 and -0.8. A value of -1.0 is important because even though it was estimated earlier that there would be need for systems to employ these combinations, none have done so to date. A value between -1.0 and 0.0 means that some systems are employing the treatment combination, but not in proportion to the projected need.

We do, however, see some important patterns in the data. For example, there is complete consistency across ground water systems with respect to the exclusive use of corrosion control: no systems currently control corrosion as their only treatment strategy, but it is an integral part of many of the treatment combinations currently in use. The same is true for activated carbon processes, although only a few systems are now using the multiple technologies for which this process is an integral part of the projected needs.

Table 9. Relative Short Fall Between Estimated Treatment Needs and Actual Treatment Combinations Used by CWS's with a Ground Water Source

Treatment Combination	No. of Treatments	Very Small Relative Short Fall	Small Relative Short Fall	Medium Relative Short Fall	Large Relative Short Fall	Very Large Relative Short Fall
		- - - - - - - - - -	- - - - - - - - - -	%	- - - - - - - - - -	- - - - - - - - - -
No Treatment	0	2.4	-0.1	-0.4	-0.7	-1.0
Alt. Treatment[c]	1	5.0	12.2	*	*	*
Disinfection (DSF)[d]	1	2.9	6.7	8.7	11.1	*
Corrosion Control (CC)[e]	1	-1.0	-1.0	-1.0	-1.0	-1.0
Ion Exchange (IE)[f]	1	-0.2	-0.9	-1.0	-1.0	-1.0
Aeration (PTA)[g]	1	-0.9	-0.7	-0.7	-0.6	-1.0
Gran. Act. Carbon (GAC)[h]	1	-1.0	-1.0	-1.0	-1.0	*
DSF / CC	2	-0.8	-0.2	0.4	2.2	*
DSF / IE	2	1.5	1.3	1.5	1.3	*
DSF/ PTA	2	-0.6	3.9	10.6	37.5	*
DSF/ GAC	2	-0.9	-0.7	-0.5	*	*
CC / IE	2	-1.0	-1.0	-1.0	-1.0	-1.0
CC /PTA	2	-1.0	-0.9	-0.9	-0.9	-1.0
CC / GAC	2	-1.0	-1.0	-0.9	-0.9	*
IE / PTA	2	-1.0	-0.8	-0.8	-1.0	*
IE / GAC	2	-0.9	-1.0	-1.0	*	*
PTA / GAC	2	-1.0	-1.0	-1.0	*	*
DSF / CC / IE	3	-0.8	-0.6	0.1	0.2	*
DSF / CC / PTA	3	-0.9	0.9	4.9	26.8	*
DSF / CC / GAC	3	-0.9	-0.7	0.0	7.2	*
DSF / IE / GAC	3	*	*	*	*	*
DSF / IE / PTA	3	*	*	*	*	*
DSF / PTA / GAC	3	-1.0	-0.4	*	*	*
DSF / PTA / IE	3	*	*	*	*	*
CC / IE / PTA	3	-1.0	-0.9	-1.0	-1.0	*
CC / IE / GAC	3	-1.0	-1.0	-1.0	*	*
CC / PTA / GAC	3	-1.0	-1.0	-1.0	-1.0	*
IE / PTA / GAC	3	*	*	*	*	*
DSF / CC / IE / PTA	4	-0.9	0.8	5.1	*	*
DSF / CC / IE / GAC	4	-0.8	-0.5	*	*	*
DSF / CC / PTA / GAC	4	*	*	*	*	*
Other Combinations[i]		-0.8	-0.9	-1.0	-1.0	-0.6

Note: These data were calculated from Table G1 by subtracting the actual proportion of systems using a specific combination of treatment options by the estimated proportion of systems needing that combination. This result is divided by the estimated proportion.

[a]Estimated percentages were calculated from EPA document, Benefits and Costs of the 1986 Amendments to the SDWA (Wade Miller, 1989).

[b]Actual percentages were obtained from FRDS multiple treatment data search results.

[c]The number of systems using alternative treatments includes those that do not directly affect SDWA treatment requirements, (e.g. fluoride treatment).

[d]Disinfection (DSF) includes treatment process codes C, O, and U. (See Exhibit F1.)

[e]Corrosion (CC) control includes treatment process codes I, H, L. (See Exhibit F1.)

[f]Ion exchange (IE) relates to code E, and includes activated both alumina, and anion and cation exchange.

[g]Aeration (PTA) includes all aeration processes: Cascade, diffused, packed tower, slat spray, and spray aeration.

[h]GAC includes both powdered and granulated activated carbon processes.

[i]This category includes treatment combinations that are not considered feasible and combinations estimated to affect less than one percent of all systems.

[j]An ' * ' occurs wherever the estimated value was zero, in which case there would have been a division by zero.

Table 10. Relative Short Fall Between Estimated Treatment Needs and Actual Treatment Combinations Used by CWS's with a Surface Water Source

Treatment Combination	No. of Treatments	Very Small Relative Short Fall	Small Relative Short Fall	Medium Relative Short Fall	Large Relative Short Fall	Very Large Relative Short Fall
No Treatment	0	3.2	0.8	-0.1	-0.2	-0.8
Alt. Treatment[c]	1	-0.4	3.8	*	*	*
Filtration (FILT)[d]	1	0.0	-0.1	-0.2	-0.3	0.4
Corrosion Control (CC)e	1	-1.0	-0.8	-0.7	-0.8	-0.9
Ion Exchange (IE)[f]	1	*	*	*	*	*
Aeration (PTA)[g]	1	*	*	*	*	*
Gran. Act. Carbon (GAC)[h]	1	-0.5	-0.5	-0.6	-0.3	*
FILT / CC	2	-0.9	-0.6	-0.4	-0.5	-0.2
FILT / IE	2	0.3	5.2	*	*	*
FILT/ PTA	2	*	*	*	*	*
FILT/ GAC	2	0.4	1.8	3.0	3.6	*
CC / IE	2	-0.5	*	*	*	*
CC /PTA	2	*	*	*	*	*
CC / GAC	2	-0.9	-0.9	-0.1	0.2	*
IE / PTA	2	*	*	*	*	*
IE / GAC	2	*	*	*	*	*
PTA / GAC	2	*	*	*	*	*
FILT / CC / IE	3	-1.0	0.2	*	*	*
FILT / CC / PTA	3	*	*	*	*	*
FILT / CC / GAC	3	0.3	4.0	6.1	9.3	45.3
FILT / IE / GAC	3	*	*	*	*	*
FILT / PTA / GAC	3	*	*	*	*	*
FILT / PTA / IE	3	*	*	*	*	*
CC / IE / PTA	3	*	*	*	*	*
CC / IE / GAC	3	*	*	*	*	*
CC / PTA / GAC	3	*	*	*	*	*
FILT / CC / IE / PTA	4	*	*	*	*	*
FILT / CC / IE / GAC	4	*	*	*	*	*
FILT / CC / PTA / GAC	4	*	*	*	*	*
Other Combinationsi		8.0	13.0	15.2	17.2	1.3

Note: These data were calculated from Table G2 by subtracting the actual proportion of systems using a specific combination of treatment options by the estimated proportion of systems needing that combination. This result is divided by the estimated proportion.

[a]Estimated percentages were calculated from EPA document, Benefits and Costs of the 1986 Amendments to the SDWA (Wade Miller, 1989).

[b]Actual percentages were obtained from FRDS multiple treatment data search results.

[c]The number of systems using alternative treatments includes those that do not directly affect SDWA treatment requirements, (e.g. fluoride treatment).

[d]Filtration includes all filtration processes: Cartridge, greensand, DE, rapid sand, slow sand, ultrafiltration and direct filtration.

[e]Corrosion (CC) control includes treatment process codes I, H, L. (See Exhibit F1.)

[f]Ion exchange (IE) relates to code E, and includes activated both alumnina, and anion and cation exchange.

[g]Aeration (PTA) includes all aeration processes: Cascade, diffused, packed tower, slat spray, and spray aeration.

[h]GAC includes both powdered and granulated activated carbon processes.

[i]This category includes treatment combinations that are not considered feasible and combinations estimated to affect less than one percent of all systems.

[j]An ' * ' occurs wherever the estimated value was zero, in which case there would have been a division by zero.

The situation is quite different for disinfection. Here, many more systems employ methods for disinfection as their only method of treatment than is estimated to be acceptable under widespread compliance with the 1986 amendments. Furthermore, three of the dual treatment strategies involving disinfection are "over subscribed" as well. This means that many of these systems are likely to install additional treatment technologies as they are faced with decisions regarding full compliance with the regulations. And, according to the predictions of need, these strategies will involve at least three distinct treatment processes. Since these are being used by only a few, if any, systems currently, this is obviously a top priority for technology development, testing, and evaluation.

One of the most encouraging aspects of this analysis is that the short falls relative to most treatment combinations decrease as one moves to categories for larger systems. This pattern is most evident for the treatment combinations involving two technologies. Accordingly, many of these treatment combinations are being used by small and medium sized systems, but not by the very small ones. These very small systems will undoubtedly be among the last to install elaborate treatment technologies, both because they are more likely to receive exemptions from treatment and because costs may be prohibitive. This is strong evidence that these treatment combinations can be used by systems at the smaller end of the size range. It should be possible to obtain first-hand information about these operations as part of a strategy for adapting them for use by the very small systems.

One can find similar patterns relative to surface water systems in table 10, but there is less that needs to be described in detail. There are fewer multiple treatment combinations applicable to surface water quality problems, and there are also fewer very small and small systems that rely on surface water.

POLICY IMPLICATIONS AND CONCLUSIONS

As stated above, the purpose of this report is to provide a descriptive summary of these various operating and design characteristics of CWS's across the country. The manuscript is one of the first in a series designed to provide a comprehensive look at the implications of the 1986 amendments. The objectives are modest relative to the scope of the overall research effort, but they are a necessary first step. Emphasis is focused on the policy implications that can be drawn from a careful analysis of the data. These data are also organized to help provide a typology of representative public water systems that can be examined to better understand the regional effects of policy implementation.

Emphasis has also been on the current water treatment objectives being pursued by CWS's and the treatment processes that are already in place. This latter information is used in conjunction with prior estimates of the probability that systems will need certain combinations of treatment processes to set priorities for further research. It is for those smaller systems that may require the addition of multiple water treatment processes that the financial implications are likely to be the most severe. Finding economically feasible treatment strategies for these systems is most challenging as well.

Much of the descriptive information about the characteristics of the CWS's across the country serves to reinforce what we may have suspected already. About 80% of the population is served by only 6% of the Nation's community water systems, but these are the largest systems. While the implementation of the 1986 amendments to the SDWA may pose some problems for these systems, the fact remains that a large percentage of the population is served by systems having the technical and financial resources to accommodate additional monitoring and treatment requirements.

The fact that only 20% of the population are served by community water systems serving fewer than 10,000 people tends to disguise the magnitude of the problems facing systems of this size. However, the problems can be put into proper perspective by recognizing that over 90% of the Nation's community water systems are involved in meeting the drinking water needs of this 20% of the population. Most would agree that even the logistics of dealing with well over 50,000 community water systems is problematic. Furthermore, since most of these community water systems are scattered across the rural landscape throughout the country, the problems are exacerbated by the widening gap between average incomes of rural vs. urban residents and the declining economic base in some rural areas as well.

The proportion of small and very small water systems exceeds the national average in New England and in EPA's three western regions. It is here where the problems facing small and very small systems are likely to have a disproportionately large effect. Given the wide variations in population density and other socio-economic differences between New England, for example, and the sparsely populated states in the West, the opportunities for restructuring either through physical consolidation or administrative or institutional cooperation, are dramatically different. This only serves to underscore the need to think about solutions that accommodate the important features of our Nation's regional diversity. Without a doubt, the inherent problems in dealing with this country's regional diversity is always one of the major challenges to implementing national policy. It is certainly true in this case, and this recognition is perhaps in large measure responsible for provisions in the 1996 amendments to establish regional centers for technical support.

We also learn from the data that systems dependent primarily on surface water tend to be the larger ones. Thus, the vast majority of small and very small systems rely primarily on ground water. This is perhaps the only bright spot in this whole picture because the level of treatment necessary for these systems is often below what is needed to guarantee acceptable levels of water quality for systems relying on surface water.

The data also suggest that issues surrounding the financing of treatment for systems under 10,000 are compounded by the patterns of system ownership. With more than one-half of the community water systems serving fewer than 10,000 people being privately owned, it is difficult to understand why provisions for credit to water systems through a revolving fund are earmarked primarily for publicly owned water systems. As written, the legislation provides assistance from a state revolving fund only to those private systems having the greatest public health and financial need. Clearly, without some well-established guidelines for allocating these funds, private systems and the people they serve could well be at a competitive disadvantage in gaining access to these funds.

There is also growing recognition that one major barrier facing small water systems is obtaining government approval for innovative, small scale technology for monitoring and treating drinking water. The problems seem to evolve around the amount of field-scale testing required and the conflicting requirements among states. While this suggests the need for a clear statement of the requirements for testing, a clear indication of the combinations of treatment processes needed by these small community water systems would help establish priorities for development and testing of new technology. The recent SDWA amendments do, however, provide treatment and monitoring flexibility, as dictated by the states, to address these issues.

On the basis of our analysis, there is, as would be expected, a short fall between the number of systems serving fewer than 10,000 employing multiple treatment processes and the estimated number required. Assuming that the data are reported accurately, there are systems that have demonstrated success with a number of multiple treatment processes, particularly in the small and medium-size categories. The experience gained by these systems would seem invaluable in efforts to accelerate the process of field testing and approval of new technology. Priorities for such analysis for ground water systems would be processes anchored by disinfection and corrosion control, combined with either an activated carbon process or aeration. For surface water systems, priorities would include multiple treatment strategies involving filtration and corrosion control, combined with ion exchange or activated carbon.

As part of EPA's efforts to develop Best Available Technologies for very small systems and on-going research as part of this cooperative agreement, much is already known about the costs of single treatment technologies and the differences in the economies of size across treatment processes. However, much of this information is based on engineering estimates, and there have been few actual installations on which to verify the cost estimates. The effects on treatment costs as these processes are operated jointly is also not well understood, and this is an additional priority for our ongoing research.

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APPENDIX A

Testing for Identical Distributions Using the Kolmogorov-Smirnov Test

To develop a clear perspective on the number and diversity of community water systems (CWS) across the United States, the FRDS-II data base is used to obtain information on various system characteristics, such as primary water source, population served, ownership, water treatment objectives and processes in place, and two other important measures of system size, average daily flow and design capacity. The *FRDS-II Data Base* as of July 1, 1994, contains records for over 57,000 CWS's nationally. However, in any data set of this size and complexity, the degree to which the information is accurate and up to date for individual systems varies, and depends on the care taken by the system personnel responsible for supplying the information to EPA. Consequently, our descriptive analysis of the data is based on a subset of the data after observations with missing or obviously erroneous data for various characteristics of the systems are removed.

As emphasized in the text, we eliminate observations where some of the most basic information on population served, ownership, and treatment classification is missing. We also eliminate systems where the information was provided, but was obviously in error because of inconsistencies between population served, average daily production, and design capacity. Over 45,600 community water systems (about 80% of the total) remain in the "sample". The purpose of this appendix is to report the results of some statistical tests regarding the similarity of the distribution of water systems by size, compared with the size distribution for the entire 57,000 systems. To the extent that they are similar, we can be confident that inferences about the population drawn from an analysis of the sample will not be biased in any way. We are obviously most concerned about small system categories. One might expect the quality of the information for these systems to be more variable than for larger systems because of the lack of personnel to do the reporting. On this basis, one might expect a larger proportion of these systems to be eliminated from the data set initially.

The statistical test is designed to test the similarity of the two distributions of CWS's according to the population served. This is essentially a test of the similarity in the size distributions of the CWS's in the two respective data sets. It would have been advisable to test the similarity of the distributions of other system characteristics as well. This, however, was not possible because of the missing or erroneous data in some of the observations which made it necessary to eliminate them in the first place. More importantly, if more than one test were conducted in sequence, the validity of each would be conditional on the results of the previous tests, and it would be difficult to have any confidence in the "levels of significance" of any of these subsequent tests. The only effective way to conduct a test on more than one characteristic would be to base it on a test of the similarity of the joint distributions. While theoretically possible, we know of no such test that could be applied empirically in this case.

There are two commonly used statistical procedures to test the null hypothesis that two distributions are the same. The first is a Chi-square test (Snedecor and Cochran, 1989), and the second is the Kolmogorov-Smirnov test (Siegel, 1956). For our purposes, the Kolmogorov-Smirnov test is used rather than the Chi-squared test because it evaluates the similarity of the distributions at all sample points. On the other hand, the Chi-squared test, evaluates the similarity of the two distributions over intervals, and the outcome depends explicitly on how these intervals are specified. The Chi-square test is certainly the more subjective of the two.

The testing procedure for the Kolmogorov-Smirnov test involves specifying the cumulative frequency distribution for the theoretical distribution and comparing it with the observed cumulative frequency distribution (Siegel, 1956). In many instances, the test is used to compare a sample with some known continuous probability distribution, but, in the case here, we have two empirical distributions to compare.

In particular, we compare the size distribution (as measured by population served) of the "sample" data set with the size distribution of the original population of CWS's found in EPA's report to Congress "Technical and Economic Capacity of States..." (EPA, 1993). The data from the EPA report include the 57,500 CWS's in the FRDS-II data system of a year earlier than the FRDS-II data from which our sample is drawn. It includes all systems, regardless of the quality of the data. In testing our "sample" against this population of systems, we are implicitly assuming that the data on retail population served is accurate. More is said about this below. Since the distribution of systems in the EPA report distinguishes between ground water and surface water systems, we test both distributions, as well as the distributions for the combined systems.

The CWS's are categorized into nine size categories which are arranged in ascending order. The data for all systems are in table A1, whereas the data for ground and surface water systems are in tables A2 and A3, respectively.

To conduct the test and develop the test statistic, let $F_0(X)$ be the specified cumulative frequency distribution function for the size distribution of CWS's in the entire population of water systems. That is, for any value of X (population category), the value of $F_0(X)$ is the

Table A1. Data for Kolmogorov-Smirnov Test of Size Distributions of all Community Water Systems

Population Category	CWS Population Distribution[1]			CWS Sample Distribution[2]			Deviations in Cumulative Proportion[3]
	Frequency	Proportion	Cumulative Proportion	Frequency	Proportion	Cumulative Proportion	
< 101	17,300	0.301	0.301	13,528	0.297	0.297	0.004
101-500	18,211	0.317	0.618	14,165	0.310	0.607	0.011
501-1,000	6,207	0.108	0.726	4,917	0.108	0.715	0.011
1,001-3,300	8,318	0.145	0.871	6,897	0.151	0.866	0.005
3,301-10,000	4,085	0.071	0.942	3,414	0.075	0.941	0.001
10,001-50,000	2,660	0.046	0.988	2,152	0.047	0.988	0.000
50,001-75,000	260	0.004	0.992	215	0.005	0.993	0.000
75,001-100,000	121	0.002	0.994	94	0.002	0.995	0.000
> 100,000	315	0.005	1.000	249	0.006	1.000	0.000

[1] CWS's distribution by system size from "Technical and Economic Capacity of States and Public Water Systems to Implement Drinking Water Regulations" (EPA, 1993).

[2] "Sample" CWS's distribution by system size constructed from FRDS-II data files for cooperative research agreement between EPA and Cornell University (1995).

[3] Cumulative deviations are in absolute value terms.

Table A2. Data for Kolmogorov-Smirnov Test Size Distributions for Ground Water Systems

Population Category	CWS Population Distribution[1]			CWS Sample Distribution[2]			Deviations in Cumulative Proportion[3]
	Frequency	Proportion	Cumulative Proportion	Frequency	Proportion	Cumulative Proportion	
< 101	16,140	0.345	0.345	12,910	0.346	0.346	0.001
101-500	15,950	0.341	0.686	12,545	0.336	0.681	0.005
501-1,000	4,980	0.107	0.793	3,967	0.106	0.787	0.005
1,001-3,300	5,814	0.124	0.917	4,804	0.129	0.916	0.001
3,301-10,000	2,374	0.051	0.968	1,912	0.051	0.967	0.001
10,001-50,000	1,275	0.027	0.995	1,028	0.028	0.995	0.000
50,001-75,000	99	0.002	0.997	87	0.002	0.997	0.000
75,001-100,000	45	0.001	0.998	39	0.001	0.998	0.000
> 100,000	89	0.002	1.000	74	0.002	1.000	0.000

[1] CWS's distribution by system size from "Technical and Economic Capacity of States and Public Water Systems to Implement Drinking Water Regulations" (EPA, 1993).

[2] "Sample" CWS's distribution by system size constructed from FRDS-II data files for cooperative research agreement between EPA and Cornell University (1995).

[3] Cumulative deviations are in absolute value terms.

Table A3. Data for Kolmogorov-Smirnov Test Size Distributions for Surface Water Systems

Population Category	CWS Population Distribution[1] Frequency	Proportion	Cumulative Proportion	CWS Sample Distribution[2] Frequency	Proportion	Cumulative Proportion	Deviations in Cumulative Proportion[3]
< 101	1,160	0.108	0.108	618	0.075	0.075	0.033
101-500	2,261	0.211	0.319	1,620	0.196	0.271	0.049
501-1,000	1,227	0.115	0.434	950	0.115	0.386	0.048
1,001-3,300	2,504	0.234	0.668	2,093	0.253	0.639	0.029
3,301-10,000	1,711	0.160	0.828	1,502	0.182	0.821	0.007
10,001-50,000	1,385	0.129	0.957	1,124	0.136	0.957	0.000
50,001-75,000	161	0.015	0.972	128	0.016	0.972	0.000
75,001-100,000	76	0.001	0.979	55	0.007	0.979	0.000
> 100,000	226	0.021	1.000	175	0.021	1.000	0.000

[1] CWS's distribution by system size from "Technical and Economic Capacity of States and Public Water Systems to Implement Drinking Water Regulations" (EPA, 1993).

[2] "Sample" CWS's distribution by system size constructed from FRDS-II data files for cooperative research agreement between EPA and Cornell University (1995).

[3] Cumulative deviations are in absolute value terms.

proportion of CWS's expected to have retail service populations equal to or less than X. Furthermore, let $S_n(X)$ be the observed cumulative frequency distribution for the size distribution of CWS's in our "sample" of n observations; $S_n(X)=k/n$, and k is the number of observations whose retail service population is equal to or less than X. Therefore, under the null hypothesis that the "sample" has been drawn from the specified distribution $F_0(X)$, $S_n(X)$ should be fairly close to $F_0(X)$ for every value of X. The Kolmogorov-Smirnov test concentrates on the largest of these deviations, where the test statistic given by:

$$(1) \qquad D = \max | S_n(X) - F_0(X) | \ ,$$

where D is the greatest absolute difference in height between the two empiric distribution functions, S and F. If an appropriately large value of D is observed, one rejects the null hypothesis that both distributions are the same in favor of the alternative hypothesis that they are not. The asymptotic sampling distribution of D is given by:

$$(2) \qquad Pr\{ D \leq zN^{-1/2} \} \ \rightarrow \ L(z) \ \ as \ \ n_1, n_2 \ \rightarrow \ \infty$$

$$(3) \qquad N = n_1 n_2 / (n_1 + n_2) \ ,$$

where n_1 and n_2 are the numbers of observations in the original and "sample" data sets, respectively; and

$$(4) \qquad L(z) = 1 - 2 \sum_{j=1}^{\infty} (-1)^{j-1} e^{-2j^2 z^2}$$

$$(5) \qquad = \frac{\sqrt{2\Pi}}{z} \sum_{j=1}^{\infty} e^{-(2j-1)^2 \Pi^2 / 8z^2} \quad for \quad z > 0,$$

$$(6) \qquad L(z) = 0 \quad for \quad z \leq 0$$

The sampling distribution of D under H_0 is known, and the significance of a given critical value of D depends on N. The critical values are found on page 251 in Siegel (1956).

In addition to containing the cumulative frequencies for the two distributions, tables A1 through A3 contain the differences in the cumulative frequencies for all CWS's, and for when they are separated into the two groups by primary water source. The test statistics and results for each set of CWS's are in table A4. As can be seen from table A4, we fail to reject H_0 for

Table A4. Kolmogorov Test Statistics and Results of Hypothesis Tests

Test Statistic	Both Ground and Surface Water Systems	Ground Water Systems	Surface Water Systems
N	25,437	20,770	4,665
Critical Value[1]	0.01	0.01	0.02
max D	0.01	0.005	0.05
Test Result	Fail to Reject H_0	Fail to Reject H_0	Reject H_0

[1] Critical value based on Type I error level of 0.01, It is calculated as $1.63/N^{0.5}$. See Siegel (1956), page 251.

both the full sample of CWS's and the subset of ground water systems. That is, we conclude that the cumulative distributions are equivalent. In the case of the ground water systems, the result, seems fairly robust with a maximum absolute deviation over all population categories of only 0.005. The results are different for the test of the size distributions for surface water systems. Because the critical value of 0.02 is below the calculated value of D, we reject H_0 and conclude that the distributions are different.

Given that these tests turned out differently for the two types of systems, a closer examination of the distributions is warranted here, both to validate the results and discuss the implications for our analysis. Our primary concern in having to rely on this 80% sample in the first place has to do with retaining a representative number of small CWS's. It was reasonable to expect that owners of smaller systems, such as trailer parks and housing complexes, would find it more difficult to complete the FRDS's data requirements, and would also be less likely to see any value in spending the time to complete the necessary forms. This would naturally result in a proportionately higher reduction in the observations in these small size ranges compared with the number eliminated in the larger size categories.

Somewhat surprisingly, the results indicate that the proportion of smaller systems retained is very close to the proportions in the entire population of ground water systems. For small surface water systems, those serving under 500 people, the effects of eliminating some observations is somewhat more serious if viewed strictly in terms of the results of the statistical tests. However, for surface water systems serving under 500 people, the percentage of systems in the sample fell by only 3 percentage points between the total population surface water

CWS's and the "sample", falling from 11% to 8%. Since there are still a significant number of systems of this size category remaining in the "sample" the only real concern is the extent to which these systems eliminated are sufficiently different than those retained to "bias" any inferences drawn from the sample.

It is impossible to know the answer to this question, but given the size of the systems, they might be expected to be quite homogenous as a group, at least in terms of the several general descriptive characteristics of the systems being examined in this report. It is also true that in "cleaning" the FRDS's data for our purposes, there were many systems where the population served was set at 25, the lowest value possible by federal PWS definition, and either average daily flow or design capacity was set much higher than reasonably expected for that population size. It is impossible to know whether these systems were actually large or small ones. There is every reason to believe that this problem existed in the data in EPA's report to Congress which is used as the base of comparison for the hypothesis tests. If this is true, it is likely that these data slightly over estimate the proportion of small systems. On the strength of these arguments, we are not overly concerned about the possibility of systematic bias in the analysis of small systems as a result of our necessary "sampling" procedure.

A more serious concern would certainly be in the effects of our "sampling" on medium and large systems because of the potential diversity of these CWS's. However, if the small-system categories are removed from the test procedure, all tests fail to reject H_0, Thus, there seems to be little concern over systematic bias in the analysis of these larger systems.

Some comments regarding the Kolmogorov-Smirnov test procedure also support our contention that the analysis based on our sample lead to reasonable results. Since the critical values of the Kolmogorov-Smirnov test depend on N, the large number of observations in the data sets being examined here reduce critical values substantially over what they would be in most tests which involve much smaller samples. Under these conditions, failure to reject the null hypothesis is difficult using the Kolmogorov-Smirnov test, and the similarity in magnitudes of the test statistic and the critical value for the tests of surface water systems is encouraging. The results of the tests could also have been influenced by disaggregating the categories further for a given N. We chose not to do this because we thought it important to keep the categories consistent with EPA's delineation used for policy purposes.

In conclusion, the testing procedure provides optimistic results concerning the validity and representative nature of the "sample" constructed for the descriptive analysis in this report. Test procedures failed to reject H_0 for the entire "sample" of CWS's and for the subset of ground water systems. But, the test led to a rejection H_0 in favor of the alternative hypothesis for the subset of surface water systems, in large measure due to the number of small systems that had to be eliminated from the analysis. However, because it is expected that this group may be quite homogenous in terms of system characteristics and operation procedures, it is unlikely that our strategy would lead to any systematic bias in the results. Therefore, further analyses based on the 80% "sample" described here should, to the best of our knowledge, provide representative results for all CWS's across the country and lead to applicable and reliable implications regarding the characteristics of water systems across the country and compliance with the 1986 amendments to EPA's Safe Drinking Water Act.

APPENDIX B

Characteristics of Community Water Systems by EPA Region

The purpose of this appendix is to provide a self-contained description of the regional diversity of community water systems throughout the United States. The data reported here are used in the text to support or highlight the regional significance of various provisions of the 1986 amendments to the Safe Drinking Water Act and changes brought about by the recent 1996 amendments to the SDWA.

As in any regional analysis, it is important to define regions that highlight the diversity that is important for the policy analysis at hand. Almost without exception, the practice of delineating regions on the basis of state, or even local political boundaries is in many respects inappropriate for the task. However, there is also rarely any choice because its on the basis of these boundaries that most data are available. In this case, we do have data at the state level, and some consideration was given to defining our own regions based primarily on geographic proximity, climate, and to some extent on urban orientation. This strategy was abandoned, primarily because the benefits in terms of being able to group similar areas seemed small relative to those associated with doing the analysis based on the EPA's 10 administrative regions. Given that we would still have been limited to regions defined on the basis of state boundaries, there seemed to be little point in merely moving four or five states from one region to another.

For administrative purposes, the Environmental Protection Agency has established 10 regional offices, each serving several of the surrounding states and territories of the United States, such as American Samoa and/or freely associated states, such as the Marshall Islands. For the purpose of this report and future research, we include in these regions only the 50 United States and the District of Columbia (DC). As stated in the earlier text, this excludes about 700 systems. The 10 regions are named for the locations of their regional offices; the states associated with each region are shown in exhibit B1.

A Regional Overview

Through tables B1 and B2, one can begin to understand the regional distribution of the community water systems and the proportion of the populations served by them. The distribution of systems by size across regions in general is consistent with that for the Nation. One could hardly expect any difference given that 87% of the systems nationwide are either

Exhibit B1. EPA Regions, Regional Office Location, and States included.

EPA Region	Regional Office	States in Region
1	Boston	CT, ME, NH, RI, VT
2	New York	NJ, NY
3	Philadelphia	DC, DE, MD, PA, VA, WV
4	Atlanta	AL, FL, GA, KY, MS, NC, SC, TN
5	Chicago	IL, IN, MI, MN, OH, WI
6	Dallas	AR, LA, NM, OK, TX
7	Kansas City	IA, KS, MO, NE
8	Denver	CO, MT, ND, SD, UT, WY
9	San Francisco	AZ, CA, HI, NV
10	Seattle	AK, ID, OR, WA

small or very small. However, in three regions (Atlanta, Chicago, and San Francisco), the proportions of small and very small systems are lower than the national average; in the San Francisco Region the proportion is significantly lower. The proportions of the populations served by these small systems in the regions are lower as well.

In contrast, the proportion of small and very small systems exceeds the national average significantly in New England and in the three EPA regions served by Dallas, Denver, and Seattle. The proportion of the population served by these systems in the Dallas region is more than double the national average.

Average Daily Production and Design Capacity

From table 3 in the text, it is clear that while there is some consistency in water production, as measured by average daily flow, and design capacity on a per capita basis across system size categories, the variation both within and between groups is substantial. The same is true at the regional level (table B3). In six of the EPA regions, average daily water production per capita is below the national average. As would be predicted by the regression equations in appendix C, the four regions where per capita production is the lowest are in the Midwest and the East: the Chicago, Boston, New York, and Philadelphia regions. Per capita production in both the Kansas City and Atlanta regions is just slightly below the national average and is explained in large measure by large proportion of the population living in rural areas. In the case of the Atlanta region, this rural orientation more than offsets the fact that

Table B1. Percentage Distribution of Community Water Systems by System Size

Population Category	Nation	1 Boston	2 New York	3 Phila.	4 Atlanta	5 Chicago	6 Dallas	7 Denver	8 Kans. City	9 San Fran.	10 Seattle
		EPA Region Number with Regional Headquarters									
	%										
Very Small											
< 101	29.6	41.4	38.7	31.6	26.9	21.8	24.7	20.0	34.7	27.1	48.0
101 to 500	31.0	35.8	29.3	33.4	29.7	28.8	31.2	37.4	33.0	22.8	32.2
Small											
510 to 1,001	10.8	5.5	8.4	9.9	10.7	14.5	12.4	14.7	10.6	9.2	5.7
1,001 to 2,500	12.0	6.7	7.8	10.5	12.4	15.5	15.1	15.9	10.5	10.9	6.0
2,501 to 3,300	3.1	1.8	2.2	3.1	4.1	3.2	4.0	2.8	2.0	3.2	1.7
Medium											
3,301 to 5,000	3.3	1.4	2.8	3.0	4.0	3.9	4.1	2.9	2.3	3.8	1.2
5,001 to 10,000	4.2	2.9	3.8	3.4	5.6	4.9	4.3	3.3	2.9	6.9	2.0
Large											
10,001 to 50,000	4.7	3.2	5.8	3.9	5.5	6.2	3.5	2.4	3.2	10.7	2.9
50,001 to 75,000	0.5	0.5	0.5	0.3	0.5	0.6	0.3	0.2	0.3	2.1	0.1
75,001 to 100,000	0.2	0.3	0.0	0.2	0.2	0.2	0.1	0.1	0.2	1.1	0.1
Very Large											
> 100,000	0.5	0.5	0.7	0.7	0.5	0.4	0.4	0.4	0.3	2.1	0.2

Table B2. Percentage of Population Served by Community Water Systems by System Size

Population Category		EPA Region Number with Regional Headquarters									
	Nation	1 Boston	2 New York	3 Phila.	4 Atlanta	5 Chicago	6 Dallas	7 Denver	8 Kans. City	9 San Fran.	10 Seattle
						%					
Very Small											
< 101	0.4	0.8	0.3	0.4	0.4	0.3	0.5	0.4	0.8	0.1	1.6
101 to 500	1.9	2.7	1.3	1.8	1.8	1.8	2.5	3.8	3.0	0.4	4.2
Small											
510 to 1,001	1.9	1.3	1.1	1.7	1.9	2.5	2.8	4.0	2.9	0.6	2.4
1,001 to 2,500	4.6	3.8	2.2	3.9	4.9	5.7	7.7	9.5	6.1	1.5	5.7
2,501 to 3,300	2.2	1.7	1.1	2.0	2.8	2.1	3.6	3.0	2.1	0.7	3.0
Medium											
3,301 to 5,000	3.2	1.8	1.9	2.8	3.9	3.7	5.3	4.5	3.4	1.3	2.9
5,001 to 10,000	7.3	6.9	4.7	5.4	9.6	8.3	9.5	8.7	7.7	4.1	8.4
Large											
10,001 to 50,000	24.7	26.4	22.0	19.2	27.9	30.9	22.3	19.1	23.5	21.8	37.7
50,001 to 75,000	6.8	8.4	5.7	4.2	6.7	8.8	5.3	4.6	7.2	10.4	2.5
75,001 to 100,000	4.2	8.9	0.3	2.8	3.7	4.8	4.1	1.5	7.6	7.5	4.9
Very Large											
> 100,000	42.9	37.4	59.3	55.7	36.5	31.2	36.4	40.7	35.7	51.5	26.7

Table B3. Average Water Production[a] and Design Capacity of Community Water Systems

Water Source		EPA Region Number with Regional Headquarters									
	Nation	1 Boston	2 New York	3 Phila.	4 Atlanta	5 Chicago	6 Dallas	7 Denver	8 Kans. City	9 San Fran.	10 Seattle
	%										
Daily Production (1,000 gal.)	714	444	1,005	562	610	621	565	381	428	3,147	325
Design Capacity (1,000 gal.)	1,875	1,107	1,916	1,304	1,267	1,342	1,745	1,250	1,110	10,143	1,075
Retail Population	4,214	3,088	5,945	4,483	4,204	4,309	3,183	2,637	2,772	12,468	1,722
Hookups	1,246	803	1,362	1,262	1,420	1,339	1,018	946	803	3,123	560
Retail Population/Hookup	5	5	7	7	4	5	4	4	4	5	7
Daily Production/Capita	126	114	114	105	120	102	142	124	135	166	154
Daily Production/Hookup	510	483	564	596	441	424	465	386	492	718	729
Design Capacity/Capita	789	722	641	530	659	545	901	868	982	1,192	1,233
Design Capacity/Hookup	2,832	2,791	2,481	2,583	2,256	2,050	2,919	2,619	3,416	4,359	4,609

[a] Water production is equivalent to average daily flow.

water systems in the South tend to have higher water production rates. A similar pattern is evident in design capacity per capita, with the exception of the Kansas City region where design capacity per capita is above the national average.

System Ownership

As is highlighted in the text, ownership of the nation's community water systems is primarily in the hands of the private sector which controls 53% of the systems) and the many local governments across which own a 41% share. The remaining systems are either owned jointly by public and private interests, the Federal and state governments, or Native Americans. All regions, likewise are dominated by the private and local government, and, for the most part are consistent with the pattern at the national level (table B4). However, in the Midwest regions, those whose regional offices are in Chicago and in Kansas City, local government ownership is substantially higher than the national average, 60 and 73%, respectively. In the Dallas and Seattle regions there are substantially higher proportions of systems owned jointly by public and private interests, 11 and 18%, respectively.

Water Treatment

As is seen in table B5, the distribution of systems in the three broad treatment classifications, "treated", "mixed", and "untreated", differs substantially by EPA region. Nationally, 60% of CWS's apply treatment to at least one of their water sources; while one-third do no treatment at all. For water systems in the Boston region, these percentages are nearly reversed, with two-thirds of the systems indicating that their water is "untreated". This region's higher proportions of ground water systems and systems of smaller size may explain most of this difference. At the other end of the spectrum, it is in the New York and Atlanta regions where the lowest proportions of untreated systems are found, 11 and 19% respectively.

Distribution of CWS's by Primary Water Source

Both the distributions of the number of CWS's by primary water source and the percentage of the water supplied differ substantially by EPA region (tables B6 and B7). The percentage of ground water systems ranges from a low of 72% in the New York region to a high of 89% in the Seattle region. This variation is to be expected, and it has implications for the cost of compliance with EPA regulations, assuming that the level of treatment required for ground water will, in general, always be less than for surface water.

Table B4. Percentage Distribution of Community Water Systems by Ownership

Ownership Category	Nation	1 Boston	2 New York	3 Phila.	4 Atlanta	5 Chicago	6 Dallas	7 Denver	8 Kans. City	9 San Fran.	10 Seattle
	EPA Region Number with Regional Headquarters										
	%										
Federal Government	1.0	0.1	0.4	0.9	0.7	0.3	0.7	0.3	0.7	6.0	1.5
Private	52.6	76.1	55.1	62.7	62.0	38.1	56.8	26.1	48.8	53.2	48.5
State Government	1.0	0.5	1.0	0.8	0.9	1.3	0.8	0.4	0.5	4.7	0.7
Local Government	41.2	23.3	41.8	35.5	35.9	59.5	30.2	73.1	50.0	32.9	29.7
Mixed public/private	3.9	0.1	1.6	0.0	0.3	0.1	11.4	0.1	0.0	3.1	18.2
Native American	0.3	0.0	0.2	0.0	0.1	0.7	0.0	0.0	0.0	0.0	1.4

Table B5. Percentage Distribution of Community Water Systems by Treatment Classification

Treatment Classification	Nation	1 Boston	2 New York	3 Phila.	4 Atlanta	5 Chicago	6 Dallas	7 Denver	8 Kans. City	9 San Fran.	10 Seattle
	EPA Region Number with Regional Headquarters										
	%										
Treated	60.8	24.4	78.3	56.4	76.4	46.0	71.4	52.7	51.9	25.1	63.0
Untreated	32.0	65.6	10.8	35.9	19.5	46.9	27.3	41.4	39.6	38.2	34.9
Mixed	7.2	9.9	10.8	7.7	4.2	7.1	1.3	5.9	8.5	36.7	2.1

Note: Treated Systems imply that the water from all of a system's sources is subjected to treatment. Untreated systems apply no treatment for any of its water sources. For the system in the mixed treatment classification, water from some sources is treated, while water from others is not.

Table B6. Percentage Distribution of the Number of Community Water Systems by Water Source

Water Source		EPA Region Number with Regional Headquarters									
		1	2	3	4	5	6	7	8	9	10
	Nation	Boston	New York	Phila.	Atlanta	Chicago	Dallas	Denver	Kans. City	San Fran.	Seattle
	%										
Ground, nonpurchased	78.7	85.9	71.3	77.0	79.7	81.6	74.9	78.1	75.8	83.2	85.4
Ground, purchased	3.2	0.4	1.0	1.4	3.8	2.6	4.0	6.1	4.5	0.6	3.9
Surface, nonpurchased	8.2	9.7	8.5	13.1	7.2	4.3	7.7	6.1	10.9	13.0	8.4
Surface, purchased	9.7	3.9	19.2	8.4	8.9	11.4	13.5	9.7	8.6	2.9	2.1
Ground UDI, nonpurchased[a]	0.1	0.0	0.0	0.1	0.4	0.0	0.0	0.0	0.2	0.2	0.1
Ground UDI, purchased[a]	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.2	0.0
Totals											
Ground Water Systems	81.9	86.3	72.3	78.4	83.5	84.3	78.8	84.2	80.3	83.7	89.3
Surface Water Systems[a]	18.1	13.7	27.7	21.6	16.5	15.7	21.2	15.8	19.7	16.3	10.7

[a] UDI means that the ground water is under the direct influence of surface water. Thus, they are subject to the same regulations as surface water and are included in the surface water system's total.

Table B7. Percentage Distribution of the Water Production by Community Water Systems by Water Source

Water Source	Nation	1 Boston	2 New York	3 Phila.	4 Atlanta	5 Chicago	6 Dallas	7 Denver	8 Kans. City	9 San Fran.	10 Seattle
	EPA Region Number with Regional Headquarters										
	%										
Ground, nonpurchased	32.4	11.2	20.3	12.7	44.3	23.8	31.7	39.6	18.8	41.4	39.5
Ground, purchased	0.9	0.1	0.2	0.5	1.5	0.6	0.8	1.4	0.3	0.1	6.8
Surface, nonpurchased	58.4	80.6	71.4	74.4	47.2	55.2	54.6	55.0	70.1	56.9	50.1
Surface, purchased	8.2	8.0	8.2	12.4	6.8	20.5	12.9	4.1	10.7	1.4	3.6
Ground UDI, nonpurchased[a]	0.1	0.0	0.0	0.1	0.3	0.0	0.0	0.0	0.0	0.1	0.1
Ground UDI, purchased[a]	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Totals											
Ground Water Systems	33.3	11.3	20.4	13.2	45.7	24.4	32.4	41.0	19.2	41.5	46.2
Surface Water Systems[a]	66.7	88.7	79.6	86.8	54.3	75.6	67.6	59.0	80.8	58.5	53.8

[a]UDI means that the ground water is under the direct influence of surface water. Thus, they are subject to the same regulations as surface water and are included in the surface water system's total.

Perhaps a more surprising result is that in the West, (regions 7, 8, and 9), over 40% of the total water production is from ground water sources. This is substantially above the 33% figure nationally, and it is nearly four times the percentage of water from ground water sources in New England and the Philadelphia region.

APPENDIX C

Relationship Between Population Served and System Flow and Design Capacity

Everyone would agree that there is a high correlation between the population served by a community water system and its average daily flow and design capacity. In an attempt to establish these relationships in a formal way, we use a sample of over 11,000 systems in the *FRDS-II Data Base* to estimate two separate equations, one for average daily flow and one for design capacity. Summary data on the variables used in the estimation appear in table C1. Even though the focus of this study is on small water systems, the 11,000 observations used to estimate the equations include observations from all systems in *FRDS-II* for which measures of output and design capacity are reported, be they large or small. Having this added variability in the data helped to estimate the coefficients in the model with greater precision, and helped improve the ability of the model to provide more accurate predictions of both average design capacity and average daily flow.

Table C1. Variables for Regressions on Average Daily Flow and Design Capacity

Variable Name	Mean	Standard Deviation	Minimum	Maximum
Average Daily Flow (gal./day)	999,103	9,861,350	500	780,000,000
Design Capacity (gal./day)	2,551,726	21,519,384	1,000	1,440,000,000
Retail Population	6,194	46,333	8	3,000,000
Number of Hookups	1,902	11,513	1	500,000
Dummy Variables: [a]				
WSSURF: Surface water=1	0.181	0.385	0	1
WSPURCH: Purchase water=1	0.074	0.262	0	1
OWNF: Federal government owned=1	0.007	0.493	0	1
OWNS: State government owned=1	0.008	0.090	0	1
OWNL: Local government owned=1	0.481	0.500	0	1
SRVRES: Residential service area=1	0.974	0.159	0	1
SRVSRES: Semi-residential service area=1	0.017	0.128	0	1
URBAN: Located in MSA=1	0.507	0.500	0	1
EPASOUTH: EPA Region 4, 6, or 9=1	0.512	0.500	0	1
EPAWEST: EPA Region 5, 6, 7, 8, 9, or 10=1	0.471	0.500	0	1

[a] The means of the dummy variables are the proportions of observations with a value of 1.

For this reason, it is not surprising that the average retail population in the sample is about 6,200, while the number of retail hookups averaged about 1,900. Average design capacity was about 2.6 million gallons per day, supporting an average flow of just under a million gallons per day. The primary water source for about 18% of the water systems in the data set is surface water, and only 7% purchase any water from other systems. Nearly half are owned by local governments, whereas about 97% serve residential areas. About half are in Metropolitan Statistical Areas (MSA), and about half are in EPA regions in the South or the West, but these regional delineations are not mutually exclusive.

The first equation that is estimated is the one for average daily flow, in gallons per day. This measure of output is regressed against the size of the retail population and the number of commercial hookups, as well as a number of dummy variables to control for differences in the primary water source, whether or not the system purchases water from another system, whether or not the system serves residential or semi-residential areas, and whether or not the system is located in a Metropolitan Statistical Area. Dummy variables also account for any differences due to whether or not the system is private, or publicly owned. Finally, differences in average daily flow due to regional location are accounted for by dummy variables for the South and the West.

The second equation that is estimated is for design capacity, again measured in gallons per day. This is regressed on the same variables as in the equation for average daily flow, except that average daily flow is also included as a regressor. The hypothesis here is that expectations about the required average daily flow affect decisions about design capacity, but not *vice versa.*[9]

For estimation purposes, the continuous variables are transformed into their logarithmic form, and the results of the estimation are in table C2. In general, the estimated equations perform quite well, with an R^2 of 0.80 and 0.92 for the equations for design capacity and average daily flow, respectively. The signs on the coefficients of the variables are also as expected, and the t-ratios are high as well.

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[9] Because average daily flow itself is estimated and it also appears as a regressor in the equation for design capacity, it was necessary to purge the variable for average daily flow of any unexplained random component before using it as an explanatory variable in the second regression. This was accomplished by using the predicted values from the average daily flow equation as the regressor in the design flow equation. This is equivalent to an instrumental variable procedure (Judge *et al.*, 1988).

Table C2. Regression Equations for Average Daily Flow and Design Capacity

Variable	Average Daily Flow			Design Capacity		
	Coefficient	Std Error	t-ratio	Coefficient	Std Error	t-ratio
		R^2=0.92			R^2=0.80	
INTERCEPT	5.20	0.08	63.26	7.55	0.10	77.65
PPRODSQ [a]				0.01	0.00	12.18
LOGPOP [a]	0.69	0.02	41.91	0.29	0.03	9.59
LOGHOOK [a]	0.10	0.02	6.07	0.23	0.02	11.41
WSSURF	0.20	0.02	11.03	-0.11	0.03	-3.92
WSPURCH	-0.23	0.02	-9.25	-0.22	0.04	-6.01
OWNF	0.54	0.07	7.95	0.41	0.10	4.19
OWNS	0.48	0.07	7.19	0.56	0.10	5.85
OWNL	0.25	0.01	16.92	0.13	0.02	6.53
SRVRES	-0.12	0.06	-2.07	-0.20	0.09	-2.39
SRVSRES	0.21	0.08	2.74	-0.27	0.11	-2.54
URBAN	0.03	0.01	2.46	0.12	0.02	7.26
EPASOUTH	0.07	0.01	5.93	0.06	0.02	3.70
EPAWEST	0.17	0.01	14.70	0.40	0.02	23.44
LPOPHOOK [a]	0.02	0.00	13.68			

[a] The variables used in the regressions are all defined in Table1, except for:
PPRODSQ = [log(average daily flow)]^2
LOGPOP = log(retail population)
LOGHOOK = log(number of hookups)
LPOPHOOK = log(retail population) x log(number of hookups).

Because the continuous variables in the equations are specified in logarithmic form, the coefficients on these variables can be interpreted as elasticities -- that is, they reflect the percentage change in the dependent variable as the independent variable changes by one percent. For example, as the retail population increases by one percent, design capacity increases by 0.29 percent. Similarly, for a one percent increase in the number of hookups, design capacity increases by 0.23 percent. The situation is not quite that simple for the effect of average daily flow on design capacity, because it is the square of the logarithm of average daily flow that appears in this equation. Thus, the elasticity of design capacity with respect to average daily production is not constant. It is twice the value of the coefficient times the logarithm of the variable, 0.02 * ln (average daily flow), in this case. By examining the coefficients on the dummy variables, it is not surprising that the design capacity is higher for systems in the South and the West and for those in urban areas. Compared with systems that serve non-residential areas, systems that serve residential and semi-residential areas have smaller design capacities. The design capacities of private systems are generally smaller than systems owned by the government, and are smaller for systems that purchase water and rely primarily on surface rather than ground water.

In terms of the effects of the dummy variables, the story is about the same for the equation to predict average daily flow as it is for design capacity. The two exceptions are: the average daily flow is higher for surface water systems than for ground water systems, and average daily flow is also higher if the system serves a semi-residential area. Similarly, as both retail population and the number of hookups increase, the average daily flow rises as well. Because of the cross product term (the product of the logarithm of population and the logarithm of hookups), the elasticities of the average daily flow are again not constant. For each variable, they depend on the level of the other variable in the cross product term. That is, the elasticity of average daily flow with respect to retail population is 0.69 + 0.02 * ln (number of hookups). For the number of hookups, the elasticity of average daily production is 0.10 + 0.02 * ln (retail population).[10]

[10] These elasticities are essentially the logarithmic derivatives of a function of the general form $\ln y = \ln a + b \ln x + c (\ln x)^2 + d [(\ln x)(\ln z)] + e (\ln z)^2 + f \ln z$. For this function we have $\partial \ln y / \partial \ln x = b + 2c (\ln x) + d (\ln z)$, and $\partial \ln y / \partial \ln z = f + 2e (\ln z) + d (\ln x)$. In the estimated functions above, not all the terms in this general expression are present.

APPENDIX D

Summary Tables for General Water Treatment Objectives of Community Water Systems

Table D1. General Treatment Objectives of Very Small Community Water Systems[a]

Treatment Objective	Obj. Code	Single Treatment Systems	Single Treatment Percentage	Multiple Treatments Systems	Multiple Treatments Percentage
Surface Water Systems[c]					
Additional Treatment Elsewhere	A	0	0.0	0	0.0
Disinfection By-Product Control	B	0	0.0	14	0.9
Corrosion Control	C	1	0.1	91	5.7
Disinfection	D	218	13.7	688	43.2
Dechlorination	E	0	0.0	3	0.2
Iron Removal	F	4	0.3	44	2.8
Inorganics Removal	I	0	0.0	24	1.5
Manganese Removal	M	0	0.0	8	0.5
No Treatment [b]	N	777	48.8	1,159	72.8
Organics Removal	O	0	0.0	44	2.8
Particulate Removal	P	57	3.6	512	32.2
Radionuclides Removal	R	0	0.0	15	0.9
Softening	S	1	0.1	62	3.9
Taste/Odor Control	T	1	0.1	59	3.7
Other (Process Fluoridation)	Z	1	0.1	41	2.6
Ground Water Systems[d]					
Additional Treatment Elsewhere	A	0	0.0	0	0.0
Disinfection By-Product Control	B	4	0.0	27	0.1
Corrosion Control	C	40	0.2	748	3.6
Disinfection	D	7,196	34.7	9,777	47.2
Dechlorination	E	1	0.0	12	0.1
Iron Removal	F	84	0.4	1,057	5.1
Inorganics Removal	I	13	0.1	120	0.6
Manganese Removal	M	6	0.0	388	1.9
No Treatment [b]	N	9,984	48.2	15,553	75.1
Organics Removal	O	6	0.0	130	0.6
Particulate Removal	P	75	0.4	361	1.7
Radionuclides Removal	R	7	0.0	45	0.2
Softening	S	100	0.5	549	2.7
Taste/Odor Control	T	29	0.1	447	2.2
Other (Process Fluoridation)	Z	32	0.2	514	2.5

[a] Frequencies exclude those system which apply no treatment themselves, but purchase treated water, since unable to tie specific treatment objective to water utilized; i.e. systems with treatment objective=N (no treatment) and treatment process = 996 (treatment applied by seller).

[b] For sole treatments, no treatment implies no treatment at all source or plant locations. For the general multiple classification, no treatment implies that the system applies no treatment to at least one source or plant location and may be in addition to other treatments.

[c] total systems = 1,591

[d] total systems = 20,708

Table D2. General Treatment Objectives of Small Community Water Systems[a]

Treatment Objective	Obj. Code	Single Treatment Systems	Single Treatment Percentage	Multiple Treatments Systems	Multiple Treatments Percentage
Surface Water Systems[c]					
Additional Treatment Elsewhere	A	0	0.0	2	0.1
Disinfection By-Product Control	B	0	0.0	61	3.0
Corrosion Control	C	4	0.2	400	19.9
Disinfection	D	356	17.7	1,364	67.9
Dechlorination	E	0	0.0	0	0.0
Iron Removal	F	0	0.0	148	7.4
Inorganics Removal	I	0	0.0	62	3.1
Manganese Removal	M	0	0.0	32	1.6
No Treatment [b]	N	443	22.0	1,248	62.1
Organics Removal	O	0	0.0	98	4.9
Particulate Removal	P	35	1.7	1,008	50.1
Radionuclides Removal	R	0	0.0	18	0.9
Softening	S	5	0.2	236	11.7
Taste/Odor Control	T	0	0.0	231	11.5
Other (Process Fluoridation)	Z	1	0.0	1,068	53.1
Ground Water Systems[d]					
Additional Treatment Elsewhere	A	0	0.0	0	0.0
Disinfection By-Product Control	B	0	0.0	10	0.1
Corrosion Control	C	18	0.3	760	10.7
Disinfection	D	2,630	36.9	4,956	69.6
Dechlorination	E	0	0.0	1	0.0
Iron Removal	F	22	0.3	1,043	14.6
Inorganics Removal	I	0	0.0	58	0.8
Manganese Removal	M	1	0.0	196	2.8
No Treatment [b]	N	1,499	21.0	3,818	53.6
Organics Removal	O	0	0.0	161	2.3
Particulate Removal	P	3	0.0	259	3.6
Radionuclides Removal	R	0	0.0	12	0.2
Softening	S	22	0.3	376	5.3
Taste/Odor Control	T	5	0.1	389	5.5
Other (Process Fluoridation)	Z	38	0.5	1,017	14.3

[a] Frequencies exclude those system which apply no treatment themselves, but purchase treated water, since unable to tie specific treatment objective to water utilized; i.e. systems with treatment objective=N (no treatment) and treatment process = 996 (treatment applied by seller).

[b] For sole treatments, no treatment implies no treatment at all source or plant locations. For the general multiple classification, no treatment implies that the system applies no treatment to at least one source or plant location and may be in addition to other treatments.

[c] total systems = 2,010

[d] total systems = 7,124

Table D3. General Treatment Objectives of Medium Community Water Systems[a]

Treatment Objective	Obj. Code	Single Treatment Systems	Single Treatment Percentage	Multiple Treatments Systems	Multiple Treatments Percentage
Surface Water Systems[c]					
Additional Treatment Elsewhere	A	0	0.0	1	0.1
Disinfection By-Product Control	B	0	0.0	55	4.8
Corrosion Control	C	1	0.1	392	33.9
Disinfection	D	155	13.4	882	76.4
Dechlorination	E	0	0.0	2	0.2
Iron Removal	F	0	0.0	128	11.1
Inorganics Removal	I	0	0.0	67	5.8
Manganese Removal	M	0	0.0	42	3.6
No Treatment[b]	N	151	13.1	592	51.3
Organics Removal	O	0	0.0	104	9.0
Particulate Removal	P	27	2.3	728	63.0
Radionuclides Removal	R	0	0.0	16	1.4
Softening	S	1	0.1	133	11.5
Taste/Odor Control	T	0	0.0	244	21.1
Other (Process Fluoridation)	Z	1	0.1	318	27.5
Ground Water Systems[d]					
Additional Treatment Elsewhere	A	0	0.0	0	0.0
Disinfection By-Product Control	B	0	0.0	7	0.4
Corrosion Control	C	5	0.3	248	14.6
Disinfection	D	516	30.4	1,274	74.9
Dechlorination	E	0	0.0	0	0.0
Iron Removal	F	3	0.2	308	18.1
Inorganics Removal	I	0	0.0	19	1.1
Manganese Removal	M	0	0.0	56	3.3
No Treatment[b]	N	230	13.5	889	52.3
Organics Removal	O	0	0.0	57	3.4
Particulate Removal	P	1	0.1	124	7.3
Radionuclides Removal	R	0	0.0	5	0.3
Softening	S	2	0.1	125	7.4
Taste/Odor Control	T	5	0.3	145	8.5
Other (Process Fluoridation)	Z	12	0.7	383	22.5

[a] Frequencies exclude those system which apply no treatment themselves, but purchase treated water, since unable to tie specific treatment objective to water utilized; i.e. systems with treatment objective=N (no treatment) and treatment process = 996 (treatment applied by seller).

[b] For sole treatments, no treatment implies no treatment at all source or plant locations. For the general multiple classification, no treatment implies that the system applies no treatment to at least one source or plant location and may be in addition to other treatments.

[c] total systems = 1,155

[d] total systems = 1,700

Table D4. General Treatment Objectives of Large Community Water Systems[a]

Treatment Objective	Obj. Code	Single Treatment		Multiple Treatments	
		Systems	Percentage	Systems	Percentage
Surface Water Systems[c]					
Additional Treatment Elsewhere	A	0	0.0	4	0.3
Disinfection By-Product Control	B	1	0.1	121	10.4
Corrosion Control	C	1	0.1	465	40.1
Disinfection	D	142	12.2	896	77.2
Dechlorination	E	0	0.0	4	0.3
Iron Removal	F	0	0.0	174	15.0
Inorganics Removal	I	0	0.0	59	5.1
Manganese Removal	M	0	0.0	63	5.4
No Treatment [b]	N	139	12.0	619	53.3
Organics Removal	O	1	0.1	110	9.5
Particulate Removal	P	28	2.4	749	64.5
Radionuclides Removal	R	0	0.0	9	0.8
Softening	S	0	0.0	141	12.1
Taste/Odor Control	T	0	0.0	312	26.9
Other (Process Fluoridation)	Z	2	0.2	378	32.6
Ground Water Systems[d]					
Additional Treatment Elsewhere	A	0	0.0	0	0.0
Disinfection By-Product Control	B	0	0.0	6	0.6
Corrosion Control	C	2	0.2	221	21.6
Disinfection	D	193	18.8	723	70.6
Dechlorination	E	0	0.0	1	0.1
Iron Removal	F	0	0.0	185	18.1
Inorganics Removal	I	0	0.0	24	2.3
Manganese Removal	M	0	0.0	27	2.6
No Treatment [b]	N	76	7.4	689	67.3
Organics Removal	O	1	0.1	70	6.8
Particulate Removal	P	0	0.0	128	12.5
Radionuclides Removal	R	0	0.0	3	0.3
Softening	S	0	0.0	122	11.9
Taste/Odor Control	T	1	0.1	153	14.9
Other (Process Fluoridation)	Z	3	0.3	281	27.4

[a] Frequencies exclude those system which apply no treatment themselves, but purchase treated water, since unable to tie specific treatment objective to water utilized; i.e. systems with treatment objective=N (no treatment) and treatment process = 996 (treatment applied by seller).

[b] For sole treatments, no treatment implies no treatment at all source or plant locations. For the general multiple classification, no treatment implies that the system applies no treatment to at least one source or plant location and may be in addition to other treatments.

[c] total systems = 1,161

[d] total systems = 1,024

Table D5. General Treatment Objectives of Very Large Community Water Systems[a]

Treatment Objective	Obj. Code	Single Treatment Systems	Single Treatment Percentage	Multiple Treatments Systems	Multiple Treatments Percentage
Surface Water Systems[c]					
Additional Treatment Elsewhere	A	0	0.0	0	0.0
Disinfection By-Product Control	B	0	0.0	21	12.7
Corrosion Control	C	0	0.0	84	50.6
Disinfection	D	5	3.0	140	84.3
Dechlorination	E	0	0.0	2	1.2
Iron Removal	F	0	0.0	25	15.1
Inorganics Removal	I	0	0.0	12	7.2
Manganese Removal	M	0	0.0	7	4.2
No Treatment [b]	N	6	3.6	100	60.2
Organics Removal	O	0	0.0	28	16.9
Particulate Removal	P	6	3.6	140	84.3
Radionuclides Removal	R	0	0.0	2	1.2
Softening	S	0	0.0	25	15.1
Taste/Odor Control	T	0	0.0	70	42.2
Other (Process Fluoridation)	Z	0	0.0	80	48.2
Ground Water Systems[d]					
Additional Treatment Elsewhere	A	0	0.0	0	0.0
Disinfection By-Product Control	B	0	0.0	0	0.0
Corrosion Control	C	0	0.0	19	27.9
Disinfection	D	8	11.8	39	57.4
Dechlorination	E	0	0.0	0	0.0
Iron Removal	F	0	0.0	7	10.3
Inorganics Removal	I	0	0.0	0	0.0
Manganese Removal	M	0	0.0	0	0.0
No Treatment [b]	N	1	1.5	58	85.3
Organics Removal	O	0	0.0	5	7.4
Particulate Removal	P	0	0.0	15	22.1
Radionuclides Removal	R	0	0.0	0	0.0
Softening	S	0	0.0	11	16.2
Taste/Odor Control	T	0	0.0	12	17.6
Other (Process Fluoridation)	Z	0	0.0	17	25.0

[a] Frequencies exclude those system which apply no treatment themselves, but purchase treated water, since unable to tie specific treatment objective to water utilized; i.e. systems with treatment objective=N (no treatment) and treatment process = 996 (treatment applied by seller).

[b] For sole treatments, no treatment implies no treatment at all source or plant locations. For the general multiple classification, no treatment implies that the system applies no treatment to at least one source or plant location and may be in addition to other treatments.

[c] total systems = 166

[d] total systems = 68

APPENDIX E

Summary Tables for CWS's Multiple Water Treatment Objectives

Table E1. Multiple Treatment Objectives Found in Medium Community Water Systems

Treatment Objectives[a]	Ground Water Systems Number	Ground Water Systems Percent	Surface Water Systems Number	Surface Water Systems Percent
BCDFIMOP			9	0.92
BCDFPT			6	0.61
C	5	0.38		
CD	80	6.11	30	3.06
CDF	39	2.98		
CDFIMOPT			6	0.61
CDFM	9	0.69		
CDFMOP	5	0.38		
CDFO	6	0.46		
CDFP	6	0.46	8	0.81
CDFPST			8	0.81
CDFPT			16	1.63
CDFS	9	0.69		
CDO	20	1.53		
CDOPT			11	1.12
CDP	6	0.46	124	12.63
CDPS	7	0.53	31	3.16
CDPST			12	1.22
CDPT			66	6.72
CDT	7	0.53		
D	676	51.60	187	19.04
DF	108	8.24		
DFM	7	0.53		
DFP	16	1.22	6	0.61
DFPS	8	0.61		
DFPT			10	1.02
DFS	19	1.45		
DFT	11	0.84		
DM	9	0.69		
DO	10	0.76		
DOP			13	1.32
DOPT			8	0.81
DP	25	1.91	153	15.58
DPS	7	0.53	29	2.95
DPST			5	0.51
DPT	6	0.46	39	3.97
DS	24	1.83		
DST	7	0.53		
DT	63	4.81		
F	9	0.69		
FIMOPT			5	0.51
P			64	6.52
PT			5	0.51
S	6	0.46		
T	8	0.61		

[a]Each letter in this column represents a particular treatment objective from table 5, e.g. CD is corrosion control combined with disinfection.

Table E2. Multiple Treatment Objectives Found in Large Community Water Systems

Treatment Objectives[a]	Ground Water Systems		Surface Water Systems	
	Number	Percent	Number	Percent
BCDFIMO			5	0.50
BCDFIMOP			15	1.50
BCDP			8	0.80
BCDPT			12	1.20
BCFPST			6	0.60
BDPS			5	0.50
BDPT			16	1.60
CD	56	7.58	20	2.01
CDF	30	4.06		
CDFMP			7	0.70
CDFO	8	1.08		
CDFP	10	1.35	12	1.20
CDFPST			18	1.81
CDFPT			20	2.01
CDFS	5	0.68		
CDIPST	5	0.68		
CDO	9	1.22		
CDOP			10	1.00
CDOPT			13	1.30
CDP			110	11.03
CDPS	8	1.08	24	2.41
CDPST	6	0.81	17	1.71
CDPT			79	7.92
CDT	15	2.03		
D	273	36.94	167	16.75
DF	40	5.41	6	0.60
DFP			6	0.60
DFPT			9	0.90
DFS	17	2.30		
DFT	6	0.81		
DO	18	2.44		
DP	11	1.49	99	9.93
DPS	15	2.03	21	2.11
DPST	10	1.35	7	0.70
DPT			44	4.41
DS	16	2.17		
DT	55	7.44		
P			85	8.53

[a]Each letter in this column represents a particular treatment objective from table 5, e.g. CD is corrosion control combined with disinfection.

Table E3. Multiple Treatment Objectives Found in Very Large Community Water Systems

Treatment Objectives[a]	Ground Water Systems		Surface Water Systems	
	Number	Percent	Number	Percent
CDOPT			6	3.80
CDP			22	13.92
CDPT			15	9.49
D	12	28.57	7	4.43
DP			16	10.13
DPT			11	6.96
P			18	11.39

[a]Each letter in this column represents a particular treatment objective from table 5, e.g. CD is corrosion control combined with disinfection.

APPENDIX F

Summary Tables for CWS's Multiple Treatment Processes

Exhibit F1. Codes for Water Treatment Processes

Treatment Code	Process Name	Types Included
A	Aeration	Cascade
		Diffused
		Packed Tower
		Slat Tray
		Spray
C	Chlorination	Chloramines
		Chlorine Dioxide
		Pre- and Post-Gaseous Chlorination
		Pre- and Post-Hypochlorination
E	Ion Exchange	Activated Alumina
		Ion Exchange
F	Filtration	Cartridge
		Diatomaceous Earth
		Greensand
		Pressure Sand
		Rapid Sand
		Slow Sand
		Ultrafiltration
H	pH Adjustment	Pre-and Post-pH Adjustment
I	Inhibitors	Bimetallic Phosphate
		Hexametaphosphate
		Orthophosphate
		Polyphosphate
		Silicate
L	Lime-Soda Ash	
N	Activated Carbon	Granular
		Powered
O	Ozonation	Pre-and Post-Ozonation
P	Permanganate	
R	Reverse Osmosis	
U	Ultraviolet Radiation	

Table F1. Multiple Treatment Processes Found in Very Small Community Water Systems[a]

Processes	Ground Water Systems Number	Ground Water Systems Percent	Surface Water Systems Number	Surface Water Systems Percent
AC	233	2.27		
ACE	5	0.05		
ACEF	7	0.07		
ACEP	24	0.23		
ACF	56	0.55		
ACFH	13	0.13		
ACFHINOP	5	0.05		
ACFL	5	0.05		
ACH	24	0.23		
ACHR	12	0.12		
AF	13	0.13		
AFHP	9	0.09		
AFP	57	0.56	8	1.01
AP	46	0.45		
C	7984	77.89	251	31.57
CE	246	2.40		
CEF	36	0.35		
CEH	10	0.10		
CEI	9	0.09		
CF	267	2.60	278	34.97
CFH	30	0.29	41	5.16
CFHL			5	0.63
CFHN			9	1.13
CFHNO	40	0.39		
CFHP	5	0.05		
CFI	5	0.05	5	0.63
CFL	11	0.11	14	1.76
CFN	5	0.05	10	1.26
CFP	12	0.12		
CH	374	3.65	7	0.88
CHI	26	0.25		
CI	142	1.39		
CL	19	0.19		
CN	19	0.19		
CR	8	0.08		
E	110	1.07		
EF	8	0.08		
EFP	10	0.10		
EP	8	0.08		
F	108	1.05	94	11.82
FH			5	0.63
H	41	0.40		
HP	9	0.09		
I	10	0.10		
L	25	0.24		
N	9	0.09		
O	5	0.05		
R	5	0.05		
U	18	0.18		

[a]The letters refer to combinations of treatment processes given in Exhibit F1.

Table F2. Multiple Treatment Processes Found in Small Community Water Systems[a]

Processes	Ground Water Systems Number	Ground Water Systems Percent	Surface Water Systems Number	Surface Water Systems Percent
AC			7	0.46
ACEFI	5	0.10		
ACEFIP			7	0.46
ACF	122	2.38	12	0.79
ACFH	53	1.04	9	0.59
ACFHL	9	0.18		
ACFI	12	0.23		
ACFL	19	0.37		
ACH	81	1.58		
ACHR	11	0.21		
ACI	11	0.21		
ACL	6	0.12		
AF	28	0.55		
AFHP	24	0.47	29	1.91
AFP	47	0.92	16	1.05
AP	15	0.29		
C	3394	66.32	423	27.85
CE	23	0.45		
CEF	43	0.84	7	0.46
CEH	8	0.16		
CEI	5	0.10		
CF	165	3.22	332	21.86
CFH	47	0.92	152	10.01
CFHI			18	1.19
CFHIN			5	0.33
CFHL	8	0.16	27	1.78
CFHLN			9	0.59
CFHN			36	2.37
CFHNO	6	0.12		
CFHP	17	0.33		
CFI	11	0.21	40	2.63
CFIL			10	0.66
CFIN			6	0.40
CFL	42	0.82	39	2.57
CFLN			20	1.32
CFN			29	1.91
CFP	18	0.35		
CH	215	4.20	20	1.32
CHI	24	0.47	5	0.33
CHL			5	0.33
CI	132	2.58	11	0.72
CL	43	0.84	9	0.59
CR	5	0.10		
ECAP	11	0.21		
EFP	5	0.10		
F	12	0.23	124	8.16
FHNP			11	0.72
FNP			5	0.33
H	13	0.25	11	0.72
I	17	0.33		
L	39	0.76	5	0.33

[a]The letters refer to combinations of treatment processes given in Exhibit F1.

Table F3. Multiple Treatment Processes Found in Medium-Size Community Water Systems[a]				
	Ground Water Systems		Surface Water Systems	
Processes	Number	Percent	Number	Percent
AC	83	6.36		
ACE	5	0.38		
ACEFIP			10	1.02
ACF	46	3.52	7	0.71
ACFH	26	1.99	11	1.12
ACFI	14	1.07		
ACFL	11	0.84		
ACH	28	2.14		
AFHP			21	2.14
AFP	8	0.61	7	0.71
C	752	57.58	194	19.80
CE	12	0.92		
CEF	6	0.46		
CF	48	3.68	168	17.14
CFH	17	1.30	128	13.06
CFHI			25	2.55
CFHIN			13	1.33
CFHL	6	0.46	14	1.43
CFHLN			6	0.61
CFHN			35	3.57
CFI			33	3.37
CFIN			9	0.92
CFL	13	1.00	17	1.73
CFLN			8	0.82
CFN			31	3.16
CFP	7	0.54		
CH	45	3.45	23	2.35
CHI	8	0.61	6	0.61
CI	43	3.29	9	0.92
CL	18	1.38	9	0.92
F			63	6.43
FHNP			17	1.73
FNP			5	0.51
H			6	0.61
L	5	0.38		

[a]The letters refer to combinations of treatment processes given in Exhibit F1.

Table F4. Multiple Treatment Processes Found in Large Community Water Systems[a]

	Ground Water Systems		Surface Water Systems	
Processes	Number	Percent	Number	Percent
AC	76	10.30	6	0.60
ACEFIP			11	1.11
ACF	19	2.57	19	1.91
ACFH	29	3.93	12	1.21
ACFHI	6	0.81		
ACFHN			9	0.91
ACFI	9	1.22		
ACFL	21	2.85		
ACH	25	3.39		
ACI	5	0.68		
AFHP			14	1.41
AFP	8	1.08	6	0.60
C	300	40.65	178	17.91
CE	5	0.68		
CEFINP			21	2.11
CEFLNP			8	0.80
CF	17	2.30	114	11.47
CFH	11	1.49	113	11.37
CFHI			38	3.82
CFHIN			25	2.52
CFHL			11	1.11
CFHN			45	4.53
CFI			23	2.31
CFILN			5	0.50
CFIN			17	1.71
CFL	19	2.57	6	0.60
CFLN			10	1.01
CFN			29	2.92
CH	33	4.47	13	1.31
CI	21	2.85	9	0.91
CL	18	2.44	17	1.71
ECAP			6	0.60
F			84	8.45
FHLP			6	0.60
FHNP			22	2.21
FNP			8	0.80

[a]The letters refer to combinations of treatment processes given in Exhibit F1.

Table F5. Multiple Treatment Processes Found in Very Large Community Water Systems[a]				
	Ground Water Systems		Surface Water Systems	
Processes	Number	Percent	Number	Percent
ACFH			5	3.16
C	12	28.57	10	6.33
CF			21	13.29
CFH			20	12.66
CFHI			5	3.16
CFHN			11	6.96
CFN			7	4.43
F			18	11.39
FHNP			7	4.43

[a]The letters refer to combinations of treatment processes given in Exhibit F1.

APPENDIX G

Summary Tables for CWS's Estimated and Actual Treatment Combinations

Table G1. Estimated Treatment Needs and Actual Treatment Combinations Used by Community Water Systems with a Ground Water Source

Treatment	No. of	Very Small		Small		Medium		Large		Very Large	
Combination	Treatments	Estimated[a]	Actual[a]	Estimated	Actual	Estimated	Actual	Estimated	Actual	Estimated	Actual
						%					
No Treatment	0	14.313	48.213	22.477	21.042	23.840	13.529	25.000	7.422	32.558	1.471
Alt. Treatment[c]	1	0.379	2.284	0.538	7.117	0.000	9.647	0.000	20.508	0.000	36.765
Disinfection (DSF)[d]	1	10.363	40.125	6.543	50.379	4.941	47.706	2.592	31.445	0.000	17.647
Corrosion Control (CC)[e]	1	21.784	0.449	34.135	1.081	35.414	0.706	37.207	0.586	44.186	0.000
Ion Exchange (IE)[f]	1	0.792	0.666	1.536	0.154	2.341	0.000	3.763	0.000	2.326	0.000
Aeration (PTA)[g]	1	5.020	0.642	3.883	1.319	3.251	0.824	2.926	1.074	2.326	0.000
Gran. Act. Carbon (GAC)	1	1.640	0.058	1.174	0.000	0.607	0.000	0.502	0.000	0.000	0.000
DSF / CC	2	15.364	3.018	9.712	7.875	7.326	9.941	3.930	12.598	0.000	16.176
DSF / IE	2	0.558	1.415	0.430	0.997	0.477	1.176	0.334	0.781	0.000	0.000
DSF/ PTA	2	3.540	1.473	1.095	5.348	0.694	8.059	0.251	9.668	0.000	5.882
DSF/ GAC	2	1.159	0.121	0.323	0.098	0.130	0.059	0.000	0.293	0.000	1.471
CC / IE	2	1.178	0.019	2.279	0.028	3.511	0.000	5.518	0.000	4.651	0.000
CC /PTA	2	7.443	0.048	5.771	0.365	4.855	0.294	4.264	0.391	2.326	0.000
CC / GAC	2	2.430	0.005	1.731	0.000	0.867	0.059	0.669	0.098	0.000	0.000
IE / PTA	2	0.271	0.010	0.254	0.056	0.303	0.059	0.334	0.000	0.000	0.000
IE / GAC	2	0.086	0.010	0.078	0.000	0.043	0.000	0.000	0.000	0.000	0.000
PTA / GAC	2	0.558	0.000	0.196	0.000	0.087	0.000	0.000	0.000	0.000	0.000
DSF / CC / IE	3	0.829	0.135	0.646	0.239	0.737	0.824	0.585	0.684	0.000	0.000
DSF / CC / PTA	3	5.248	0.309	1.633	3.046	0.997	5.882	0.418	11.621	0.000	14.706
DSF / CC / GAC	3	1.717	0.212	0.489	0.140	0.173	0.176	0.084	0.684	0.000	0.000
DSF / IE / GAC	3	0.000	0.034	0.000	0.154	0.000	0.118	0.000	0.098	0.000	0.000
DSF / IE / PTA	3	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
DSF / PTA / GAC	3	0.395	0.014	0.049	0.028	0.000	0.118	0.000	0.488	0.000	0.000
DSF / PTA / IE	3	0.000	0.116	0.000	0.056	0.000	0.000	0.000	0.195	0.000	0.000
CC / IE / PTA	3	0.401	0.000	0.381	0.028	0.477	0.000	0.585	0.000	0.000	0.000
CC / IE / GAC	3	0.126	0.000	0.117	0.000	0.087	0.000	0.000	0.000	0.000	0.000
CC / PTA / GAC	3	0.829	0.000	0.284	0.000	0.130	0.000	0.084	0.000	0.000	0.000
IE / PTA / GAC	3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
DSF / CC / IE / PTA	4	0.28	0.02	0.12	0.21	0.09	0.53	0.00	0.68	0.00	0.00
DSF / CC / IE / GAC	4	0.09	0.02	0.03	0.01	0.00	0.00	0.00	0.00	0.00	0.00
DSF / CC / PTA / GAC	4	0.00	0.02	0.00	0.00	0.00	0.06	0.00	0.39	0.00	1.47
Other Combinations[i]		3.20	0.55	4.10	0.22	8.63	0.24	10.95	0.29	11.63	4.41

[a]Estimated percentages were calculated from EPA document, Benefits and Costs of the 1986 Amendments to the SDWA (Wade Miller, 1989).

[b]Actual percentages were obtained from FRDS multiple treatment data search results.

[c]The number of systems using alternative treatments includes those that do not directly affect SDWA treatment requirements, (e.g. fluoride treatment).

[d]Disinfection (DSF) includes treatment process codes C, O, and U. (See Exhibit F1.)

[e]Corrosion (CC) control includes treatment process codes I, H, L. (See Exhibit F1.)

[f]Ion exchange (IE) relates to code E, and includes activated both alumina, and anion and cation exchange.

[g]Aeration (PTA) includes all aeration processes: Cascade, diffused, packed tower, slat spray, and spray aeration.

[h]GAC includes both powdered and granulated activated carbon processes.

[i]This category includes treatment combinations that are not considered feasible and combinations estimated to affect less than one percent of all systems.

Table G2. Estimated Treatment Needs and Actual Treatment Combinations Used by Community Water Systems with a Surface Water Source

Treatment Combination	No. of Treatments	Very Small Estimated[a]	Very Small Actual[b]	Small Estimated	Small Actual	Medium Estimated	Medium Actual	Large Estimated	Large Actual	Very Large Estimated	Very Large Actual
		%									
No Treatment	0	11.615	48.837	12.486	22.040	14.965	13.074	15.107	11.972	22.318	3.614
Alt. Treatment[c]	1	1.988	1.194	0.502	2.388	0.000	2.078	0.000	2.412	0.000	1.205
Filtration (FILT)[d]	1	24.907	23.759	25.585	22.736	23.702	20.087	23.605	17.227	16.738	24.096
Corrosion Control (CC)e	1	20.186	0.880	19.398	3.831	22.145	5.714	22.403	4.393	33.047	3.614
Ion Exchange (IE)[f]	1	0.000	0.126	0.000	0.199	0.000	0.260	0.000	0.086	0.000	0.000
Aeration (PTA)[g]	1	0.000	0.314	0.000	0.398	0.000	0.346	0.000	0.603	0.000	0.602
Gran. Act. Carbon (GAC	1	0.248	0.126	0.279	0.149	0.433	0.173	0.515	0.345	0.000	0.000
FILT / CC	2	36.894	5.091	38.071	15.025	35.121	20.173	34.936	18.949	24.893	19.277
FILT / IE	2	0.186	0.251	0.056	0.348	0.000	0.260	0.000	0.000	0.000	0.000
FILT/ PTA	2	0.000	0.629	0.000	1.393	0.000	1.212	0.000	2.153	0.000	3.012
FILT/ GAC	2	0.497	0.691	0.613	1.741	0.779	3.117	0.687	3.187	0.000	4.819
CC / IE	2	0.124	0.063	0.000	0.050	0.000	0.173	0.000	0.086	0.000	0.000
CC /PTA	2	0.000	0.063	0.000	0.100	0.000	0.260	0.000	0.345	0.000	0.602
CC / GAC	2	0.435	0.063	0.446	0.050	0.692	0.606	0.773	0.947	0.000	0.602
IE / PTA	2	0.000	0.000	0.000	0.149	0.000	0.519	0.000	0.689	0.000	0.000
IE / GAC	2	0.000	0.126	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
PTA / GAC	2	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
FILT / CC / IE	3	0.248	0.000	0.167	0.199	0.000	0.606	0.000	1.981	0.000	1.205
FILT / CC / PTA	3	0.000	0.189	0.000	2.388	0.000	3.636	0.000	3.101	0.000	4.217
FILT / CC / GAC	3	0.870	1.131	0.892	4.478	1.125	7.965	1.116	11.456	0.429	19.880
FILT / IE / GAC	3	0.000	0.063	0.000	0.100	0.000	0.000	0.000	0.172	0.000	0.602
FILT / PTA / GAC	3	0.000	0.063	0.000	0.100	0.000	0.173	0.000	0.258	0.000	0.602
FILT / PTA / IE	3	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.086	0.000	0.000
CC / IE / PTA	3	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.086	0.000	0.000
CC / IE / GAC	3	0.000	0.000	0.000	0.100	0.000	0.000	0.000	0.086	0.000	0.000
CC / PTA / GAC	3	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.086	0.000	0.000
FILT / CC / IE / PTA	4	0.000	0.063	0.000	0.398	0.000	1.039	0.000	1.034	0.000	0.000
FILT / CC / IE / GAC	4	0.000	0.063	0.000	0.249	0.000	0.779	0.000	0.947	0.000	3.012
FILT / CC / PTA / GAC	4	0.000	0.000	0.000	0.299	0.000	0.952	0.000	1.723	0.000	3.012
Other Combinations[i]		1.801	16.216	1.505	21.095	1.038	16.797	0.858	15.590	2.575	6.024

[a]Estimated percentages were calculated from EPA document, Benefits and Costs of the 1986 Amendments to the SDWA (Wade Miller, 1989).

[b]Actual percentages were obtained from FRDS multiplc treatment data search results.

[c]Thc number of systems using alternative treatments includes those that do not directly affect SDWA treatment requirements, (e.g. fluoride treatment).

[d]Filtration includes all filtration processes: Cartridge, greensand, DE, rapid sand, slow sand, ultrafiltration and direct filtration.

[e]Corrosion (CC) control includes treatment process codes I, H, L. (See Exhibit F1.)

[f]Ion exchange (IE) relates to code E, and includes activated both alumina, and anion and cation exchange.

[g]Aeration (PTA) includes all aeration processes: Cascade, diffused, packed tower, slat spray, and spray aeration.

[h]GAC includes both powdered and granulated activated carbon processes.

[i]This category includes treatment combinations that are not considered feasible and combinations estimated to affect less than one percent of all systems.

ATTACHMENT 1

CWS Multiple Objective Combinations by Population Category and Water Source

Very Small Ground Water Systems

Treatment Objectives	Frequency	Percent	Cumulative Frequency	Cumulative Percent
B	4	0.0	4	0.0
BCD	2	0.0	6	0.1
BCR	1	0.0	7	0.1
BD	10	0.1	17	0.2
BDEFIMOPRST	1	0.0	18	0.2
BDEIOPRST	1	0.0	19	0.2
BDEORT	1	0.0	20	0.2
BDI	1	0.0	21	0.2
BDIMOPRST	1	0.0	22	0.2
BDIOPRS	1	0.0	23	0.2
BDIPRS	1	0.0	24	0.2
BDOT	1	0.0	25	0.2
BEIORST	1	0.0	26	0.3
BIRS	1	0.0	27	0.3
C	47	0.5	74	0.7
CD	495	4.8	569	5.5
CDEI	1	0.0	570	5.5
CDF	51	0.5	621	6.0
CDFI	2	0.0	623	6.0
CDFIMPT	1	0.0	624	6.0
CDFM	30	0.3	654	6.3
CDFMP	2	0.0	656	6.4
CDFMR	1	0.0	657	6.4
CDFMS	1	0.0	658	6.4
CDFO	2	0.0	660	6.4
CDFOP	1	0.0	661	6.4
CDFP	7	0.1	668	6.5
CDFPS	1	0.0	669	6.5
CDFS	5	0.0	674	6.5
CDFT	1	0.0	675	6.5
CDI	9	0.1	684	6.6
CDIPT	1	0.0	685	6.6
CDIST	3	0.0	688	6.7
CDM	4	0.0	692	6.7
CDMS	1	0.0	693	6.7
CDO	19	0.2	712	6.9
CDOP	1	0.0	713	6.9
CDOT	3	0.0	716	6.9
CDP	6	0.1	722	7.0
CDPS	3	0.0	725	7.0
CDPST	4	0.0	729	7.1
CDPT	1	0.0	730	7.1
CDR	3	0.0	733	7.1
CDS	14	0.1	747	7.2
CDST	5	0.0	752	7.3
CDT	5	0.0	757	7.3
CF	6	0.1	763	7.4
CFM	1	0.0	764	7.4
CFMS	1	0.0	765	7.4
CFR	1	0.0	766	7.4
CM	1	0.0	767	7.4
CO	1	0.0	768	7.4
CPS	1	0.0	769	7.4
CS	3	0.0	772	7.5
D	7506	72.7	8278	80.2
DEF	1	0.0	8279	80.2

Very Small Ground Water Systems (continued)

Treatment Objectives	Frequency	Percent	Cumulative Frequency	Cumulative Percent
DEFMT	1	0.0	8280	80.2
DEIS	1	0.0	8281	80.2
DET	1	0.0	8282	80.2
DF	380	3.7	8662	83.9
DFI	4	0.0	8666	83.9
DFIM	4	0.0	8670	84.0
DFIMST	1	0.0	8671	84.0
DFIP	1	0.0	8672	84.0
DFIPR	1	0.0	8673	84.0
DFIRS	1	0.0	8674	84.0
DFIS	1	0.0	8675	84.0
DFM	189	1.8	8864	85.8
DFMO	1	0.0	8865	85.9
DFMOT	2	0.0	8867	85.9
DFMP	6	0.1	8873	85.9
DFMPS	2	0.0	8875	86.0
DFMPT	1	0.0	8876	86.0
DFMS	6	0.1	8882	86.0
DFMT	4	0.0	8886	86.1
DFO	4	0.0	8890	86.1
DFOP	3	0.0	8893	86.1
DFOST	1	0.0	8894	86.1
DFOT	1	0.0	8895	86.2
DFP	33	0.3	8928	86.5
DFPR	4	0.0	8932	86.5
DFPS	6	0.1	8938	86.6
DFPST	3	0.0	8941	86.6
DFPT	14	0.1	8955	86.7
DFRS	1	0.0	8956	86.7
DFS	56	0.5	9012	87.3
DFST	3	0.0	9015	87.3
DFT	20	0.2	9035	87.5
DI	25	0.2	9060	87.7
DIM	10	0.1	9070	87.8
DIO	1	0.0	9071	87.9
DIORST	2	0.0	9073	87.9
DIP	3	0.0	9076	87.9
DIPS	4	0.0	9080	87.9
DIPT	2	0.0	9082	88.0
DIRS	2	0.0	9084	88.0
DIS	5	0.0	9089	88.0
DIST	1	0.0	9090	88.0
DM	64	0.6	9154	88.7
DMPS	1	0.0	9155	88.7
DMT	1	0.0	9156	88.7
DO	16	0.2	9172	88.8
DOP	3	0.0	9175	88.9
DOS	1	0.0	9176	88.9
DOST	1	0.0	9177	88.9
DOT	49	0.5	9226	89.4
DP	109	1.1	9335	90.4
DPR	1	0.0	9336	90.4
DPS	14	0.1	9350	90.6
DPST	4	0.0	9354	90.6
DPT	10	0.1	9364	90.7
DR	2	0.0	9366	90.7
DRS	2	0.0	9368	90.7
DS	224	2.2	9592	92.9
DST	15	0.1	9607	93.0
DT	239	2.3	9846	95.4
E	1	0.0	9847	95.4

Very Small Ground Water Systems (continued)

Treatment Objectives	Frequency	Percent	Cumulative Frequency	Cumulative Percent
EFM	2	0.0	9849	95.4
F	130	1.3	9979	96.6
FI	1	0.0	9980	96.7
FIM	2	0.0	9982	96.7
FM	21	0.2	10003	96.9
FMO	1	0.0	10004	96.9
FMP	1	0.0	10005	96.9
FMPST	1	0.0	10006	96.9
FMR	1	0.0	10007	96.9
FMS	1	0.0	10008	96.9
FMT	1	0.0	10009	96.9
FOP	2	0.0	10011	97.0
FOST	1	0.0	10012	97.0
FP	9	0.1	10021	97.1
FPS	2	0.0	10023	97.1
FR	1	0.0	10024	97.1
FS	9	0.1	10033	97.2
FT	1	0.0	10034	97.2
I	15	0.1	10049	97.3
IP	1	0.0	10050	97.3
IRS	5	0.0	10055	97.4
IS	1	0.0	10056	97.4
IST	1	0.0	10057	97.4
M	19	0.2	10076	97.6
O	6	0.1	10082	97.6
OPST	1	0.0	10083	97.7
P	81	0.8	10164	98.4
PS	3	0.0	10167	98.5
PT	1	0.0	10168	98.5
R	7	0.1	10175	98.5
RT	1	0.0	10176	98.6
S	116	1.1	10292	99.7
ST	1	0.0	10293	99.7
T	32	0.3	10325	100.0

Very Small Surface Water Systems

Treatment Objectives	Frequency	Percent	Cumulative Frequency	Cumulative Percent
BCDFIMOP	1	0.1	1	0.1
BCDIOPRS	1	0.1	2	0.3
BCOP	1	0.1	3	0.4
BDEFIMOS	1	0.1	4	0.5
BDFIOP	1	0.1	5	0.6
BDFIOPST	1	0.1	6	0.8
BDFIPT	1	0.1	7	0.9
BDFPT	1	0.1	8	1.0
BDIOPRS	3	0.4	11	1.4
BDOPT	1	0.1	12	1.5
BDP	2	0.3	14	1.8
C	1	0.1	15	1.9
CD	8	1.0	23	2.9
CDF	1	0.1	24	3.0
CDFIOPT	1	0.1	25	3.1
CDFMP	2	0.3	27	3.4
CDFOPT	2	0.3	29	3.6
CDFP	2	0.3	31	3.9
CDFPR	2	0.3	33	4.1
CDFPST	1	0.1	34	4.3

Very Small Surface Water Systems (continued)

Treatment Objectives	Frequency	Percent	Cumulative Frequency	Cumulative Percent
CDIOPT	1	0.1	35	4.4
CDIP	2	0.3	37	4.6
CDOP	2	0.3	39	4.9
CDOPT	4	0.5	43	5.4
CDP	26	3.3	69	8.6
CDPS	12	1.5	81	10.1
CDPST	1	0.1	82	10.3
CDPT	8	1.0	90	11.3
CDS	2	0.3	92	11.5
CMP	1	0.1	93	11.6
CP	1	0.1	94	11.8
CPR	1	0.1	95	11.9
CPS	5	0.6	100	12.5
CRT	1	0.1	101	12.6
CS	1	0.1	102	12.8
D	237	29.7	339	42.4
DEI	1	0.1	340	42.6
DEPST	1	0.1	341	42.7
DF	6	0.8	347	43.4
DFIMOPS	1	0.1	348	43.6
DFM	2	0.3	350	43.8
DFOPT	2	0.3	352	44.1
DFP	3	0.4	355	44.4
DFPR	4	0.5	359	44.9
DFPS	2	0.3	361	45.2
DFPT	1	0.1	362	45.3
DFS	1	0.1	363	45.4
DFT	1	0.1	364	45.6
DI	2	0.3	366	45.8
DIO	1	0.1	367	45.9
DIOPT	2	0.3	369	46.2
DIP	2	0.3	371	46.4
DIPT	1	0.1	372	46.6
DIS	1	0.1	373	46.7
DOP	10	1.3	383	47.9
DOPT	3	0.4	386	48.3
DOT	5	0.6	391	48.9
DP	262	32.8	653	81.7
DPR	3	0.4	656	82.1
DPS	23	2.9	679	85.0
DPST	2	0.3	681	85.2
DPT	10	1.3	691	86.5
DS	2	0.3	693	86.7
DT	7	0.9	700	87.6
F	4	0.5	704	88.1
P	93	11.6	797	99.7
S	1	0.1	798	99.9
T	1	0.1	799	100.0

Small Ground Water Systems

Treatment Objectives	Frequency	Percent	Cumulative Frequency	Cumulative Percent
BCD	3	0.1	3	0.1
BCFPST	1	0.0	4	0.1
BD	1	0.0	5	0.1
BDF	1	0.0	6	0.1
BDFMST	1	0.0	7	0.1
BDIOPRST	1	0.0	8	0.2

Small Ground Water Systems (continued)

Treatment Objectives	Frequency	Percent	Cumulative Frequency	Cumulative Percent
BDIPRS	2	0.0	10	0.2
C	25	0.5	35	0.7
CD	343	6.7	378	7.3
CDF	102	2.0	480	9.3
CDFIOS	1	0.0	481	9.3
CDFIP	1	0.0	482	9.3
CDFIPS	1	0.0	483	9.4
CDFM	26	0.5	509	9.9
CDFMOP	2	0.0	511	9.9
CDFMOT	1	0.0	512	9.9
CDFMPT	2	0.0	514	10.0
CDFMS	1	0.0	515	10.0
CDFMT	1	0.0	516	10.0
CDFO	27	0.5	543	10.5
CDFOP	2	0.0	545	10.6
CDFP	17	0.3	562	10.9
CDFPS	8	0.2	570	11.1
CDFPST	2	0.0	572	11.1
CDFPT	7	0.1	579	11.2
CDFR	1	0.0	580	11.2
CDFRST	1	0.0	581	11.3
CDFS	11	0.2	592	11.5
CDFST	1	0.0	593	11.5
CDFT	5	0.1	598	11.6
CDI	7	0.1	605	11.7
CDIPST	1	0.0	606	11.8
CDIPT	2	0.0	608	11.8
CDIS	1	0.0	609	11.8
CDIST	3	0.1	612	11.9
CDIT	2	0.0	614	11.9
CDM	2	0.0	616	11.9
CDMO	1	0.0	617	12.0
CDMS	1	0.0	618	12.0
CDO	72	1.4	690	13.4
CDOPT	1	0.0	691	13.4
CDOT	1	0.0	692	13.4
CDP	6	0.1	698	13.5
CDPRST	1	0.0	699	13.6
CDPS	7	0.1	706	13.7
CDPST	10	0.2	716	13.9
CDPT	1	0.0	717	13.9
CDRT	2	0.0	719	13.9
CDS	14	0.3	733	14.2
CDST	5	0.1	738	14.3
CDT	13	0.3	751	14.6
CF	3	0.1	754	14.6
CFIPS	1	0.0	755	14.6
CFM	3	0.1	758	14.7
CFMP	1	0.0	759	14.7
CFMPST	1	0.0	760	14.7
CFS	1	0.0	761	14.8
CIM	1	0.0	762	14.8
CM	1	0.0	763	14.8
CS	3	0.1	766	14.9
D	3114	60.4	3880	75.2
DEFP	1	0.0	3881	75.3
DF	375	7.3	4256	82.5
DFI	5	0.1	4261	82.6
DFIMO	1	0.0	4262	82.6
DFIMP	2	0.0	4264	82.7
DFIMS	1	0.0	4265	82.7

Small Ground Water Systems (continued)

Treatment Objectives	Frequency	Percent	Cumulative Frequency	Cumulative Percent
DFIO	1	0.0	4266	82.7
DFIP	1	0.0	4267	82.7
DFIPS	1	0.0	4268	82.8
DFIPST	1	0.0	4269	82.8
DFIS	4	0.1	4273	82.9
DFIST	1	0.0	4274	82.9
DFM	90	1.7	4364	84.6
DFMOP	1	0.0	4365	84.6
DFMP	5	0.1	4370	84.7
DFMS	5	0.1	4375	84.8
DFMST	1	0.0	4376	84.9
DFMT	2	0.0	4378	84.9
DFO	6	0.1	4384	85.0
DFOP	2	0.0	4386	85.0
DFOT	1	0.0	4387	85.1
DFP	39	0.8	4426	85.8
DFPS	13	0.3	4439	86.1
DFPST	4	0.1	4443	86.2
DFPT	11	0.2	4454	86.4
DFRST	2	0.0	4456	86.4
DFRT	1	0.0	4457	86.4
DFS	110	2.1	4567	88.6
DFST	10	0.2	4577	88.8
DFT	24	0.5	4601	89.2
DI	3	0.1	4604	89.3
DIM	1	0.0	4605	89.3
DIP	5	0.1	4610	89.4
DIPS	1	0.0	4611	89.4
DIPT	2	0.0	4613	89.5
DIS	1	0.0	4614	89.5
DIT	3	0.1	4617	89.5
DM	15	0.3	4632	89.8
DMO	1	0.0	4633	89.8
DMOT	1	0.0	4634	89.9
DMP	2	0.0	4636	89.9
DMS	1	0.0	4637	89.9
DMT	2	0.0	4639	90.0
DO	16	0.3	4655	90.3
DOP	3	0.1	4658	90.3
DOPS	1	0.0	4659	90.3
DOS	2	0.0	4661	90.4
DOST	1	0.0	4662	90.4
DOT	11	0.2	4673	90.6
DP	35	0.7	4708	91.3
DPS	8	0.2	4716	91.4
DPST	13	0.3	4729	91.7
DPT	15	0.3	4744	92.0
DR	1	0.0	4745	92.0
DS	48	0.9	4793	92.9
DST	14	0.3	4807	93.2
DT	189	3.7	4996	96.9
F	65	1.3	5061	98.1
FM	8	0.2	5069	98.3
FMP	1	0.0	5070	98.3
FOP	2	0.0	5072	98.4
FP	3	0.1	5075	98.4
FPS	1	0.0	5076	98.4
FS	7	0.1	5083	98.6
FT	2	0.0	5085	98.6
M	9	0.2	5094	98.8
MT	2	0.0	5096	98.8

Small Ground Water Systems (continued)

Treatment Objectives	Frequency	Percent	Cumulative Frequency	Cumulative Percent
O	1	0.0	5097	98.8
OPT	1	0.0	5098	98.9
P	6	0.1	5104	99.0
PST	1	0.0	5105	99.0
S	44	0.9	5149	99.8
T	8	0.2	5157	100.0

Small Surface Water Systems

Treatment Objectives	Frequency	Percent	Cumulative Frequency	Cumulative Percent
BCDFIMO	2	0.1	2	0.1
BCDFIMOP	6	0.4	8	0.5
BCDFIMOPR	3	0.2	11	0.7
BCDFIOP	1	0.1	12	0.8
BCDFP	1	0.1	13	0.9
BCDIMOPT	1	0.1	14	0.9
BCDIOPRS	3	0.2	17	1.1
BCDIOPRST	1	0.1	18	1.2
BCDIOPT	1	0.1	19	1.2
BCDOPT	1	0.1	20	1.3
BCDP	1	0.1	21	1.4
BCDPT	1	0.1	22	1.4
BCFMOPT	1	0.1	23	1.5
BDFIPT	1	0.1	24	1.6
BDFPS	1	0.1	25	1.6
BDFPT	1	0.1	26	1.7
BDFS	1	0.1	27	1.8
BDIOPRS	7	0.5	34	2.2
BDIOPRST	1	0.1	35	2.3
BDIOPST	1	0.1	36	2.4
BDP	7	0.5	43	2.8
BDPS	15	1.0	58	3.8
BDPT	1	0.1	59	3.9
BDS	2	0.1	61	4.0
C	10	0.7	71	4.7
CD	31	2.0	102	6.7
CDFIMOP	1	0.1	103	6.8
CDFIMOPT	3	0.2	106	7.0
CDFIMPST	1	0.1	107	7.0
CDFIOPT	1	0.1	108	7.1
CDFIP	1	0.1	109	7.2
CDFIPT	2	0.1	111	7.3
CDFM	1	0.1	112	7.4
CDFMO	1	0.1	113	7.4
CDFMOP	1	0.1	114	7.5
CDFMP	2	0.1	116	7.6
CDFOP	3	0.2	119	7.8
CDFP	7	0.5	126	8.3
CDFPS	2	0.1	128	8.4
CDFPST	14	0.9	142	9.3
CDFPT	11	0.7	153	10.1
CDIMPT	1	0.1	156	10.3
CDIOPS	1	0.1	157	10.3
CDIOPT	2	0.1	159	10.5
CDOP	4	0.3	163	10.7
CDOPST	2	0.1	165	10.8
CDOPT	7	0.5	172	11.3
CDFST	1	0.1	154	10.1

Small Surface Water Systems (continued)

Treatment Objectives	Frequency	Percent	Cumulative Frequency	Cumulative Percent
CDIM	1	0.1	155	10.2
CDP	130	8.5	302	19.9
CDPR	1	0.1	303	19.9
CDPRT	1	0.1	304	20.0
CDPS	64	4.2	368	24.2
CDPST	10	0.7	378	24.9
CDPT	39	2.6	417	27.4
CDS	5	0.3	422	27.7
CDT	4	0.3	426	28.0
CF	1	0.1	427	28.1
CFPST	1	0.1	428	28.1
CFPT	1	0.1	429	28.2
CP	3	0.2	432	28.4
CPS	4	0.3	436	28.7
CPST	1	0.1	437	28.7
CT	1	0.1	438	28.8
D	402	26.4	840	55.2
DF	9	0.6	849	55.8
DFIMPST	1	0.1	850	55.9
DFIOP	1	0.1	851	56.0
DFIOPT	1	0.1	852	56.0
DFM	5	0.3	857	56.3
DFOP	2	0.1	859	56.5
DFOPT	1	0.1	860	56.5
DFP	12	0.8	872	57.3
DFPS	10	0.7	882	58.0
DFPST	2	0.1	884	58.1
DFPT	26	1.7	910	59.8
DFRS	1	0.1	911	59.9
DFS	2	0.1	913	60.0
DI	1	0.1	914	60.1
DIOP	1	0.1	915	60.2
DIOPS	1	0.1	916	60.2
DIP	5	0.3	921	60.6
DIPS	4	0.3	925	60.8
DIPST	1	0.1	926	60.9
DIPT	3	0.2	929	61.1
DM	1	0.1	930	61.1
DOP	17	1.1	947	62.3
DOPS	2	0.1	949	62.4
DOPST	1	0.1	950	62.5
DOPT	11	0.7	961	63.2
DOT	2	0.1	963	63.3
DP	298	19.6	1261	82.9
DPS	50	3.3	1311	86.2
DPST	7	0.5	1318	86.7
DPT	47	3.1	1365	89.7
DS	9	0.6	1374	90.3
DT	12	0.8	1386	91.1
FOPT	1	0.1	1387	91.2
FP	1	0.1	1388	91.3
IOP	1	0.1	1389	91.3
OP	1	0.1	1390	91.4
P	123	8.1	1513	99.5
S	7	0.5	1520	99.9
T	1	0.1	1521	100.0

Medium Ground Water Systems

Treatment Objectives	Frequency	Percent	Cumulative Frequency	Cumulative Percent
BCD	1	0.1	1	0.1
BCDFIPST	1	0.1	2	0.2
BCDFMS	1	0.1	3	0.2
BCFMOPT	1	0.1	4	0.3
BDFIMOPRST	1	0.1	5	0.4
BDFMST	1	0.1	6	0.5
BDS	1	0.1	7	0.5
C	5	0.4	12	0.9
CD	80	6.1	92	7.0
CDF	39	3.0	131	10.0
CDFI	4	0.3	135	10.3
CDFIM	1	0.1	136	10.4
CDFM	9	0.7	145	11.1
CDFMO	1	0.1	146	11.1
CDFMOP	5	0.4	151	11.5
CDFMOS	1	0.1	152	11.6
CDFMPT	1	0.1	153	11.7
CDFMS	3	0.2	156	11.9
CDFMT	1	0.1	157	12.0
CDFO	6	0.5	163	12.4
CDFOP	1	0.1	164	12.5
CDFP	6	0.5	170	13.0
CDFPRST	1	0.1	171	13.1
CDFPS	4	0.3	175	13.4
CDFPST	3	0.2	178	13.6
CDFPT	2	0.2	180	13.7
CDFS	9	0.7	189	14.4
CDFST	2	0.2	191	14.6
CDFT	4	0.3	195	14.9
CDI	1	0.1	196	15.0
CDIP	1	0.1	197	15.0
CDIPT	1	0.1	198	15.1
CDM	2	0.2	200	15.3
CDO	20	1.5	220	16.8
CDOP	1	0.1	221	16.9
CDOS	1	0.1	222	16.9
CDP	6	0.5	228	17.4
CDPS	7	0.5	235	17.9
CDPST	2	0.2	237	18.1
CDPT	3	0.2	240	18.3
CDS	1	0.1	241	18.4
CDST	1	0.1	242	18.5
CDT	7	0.5	249	19.0
CF	1	0.1	250	19.1
CT	1	0.1	251	19.2
D	676	51.6	927	70.8
DF	108	8.2	1035	79.0
DFI	2	0.2	1037	79.2
DFIM	1	0.1	1038	79.2
DFIMPT	1	0.1	1039	79.3
DFIP	1	0.1	1040	79.4
DFM	7	0.5	1047	79.9
DFMOP	1	0.1	1048	80.0
DFMP	2	0.2	1050	80.2
DFMS	1	0.1	1051	80.2
DFMST	1	0.1	1052	80.3
DFMT	2	0.2	1054	80.5
DFO	2	0.2	1056	80.6
DFP	16	1.2	1072	81.8
DFPS	8	0.6	1080	82.4
DFPST	1	0.1	1081	82.5

Medium Ground Water Systems (continued)

Treatment Objectives	Frequency	Percent	Cumulative Frequency	Cumulative Percent
DFPT	1	0.1	1082	82.6
DFR	1	0.1	1083	82.7
DFS	19	1.5	1102	84.1
DFST	1	0.1	1103	84.2
DFT	11	0.8	1114	85.0
DI	2	0.2	1116	85.2
DIPS	1	0.1	1117	85.3
DIS	1	0.1	1118	85.3
DM	9	0.7	1127	86.0
DO	10	0.8	1137	86.8
DOPST	1	0.1	1138	86.9
DOS	1	0.1	1139	86.9
DOT	4	0.3	1143	87.3
DP	25	1.9	1168	89.2
DPS	7	0.5	1175	89.7
DPST	4	0.3	1179	90.0
DPT	6	0.5	1185	90.5
DR	1	0.1	1186	90.5
DRT	1	0.1	1187	90.6
DS	24	1.8	1211	92.4
DST	7	0.5	1218	93.0
DT	63	4.8	1281	97.8
F	9	0.7	1290	98.5
FM	1	0.1	1291	98.5
FMS	1	0.1	1292	98.6
FS	1	0.1	1293	98.7
M	1	0.1	1294	98.8
P	2	0.2	1296	98.9
S	6	0.5	1302	99.4
T	8	0.6	1310	100.0

Medium Surface Water Systems

Treatment Objectives	Frequency	Percent	Cumulative Frequency	Cumulative Percent
BCDFIMO	1	0.1	1	0.1
BCDFIMOP	9	0.9	10	1.0
BCDFIMOPR	1	0.1	11	1.1
BCDFIMOPRT	1	0.1	12	1.2
BCDFIMOPT	1	0.1	13	1.3
BCDFIOPR	3	0.3	16	1.6
BCDFIOPRST	1	0.1	17	1.7
BCDFIOPT	1	0.1	18	1.8
BCDFPT	6	0.6	24	2.4
BCDFT	1	0.1	25	2.5
BCDIOP	1	0.1	26	2.6
BCDIOPRST	1	0.1	27	2.7
BCDIOPST	1	0.1	28	2.9
BCDP	2	0.2	30	3.1
BCDPT	1	0.1	31	3.2
BCFP	1	0.1	32	3.3
BCFPST	1	0.1	33	3.4
BCIOPRS	3	0.3	36	3.7
BD	1	0.1	37	3.8
BDFIMOPRS	2	0.2	39	4.0
BDFIOP	1	0.1	40	4.1
BDFIOPRS	2	0.2	42	4.3
BDFP	1	0.1	43	4.4
BDFPT	1	0.1	44	4.5

Medium Surface Water Systems (continued)

Treatment Objectives	Frequency	Percent	Cumulative Frequency	Cumulative Percent
BDIOPRS	1	0.1	45	4.6
BDIOPRST	1	0.1	46	4.7
BDOPT	1	0.1	47	4.8
BDPS	4	0.4	51	5.2
BDPST	2	0.2	53	5.4
BDPT	1	0.1	54	5.5
BF	1	0.1	55	5.6
C	4	0.4	59	6.0
CD	30	3.1	89	9.1
CDEPS	1	0.1	90	9.2
CDF	3	0.3	93	9.5
CDFIMOPST	1	0.1	94	9.6
CDFIMOPT	6	0.6	100	10.2
CDFIP	1	0.1	101	10.3
CDFM	2	0.2	103	10.5
CDFMOP	1	0.1	104	10.6
CDFMP	1	0.1	105	10.7
CDFOP	1	0.1	106	10.8
CDFOPT	3	0.3	109	11.1
CDFP	8	0.8	117	11.9
CDFPS	1	0.1	118	12.0
CDFPST	8	0.8	126	12.8
CDFPT	16	1.6	142	14.5
CDFS	1	0.1	143	14.6
CDIOP	2	0.2	145	14.8
CDIOPS	1	0.1	146	14.9
CDIP	1	0.1	147	15.0
CDIPS	1	0.1	148	15.1
CDIPT	1	0.1	149	15.2
CDMOPT	1	0.1	150	15.3
CDMP	2	0.2	152	15.5
CDOP	4	0.4	156	15.9
CDOPT	11	1.1	167	17.0
CDOS	1	0.1	168	17.1
CDP	124	12.6	292	29.7
CDPS	31	3.2	323	32.9
CDPST	12	1.2	335	34.1
CDPT	66	6.7	401	40.8
CDS	2	0.2	403	41.0
CDT	4	0.4	407	41.4
CIMOPT	1	0.1	408	41.5
CPS	2	0.2	410	41.8
CPST	1	0.1	411	41.9
D	187	19.0	598	60.9
DE	1	0.1	599	61.0
DF	2	0.2	601	61.2
DFIMOP	1	0.1	602	61.3
DFIOPT	2	0.2	604	61.5
DFM	1	0.1	605	61.6
DFMP	1	0.1	606	61.7
DFOPT	2	0.2	608	61.9
DFP	6	0.6	614	62.5
DFPS	4	0.4	618	62.9
DFPST	2	0.2	620	63.1
DFPT	10	1.0	630	64.2
DI	1	0.1	631	64.3
DIMOP	1	0.1	632	64.4
DIOPT	1	0.1	633	64.5
DIP	2	0.2	635	64.7
DIPS	1	0.1	636	64.8
DIPT	2	0.2	638	65.0

Medium Surface Water Systems (continued)

Treatment Objectives	Frequency	Percent	Cumulative Frequency	Cumulative Percent
DMP	1	0.1	639	65.1
DMPT	1	0.1	640	65.2
DOP	13	1.3	653	66.5
DOPST	1	0.1	654	66.6
DOPT	8	0.8	662	67.4
DOT	1	0.1	663	67.5
DP	153	15.6	816	83.1
DPS	29	3.0	845	86.0
DPST	5	0.5	850	86.6
DPT	39	4.0	889	90.5
DS	2	0.2	891	90.7
DST	1	0.1	892	90.8
DT	3	0.3	895	91.1
FIMOPT	5	0.5	900	91.6
FIOPS	1	0.1	901	91.8
FIT	1	0.1	902	91.9
FP	1	0.1	903	92.0
FPT	1	0.1	904	92.1
I	1	0.1	905	92.2
IMOPT	1	0.1	906	92.3
IOP	1	0.1	907	92.4
OP	1	0.1	908	92.5
P	64	6.5	972	99.0
PS	2	0.2	974	99.2
PST	1	0.1	975	99.3
PT	5	0.5	980	99.8
S	2	0.2	982	100.0

Large Ground Water Systems

Treatment Objectives	Frequency	Percent	Cumulative Frequency	Cumulative Percent
BCDF	3	0.4	3	0.4
BCDFIOPS	1	0.1	4	0.5
BCDFO	1	0.1	5	0.7
BDIOPT	1	0.1	6	0.8
C	3	0.4	9	1.2
CD	56	7.6	65	8.8
CDF	30	4.1	95	12.9
CDFI	2	0.3	97	13.1
CDFIMP	1	0.1	98	13.3
CDFIP	1	0.1	99	13.4
CDFIPT	1	0.1	100	13.5
CDFMO	4	0.5	104	14.1
CDFMOP	2	0.3	106	14.3
CDFMOPT	1	0.1	107	14.5
CDFMPS	1	0.1	108	14.6
CDFMS	1	0.1	109	14.7
CDFMT	1	0.1	110	14.9
CDFO	8	1.1	118	16.0
CDFOP	1	0.1	119	16.1
CDFOPS	1	0.1	120	16.2
CDFOPT	1	0.1	121	16.4
CDFOT	1	0.1	122	16.5
CDFP	10	1.4	132	17.9
CDFPS	4	0.5	136	18.4
CDFPST	4	0.5	140	18.9
CDFPT	3	0.4	143	19.4
CDFS	5	0.7	148	20.0

Large Ground Water Systems (continued)

Treatment Objectives	Frequency	Percent	Cumulative Frequency	Cumulative Percent
CDFST	1	0.1	149	20.2
CDFT	4	0.5	153	20.7
CDIO	1	0.1	154	20.8
CDIP	1	0.1	155	21.0
CDIPST	5	0.7	160	21.7
CDIT	1	0.1	161	21.8
CDO	9	1.2	170	23.0
CDOP	1	0.1	171	23.1
CDOPRS	1	0.1	172	23.3
CDOPT	4	0.5	176	23.8
CDOS	1	0.1	177	24.0
CDOST	1	0.1	178	24.1
CDOT	1	0.1	179	24.2
CDP	1	0.1	180	24.4
CDPS	8	1.1	188	25.4
CDPST	6	0.8	194	26.3
CDPT	3	0.4	197	26.7
CDR	1	0.1	198	26.8
CDS	3	0.4	201	27.2
CDST	3	0.4	204	27.6
CDT	15	2.0	219	29.6
CIPST	1	0.1	220	29.8
CP	1	0.1	221	29.9
CT	1	0.1	222	30.0
D	273	36.9	495	67.0
DEFP	1	0.1	496	67.1
DF	40	5.4	536	72.5
DFIS	1	0.1	537	72.7
DFM	3	0.4	540	73.1
DFMP	1	0.1	541	73.2
DFMPS	1	0.1	542	73.3
DFMPT	2	0.3	544	73.6
DFMS	1	0.1	545	73.7
DFMT	1	0.1	546	73.9
DFO	1	0.1	547	74.0
DFP	4	0.5	551	74.6
DFPS	4	0.5	555	75.1
DFPST	1	0.1	556	75.2
DFPT	3	0.4	559	75.6
DFS	17	2.3	576	77.9
DFST	1	0.1	577	78.1
DFT	6	0.8	583	78.9
DI	1	0.1	584	79.0
DIM	1	0.1	585	79.2
DIOS	1	0.1	586	79.3
DIPT	2	0.3	588	79.6
DIT	1	0.1	589	79.7
DM	3	0.4	592	80.1
DMT	1	0.1	593	80.2
DO	18	2.4	611	82.7
DOPS	1	0.1	612	82.8
DOPST	2	0.3	614	83.1
DOPT	1	0.1	615	83.2
DOS	1	0.1	616	83.4
DOST	1	0.1	617	83.5
DOT	2	0.3	619	83.8
DP	11	1.5	630	85.3
DPS	15	2.0	645	87.3
DPST	10	1.4	655	88.6
DPT	1	0.1	656	88.8
DRT	1	0.1	657	88.9

Large Ground Water Systems (continued)

Treatment Objectives	Frequency	Percent	Cumulative Frequency	Cumulative Percent
DS	16	2.2	673	91.1
DST	1	0.1	674	91.2
DT	55	7.4	729	98.6
F	3	0.4	732	99.1
FMP	1	0.1	733	99.2
IMT	1	0.1	734	99.3
O	1	0.1	735	99.5
P	2	0.3	737	99.7
S	1	0.1	738	99.9
T	1	0.1	739	100.0

Large Surface Water Systems

Treatment Objectives	Frequency	Percent	Cumulative Frequency	Cumulative Percent
B	3	0.3	3	0.3
BCDEFIOPT	1	0.1	4	0.4
BCDEOPT	1	0.1	5	0.5
BCDEP	1	0.1	6	0.6
BCDFIM	1	0.1	7	0.7
BCDFIMO	5	0.5	12	1.2
BCDFIMOP	15	1.5	27	2.7
BCDFIMOPR	2	0.2	29	2.9
BCDFIMOPRST	1	0.1	30	3.0
BCDFIMOPST	1	0.1	31	3.1
BCDFIMOPT	1	0.1	32	3.2
BCDFIMPT	1	0.1	33	3.3
BCDFOP	1	0.1	34	3.4
BCDFOPT	1	0.1	35	3.5
BCDFP	2	0.2	37	3.7
BCDFPS	2	0.2	39	3.9
BCDFPT	3	0.3	42	4.2
BCDIMOPT	1	0.1	43	4.3
BCDIOP	1	0.1	44	4.4
BCDIOPRS	1	0.1	45	4.5
BCDIOPRST	2	0.2	47	4.7
BCDOP	1	0.1	48	4.8
BCDOPST	1	0.1	49	4.9
BCDOPT	2	0.2	51	5.1
BCDP	8	0.8	59	5.9
BCDPS	2	0.2	61	6.1
BCDPST	2	0.2	63	6.3
BCDPT	12	1.2	75	7.5
BCFPST	6	0.6	81	8.1
BD	2	0.2	83	8.3
BDFPS	1	0.1	84	8.4
BDFPT	2	0.2	86	8.6
BDOPS	1	0.1	87	8.7
BDOPT	2	0.2	89	8.9
BDOST	1	0.1	90	9.0
BDP	3	0.3	93	9.3
BDPS	5	0.5	98	9.8
BDPST	2	0.2	100	10.0
BDPT	16	1.6	116	11.6
BDS	2	0.2	118	11.8
BDT	2	0.2	120	12.0
BP	1	0.1	121	12.1
C	2	0.2	123	12.3
CD	20	2.0	143	14.3

Large Surface Water Systems (continued)

Treatment Objectives	Frequency	Percent	Cumulative Frequency	Cumulative Percent
CDF	2	0.2	145	14.5
CDFI	1	0.1	146	14.6
CDFIM	1	0.1	147	14.7
CDFIMOP	1	0.1	148	14.8
CDFIMOPR	1	0.1	149	14.9
CDFIMOPT	2	0.2	151	15.1
CDFIMS	1	0.1	152	15.2
CDFIOP	1	0.1	153	15.3
CDFIOPRT	1	0.1	154	15.4
CDFIOPT	1	0.1	155	15.5
CDFIP	1	0.1	156	15.6
CDFIPT	1	0.1	157	15.7
CDFMOP	3	0.3	160	16.0
CDFMOPT	2	0.2	162	16.2
CDFMP	7	0.7	169	17.0
CDFMPT	1	0.1	170	17.1
CDFOP	3	0.3	173	17.4
CDFOPS	1	0.1	174	17.5
CDFOPT	3	0.3	177	17.8
CDFP	12	1.2	189	19.0
CDFPS	2	0.2	191	19.2
CDFPST	18	1.8	209	21.0
CDFPT	20	2.0	229	23.0
CDIOPST	1	0.1	230	23.1
CDIP	2	0.2	232	23.3
CDIPRS	1	0.1	233	23.4
CDIPS	1	0.1	234	23.5
CDIPT	2	0.2	236	23.7
CDIT	1	0.1	237	23.8
CDM	2	0.2	239	24.0
CDMP	3	0.3	242	24.3
CDMPT	2	0.2	244	24.5
CDMT	1	0.1	245	24.6
CDO	1	0.1	246	24.7
CDOP	10	1.0	256	25.7
CDOPS	2	0.2	258	25.9
CDOPT	13	1.3	271	27.2
CDOT	2	0.2	273	27.4
CDP	110	11.0	383	38.4
CDPS	24	2.4	407	40.8
CDPST	17	1.7	424	42.5
CDPT	79	7.9	503	50.5
CDT	1	0.1	504	50.6
CFMT	1	0.1	505	50.7
CP	1	0.1	506	50.8
CPT	1	0.1	507	50.9
CT	1	0.1	508	51.0
D	167	16.8	675	67.7
DEPT	1	0.1	676	67.8
DF	6	0.6	682	68.4
DFI	1	0.1	683	68.5
DFIMOPST	1	0.1	684	68.6
DFIMPT	1	0.1	685	68.7
DFIOP	1	0.1	686	68.8
DFIPS	1	0.1	687	68.9
DFIPT	1	0.1	688	69.0
DFM	1	0.1	689	69.1
DFMP	1	0.1	690	69.2
DFOS	2	0.2	694	69.6
DFP	6	0.6	700	70.2

Large Surface Water Systems (continued)

Treatment Objectives	Frequency	Percent	Cumulative Frequency	Cumulative Percent
DFPS	2	0.2	702	70.4
DFPST	1	0.1	703	70.5
DFPT	9	0.9	712	71.4
DFS	2	0.2	714	71.6
DFT	1	0.1	715	71.7
DM	1	0.1	716	71.8
DO	3	0.3	719	72.1
DOP	3	0.3	722	72.4
DOPST	2	0.2	724	72.6
DOPT	4	0.4	728	73.0
DOT	1	0.1	729	73.1
DP	99	9.9	828	83.0
DPS	21	2.1	849	85.2
DPST	7	0.7	856	85.9
DPT	44	4.4	900	90.3
DS	4	0.4	904	90.7
DT	2	0.2	906	90.9
F	1	0.1	907	91.0
FOPT	1	0.1	908	91.1
MT	1	0.1	909	91.2
O	1	0.1	910	91.3
P	85	8.5	995	99.8
PT	1	0.1	996	99.9
T	1	0.1	997	100.0

Very Large Ground Water Systems

Treatment Objectives	Frequency	Percent	Cumulative Frequency	Cumulative Percent
CDF	3	7.1	3	7.1
CDFP	1	2.4	4	9.5
CDFPS	1	2.4	5	11.9
CDFPT	1	2.4	6	14.3
CDFS	1	2.4	7	16.7
CDOPS	1	2.4	8	19.0
CDOPT	1	2.4	9	21.4
CDOT	1	2.4	10	23.8
CDPS	3	7.1	13	31.0
CDPT	1	2.4	14	33.3
CDS	1	2.4	15	35.7
CDT	4	9.5	19	45.2
D	12	28.6	31	73.8
DO	2	4.8	33	78.6
DPS	1	2.4	34	81.0
DPST	2	4.8	36	85.7
DS	1	2.4	37	88.1
DT	2	4.8	39	92.9
P	3	7.1	42	100.0

Very Large Surface Water Systems

Treatment Objectives	Frequency	Percent	Cumulative Frequency	Cumulative Percent
BCDEFMOPT	1	0.6	1	0.6
BCDFIMO	2	1.3	3	1.9
BCDFIMOPRT	1	0.6	4	2.5
BCDFIMOPST	1	0.6	5	3.2

Very Large Surface Water Systems (continued)

Treatment Objectives	Frequency	Percent	Cumulative Frequency	Cumulative Percent
BCDFIOPST	1	0.6	6	3.8
BCDFP	1	0.6	7	4.4
BCDOPT	1	0.6	8	5.1
BCDPST	2	1.3	10	6.3
BCDPT	3	1.9	13	8.2
BCFPST	1	0.6	14	8.9
BD	1	0.6	15	9.5
BDFOPT	1	0.6	16	10.1
BDPS	1	0.6	17	10.8
BDPT	4	2.5	21	13.3
CD	2	1.3	23	14.6
CDEP	1	0.6	24	15.2
CDFIMOPST	1	0.6	25	15.8
CDFIOPT	1	0.6	26	16.5
CDFIPT	2	1.3	28	17.7
CDFMOPST	1	0.6	29	18.4
CDFOPT	2	1.3	31	19.6
CDFPS	1	0.6	32	20.3
CDFPST	3	1.9	35	22.2
CDFPT	2	1.3	37	23.4
CDIOPT	1	0.6	38	24.1
CDO	1	0.6	39	24.7
CDOP	2	1.3	41	25.9
CDOPT	6	3.8	47	29.7
CDP	22	13.9	69	43.7
CDPRST	1	0.6	70	44.3
CDPS	1	0.6	71	44.9
CDPST	3	1.9	74	46.8
CDPT	15	9.5	89	56.3
CDS	1	0.6	90	57.0
CDT	1	0.6	91	57.6
D	7	4.4	98	62.0
DF	1	0.6	99	62.7
DFO	1	0.6	100	63.3
DFP	1	0.6	101	63.9
DIPS	2	1.3	103	65.2
DOP	2	1.3	105	66.5
DOPT	2	1.3	107	67.7
DP	16	10.1	123	77.8
DPS	4	2.5	127	80.4
DPST	1	0.6	128	81.0
DPT	11	7.0	139	88.0
DT	1	0.6	140	88.6
P	18	11.4	158	100.0

ATTACHMENT 2

CWS Multiple Treatment Combinations by Population Category and Water Source

Very Small Ground Water Systems

Treatment Combination	Frequency	Percent	Cumulative Frequency	Cumulative Percent
A	17	0.2	17	0.2
AC	233	2.3	250	2.4
ACE	5	0.0	255	2.5
ACEF	7	0.1	262	2.6
ACEFIP	2	0.0	264	2.6
ACEH	3	0.0	267	2.6
ACEN	1	0.0	268	2.6
ACEP	24	0.2	292	2.8
ACF	56	0.5	348	3.4
ACFH	13	0.1	361	3.5
ACFHI	1	0.0	362	3.5
ACFHINOP	5	0.0	367	3.6
ACFHR	1	0.0	368	3.6
ACFI	4	0.0	372	3.6
ACFL	5	0.0	377	3.7
ACFNPR	1	0.0	378	3.7
ACFP	1	0.0	379	3.7
ACFR	2	0.0	381	3.7
ACH	24	0.2	405	4.0
ACHR	12	0.1	417	4.1
ACI	2	0.0	419	4.1
ACIP	1	0.0	420	4.1
ACL	1	0.0	421	4.1
ACN	1	0.0	422	4.1
ACP	1	0.0	423	4.1
AE	2	0.0	425	4.1
AEFN	1	0.0	426	4.2
AF	13	0.1	439	4.3
AFHP	9	0.1	448	4.4
AFI	1	0.0	449	4.4
AFP	57	0.6	506	4.9
AP	46	0.4	552	5.4
C	7984	77.9	8536	83.3
CE	246	2.4	8782	85.7
CEF	36	0.4	8818	86.0
CEFH	4	0.0	8822	86.1
CEFHILNP	2	0.0	8824	86.1
CEFHL	1	0.0	8825	86.1
CEFHLP	1	0.0	8826	86.1
CEFI	1	0.0	8827	86.1
CEFO	1	0.0	8828	86.1
CEFP	1	0.0	8829	86.1
CEFR	4	0.0	8833	86.2
CEH	10	0.1	8843	86.3
CEHP	1	0.0	8844	86.3
CEI	9	0.1	8853	86.4
CEINU	1	0.0	8854	86.4
CELN	1	0.0	8855	86.4
CEN	2	0.0	8857	86.4
CENP	2	0.0	8859	86.4
CER	1	0.0	8860	86.4
CEU	2	0.0	8862	86.5
CF	267	2.6	9129	89.1
CFH	30	0.3	9159	89.3

Very Small Ground Water Systems (continued)

Treatment Combination	Frequency	Percent	Cumulative Frequency	Cumulative Percent
CFHI	3	0.0	9162	89.4
CFHL	1	0.0	9163	89.4
CFHLO	1	0.0	9164	89.4
CFHN	2	0.0	9166	89.4
CFHNO	40	0.4	9206	89.8
CFHP	5	0.0	9211	89.9
CFI	5	0.0	9216	89.9
CFIL	1	0.0	9217	89.9
CFL	11	0.1	9228	90.0
CFLNR	1	0.0	9229	90.0
CFN	5	0.0	9234	90.1
CFNR	1	0.0	9235	90.1
CFO	4	0.0	9239	90.1
CFP	12	0.1	9251	90.2
CFR	1	0.0	9252	90.3
CFU	3	0.0	9255	90.3
CH	374	3.6	9629	93.9
CHI	26	0.3	9655	94.2
CHIL	1	0.0	9656	94.2
CHL	2	0.0	9658	94.2
CHN	1	0.0	9659	94.2
CHP	1	0.0	9660	94.2
CHR	1	0.0	9661	94.2
CI	142	1.4	9803	95.6
CIL	1	0.0	9804	95.6
CL	19	0.2	9823	95.8
CLP	1	0.0	9824	95.8
CN	19	0.2	9843	96.0
CP	1	0.0	9844	96.0
CR	8	0.1	9852	96.1
CU	3	0.0	9855	96.1
E	110	1.1	9965	97.2
ECAP	3	0.0	9968	97.2
EF	8	0.1	9976	97.3
EFP	10	0.1	9986	97.4
EH	2	0.0	9988	97.4
EHU	1	0.0	9989	97.4
EI	2	0.0	9991	97.5
EN	2	0.0	9993	97.5
EP	8	0.1	10001	97.6
ER	2	0.0	10003	97.6
EU	2	0.0	10005	97.6
F	108	1.1	10113	98.7
FH	3	0.0	10116	98.7
FHL	1	0.0	10117	98.7
FHP	1	0.0	10118	98.7
FL	3	0.0	10121	98.7
FN	1	0.0	10122	98.7
FP	1	0.0	10123	98.8
FU	2	0.0	10125	98.8
H	41	0.4	10166	99.2
HN	1	0.0	10167	99.2
HP	9	0.1	10176	99.3
I	10	0.1	10186	99.4
L	25	0.2	10211	99.6
N	9	0.1	10220	99.7
NP	2	0.0	10222	99.7
O	5	0.0	10227	99.8
OU	1	0.0	10228	99.8
R	5	0.0	10233	99.8
U	18	0.2	10251	100.0

Very Small Surface Water Systems

Treatment Combination	Frequency	Percent	Cumulative Frequency	Cumulative Percent
AC	3	0.4	3	0.4
ACEFIP	1	0.1	4	0.5
ACF	2	0.3	6	0.8
ACFLP	1	0.1	7	0.9
ACFN	1	0.1	8	1.0
ACH	1	0.1	9	1.1
AFHP	2	0.3	11	1.4
AFP	8	1.0	19	2.4
AP	2	0.3	21	2.6
C	251	31.6	272	34.2
CE	2	0.3	274	34.5
CEF	3	0.4	277	34.8
CEFLNP	1	0.1	278	35.0
CEHP	1	0.1	279	35.1
CENO	1	0.1	280	35.2
CF	278	35.0	558	70.2
CFH	41	5.2	599	75.3
CFHI	1	0.1	600	75.5
CFHIN	2	0.3	602	75.7
CFHIR	1	0.1	603	75.8
CFHL	5	0.6	608	76.5
CFHN	9	1.1	617	77.6
CFHNO	1	0.1	618	77.7
CFHNP	1	0.1	619	77.9
CFHO	1	0.1	620	78.0
CFI	5	0.6	625	78.6
CFIL	1	0.1	626	78.7
CFIN	1	0.1	627	78.9
CFL	14	1.8	641	80.6
CFLN	1	0.1	642	80.8
CFN	10	1.3	652	82.0
CFNO	1	0.1	653	82.1
CFO	1	0.1	654	82.3
CFR	1	0.1	655	82.4
CFU	1	0.1	656	82.5
CH	7	0.9	663	83.4
CHLN	1	0.1	664	83.5
CI	4	0.5	668	84.0
CL	1	0.1	669	84.2
CU	1	0.1	670	84.3
EFNORU	1	0.1	671	84.4
EFRU	1	0.1	672	84.5
ENOR	1	0.1	673	84.7
F	94	11.8	767	96.5
FH	5	0.6	772	97.1
FHL	3	0.4	775	97.5
FHLP	1	0.1	776	97.6
FHNP	3	0.4	779	98.0
FI	2	0.3	781	98.2
FIU	1	0.1	782	98.4
FU	3	0.4	785	98.7
H	1	0.1	786	98.9
L	1	0.1	787	99.0
N	1	0.1	788	99.1
NOR	1	0.1	789	99.2
O	2	0.3	791	99.5
RU	2	0.3	793	99.7
U	2	0.3	795	100.0

Small Ground Water Systems

Treatment Combination	Frequency	Percent	Cumulative Frequency	Cumulative Percent
A	4	0.1	4	0.1
AC	227	4.4	231	4.5
ACE	8	0.2	239	4.7
ACEF	21	0.4	260	5.1
ACEFH	3	0.1	263	5.1
ACEFHL	1	0.0	264	5.2
ACEFHP	1	0.0	265	5.2
ACEFI	5	0.1	270	5.3
ACEFIP	2	0.0	272	5.3
ACEFL	1	0.0	273	5.3
ACEH	1	0.0	274	5.4
ACEHI	1	0.0	275	5.4
ACEN	1	0.0	276	5.4
ACEP	4	0.1	280	5.5
ACF	122	2.4	402	7.9
ACFH	53	1.0	455	8.9
ACFHI	2	0.0	457	8.9
ACFHIL	1	0.0	458	8.9
ACFHL	9	0.2	467	9.1
ACFHP	1	0.0	468	9.1
ACFHR	3	0.1	471	9.2
ACFI	12	0.2	483	9.4
ACFIL	1	0.0	484	9.5
ACFL	19	0.4	503	9.8
ACFLR	1	0.0	504	9.8
ACFR	3	0.1	507	9.9
ACH	81	1.6	588	11.5
ACHI	2	0.0	590	11.5
ACHLR	1	0.0	591	11.5
ACHN	1	0.0	592	11.6
ACHR	11	0.2	603	11.8
ACI	11	0.2	614	12.0
ACIL	2	0.0	616	12.0
ACL	6	0.1	622	12.2
ACN	1	0.0	623	12.2
AEF	4	0.1	627	12.3
AEFI	1	0.0	628	12.3
AEFL	1	0.0	629	12.3
AF	28	0.5	657	12.8
AFH	1	0.0	658	12.9
AFHP	24	0.5	682	13.3
AFP	47	0.9	729	14.2
AL	1	0.0	730	14.3
AP	15	0.3	745	14.6
C	3394	66.3	4139	80.9
CE	23	0.4	4162	81.3
CEF	43	0.8	4205	82.2
CEFHP	1	0.0	4206	82.2
CEFI	1	0.0	4207	82.2
CEFL	2	0.0	4209	82.2
CEFO	1	0.0	4210	82.3
CEFP	3	0.1	4213	82.3
CEH	8	0.2	4221	82.5
CEHIN	1	0.0	4222	82.5
CEI	5	0.1	4227	82.6
CEP	1	0.0	4228	82.6
CF	165	3.2	4393	85.8
CFH	47	0.9	4440	86.8
CFHI	1	0.0	4441	86.8
CFHIL	3	0.1	4444	86.8

Small Ground Water Systems (continued)

Treatment Combination	Frequency	Percent	Cumulative Frequency	Cumulative Percent
CFHIP	1	0.0	4445	86.9
CFHL	8	0.2	4453	87.0
CFHLN	1	0.0	4454	87.0
CFHLP	1	0.0	4455	87.0
CFHNO	6	0.1	4461	87.2
CFHP	17	0.3	4478	87.5
CFHR	1	0.0	4479	87.5
CFI	11	0.2	4490	87.7
CFIL	4	0.1	4494	87.8
CFIP	3	0.1	4497	87.9
CFL	42	0.8	4539	88.7
CFLN	1	0.0	4540	88.7
CFN	3	0.1	4543	88.8
CFP	18	0.4	4561	89.1
CFR	3	0.1	4564	89.2
CH	215	4.2	4779	93.4
CHI	24	0.5	4803	93.8
CHL	3	0.1	4806	93.9
CHN	1	0.0	4807	93.9
CHR	1	0.0	4808	93.9
CI	132	2.6	4940	96.5
CIL	1	0.0	4941	96.5
CIN	1	0.0	4942	96.6
CIP	1	0.0	4943	96.6
CL	43	0.8	4986	97.4
CLP	2	0.0	4988	97.5
CN	3	0.1	4991	97.5
CNP	1	0.0	4992	97.5
CO	1	0.0	4993	97.6
CP	1	0.0	4994	97.6
CR	5	0.1	4999	97.7
E	3	0.1	5002	97.7
ECAP	11	0.2	5013	97.9
EFP	5	0.1	5018	98.0
EI	1	0.0	5019	98.1
EP	3	0.1	5022	98.1
F	12	0.2	5034	98.4
FH	2	0.0	5036	98.4
FHI	1	0.0	5037	98.4
FL	2	0.0	5039	98.5
FP	1	0.0	5040	98.5
H	13	0.3	5053	98.7
HL	1	0.0	5054	98.7
HP	1	0.0	5055	98.8
I	17	0.3	5072	99.1
IL	1	0.0	5073	99.1
L	39	0.8	5112	99.9
LP	1	0.0	5113	99.9
O	2	0.0	5115	99.9
R	3	0.1	5118	100.0

Small Surface Water Systems

Treatment Combination	Frequency	Percent	Cumulative Frequency	Cumulative Percent
AC	7	0.5	7	0.5
ACEFIP	7	0.5	14	0.9
ACEFLP	1	0.1	15	1.0
ACF	12	0.8	27	1.8

Small Surface Water Systems (continued)

Treatment Combination	Frequency	Percent	Cumulative Frequency	Cumulative Percent
ACFH	9	0.6	36	2.4
ACFHI	1	0.1	37	2.4
ACFHL	4	0.3	41	2.7
ACFHN	3	0.2	44	2.9
ACFHNP	2	0.1	46	3.0
ACFI	1	0.1	47	3.1
ACFILNP	2	0.1	49	3.2
ACFIN	1	0.1	50	3.3
ACFL	2	0.1	52	3.4
ACFN	2	0.1	54	3.6
ACH	1	0.1	55	3.6
ACI	1	0.1	56	3.7
AFHP	29	1.9	85	5.6
AFP	16	1.1	101	6.6
AP	1	0.1	102	6.7
C	423	27.8	525	34.6
CE	4	0.3	529	34.8
CEF	7	0.5	536	35.3
CEFH	1	0.1	537	35.4
CEFHN	1	0.1	538	35.4
CEFINP	1	0.1	539	35.5
CEFL	1	0.1	540	35.5
CEFLNP	4	0.3	544	35.8
CEFLP	1	0.1	545	35.9
CEFN	2	0.1	547	36.0
CEI	1	0.1	548	36.1
CELN	2	0.1	550	36.2
CF	332	21.9	882	58.1
CFH	152	10.0	1034	68.1
CFHI	18	1.2	1052	69.3
CFHILP	1	0.1	1053	69.3
CFHIN	5	0.3	1058	69.7
CFHL	27	1.8	1085	71.4
CFHLN	9	0.6	1094	72.0
CFHLP	1	0.1	1095	72.1
CFHN	36	2.4	1131	74.5
CFHNP	1	0.1	1132	74.5
CFHP	2	0.1	1134	74.7
CFI	40	2.6	1174	77.3
CFIL	10	0.7	1184	77.9
CFILN	2	0.1	1186	78.1
CFIN	6	0.4	1192	78.5
CFL	39	2.6	1231	81.0
CFLN	20	1.3	1251	82.4
CFN	29	1.9	1280	84.3
CFNP	1	0.1	1281	84.3
CFU	1	0.1	1282	84.4
CH	20	1.3	1302	85.7
CHI	5	0.3	1307	86.0
CHL	5	0.3	1312	86.4
CHLP	2	0.1	1314	86.5
CHNP	1	0.1	1315	86.6
CI	11	0.7	1326	87.3
CIL	1	0.1	1327	87.4
CL	9	0.6	1336	88.0
CLP	4	0.3	1340	88.2
CN	3	0.2	1343	88.4
CO	1	0.1	1344	88.5
ECAP	3	0.2	1347	88.7
F	124	8.2	1471	96.8
FH	4	0.3	1475	97.1

Small Surface Water Systems (continued)

Treatment Combination	Frequency	Percent	Cumulative Frequency	Cumulative Percent
FHL	2	0.1	1477	97.2
FHLP	4	0.3	1481	97.5
FHNP	11	0.7	1492	98.2
FL	2	0.1	1494	98.4
FNP	5	0.3	1499	98.7
H	11	0.7	1510	99.4
HI	2	0.1	1512	99.5
HP	1	0.1	1513	99.6
I	1	0.1	1514	99.7
L	5	0.3	1519	100.0

Medium Ground Water Systems

Treatment Combination	Frequency	Percent	Cumulative Frequency	Cumulative Percent
A	2	0.2	2	0.2
AC	83	6.4	85	6.5
ACE	5	0.4	90	6.9
ACEF	2	0.2	92	7.0
ACEFH	2	0.2	94	7.2
ACEFI	2	0.2	96	7.4
ACEFIP	1	0.1	97	7.4
ACEFIPR	1	0.1	98	7.5
ACEFLP	1	0.1	99	7.6
ACEI	2	0.2	101	7.7
ACF	46	3.5	147	11.3
ACFH	26	2.0	173	13.2
ACFHIL	1	0.1	174	13.3
ACFHL	3	0.2	177	13.6
ACFHLR	1	0.1	178	13.6
ACFHN	1	0.1	179	13.7
ACFHP	3	0.2	182	13.9
ACFHR	1	0.1	183	14.0
ACFI	14	1.1	197	15.1
ACFL	11	0.8	208	15.9
ACFR	1	0.1	209	16.0
ACH	28	2.1	237	18.1
ACHI	4	0.3	241	18.5
ACHL	1	0.1	242	18.5
ACI	3	0.2	245	18.8
ACL	4	0.3	249	19.1
ACN	2	0.2	251	19.2
AEF	1	0.1	252	19.3
AF	2	0.2	254	19.4
AFHP	4	0.3	258	19.8
AFI	1	0.1	259	19.8
AFP	8	0.6	267	20.4
AP	2	0.2	269	20.6
C	752	57.6	1021	78.2
CE	12	0.9	1033	79.1
CEF	6	0.5	1039	79.6
CEFH	3	0.2	1042	79.8
CEFHL	1	0.1	1043	79.9
CEFHP	2	0.2	1045	80.0
CEFI	1	0.1	1046	80.1
CEFIP	3	0.2	1049	80.3
CEFP	2	0.2	1051	80.5
CEH	3	0.2	1054	80.7
CEHP	1	0.1	1055	80.8

Medium Ground Water Systems (continued)

Treatment Combination	Frequency	Percent	Cumulative Frequency	Cumulative Percent
CF	48	3.7	1103	84.5
CFH	17	1.3	1120	85.8
CFHI	4	0.3	1124	86.1
CFHIL	2	0.2	1126	86.2
CFHIP	2	0.2	1128	86.4
CFHL	6	0.5	1134	86.8
CFHNO	1	0.1	1135	86.9
CFHP	4	0.3	1139	87.2
CFI	2	0.2	1141	87.4
CFIP	1	0.1	1142	87.4
CFL	13	1.0	1155	88.4
CFLN	1	0.1	1156	88.5
CFLP	1	0.1	1157	88.6
CFN	1	0.1	1158	88.7
CFO	2	0.2	1160	88.8
CFP	7	0.5	1167	89.4
CFR	1	0.1	1168	89.4
CH	45	3.4	1213	92.9
CHI	8	0.6	1221	93.5
CHIL	1	0.1	1222	93.6
CHN	1	0.1	1223	93.6
CI	43	3.3	1266	96.9
CIL	2	0.2	1268	97.1
CL	18	1.4	1286	98.5
CP	1	0.1	1287	98.5
ECAP	2	0.2	1289	98.7
F	4	0.3	1293	99.0
FHNP	1	0.1	1294	99.1
H	3	0.2	1297	99.3
HI	2	0.2	1299	99.5
I	1	0.1	1300	99.5
L	5	0.4	1305	99.9
LP	1	0.1	1306	100.0

Medium Surface Water Systems

Treatment Combination	Frequency	Percent	Cumulative Frequency	Cumulative Percent
AC	4	0.4	4	0.4
ACE	1	0.1	5	0.5
ACEFH	1	0.1	6	0.6
ACEFHINP	2	0.2	8	0.8
ACEFIP	10	1.0	18	1.8
ACEFLP	1	0.1	19	1.9
ACEP	1	0.1	20	2.0
ACF	7	0.7	27	2.8
ACFH	11	1.1	38	3.9
ACFHI	2	0.2	40	4.1
ACFHIL	1	0.1	41	4.2
ACFHIP	1	0.1	42	4.3
ACFHL	1	0.1	43	4.4
ACFHLN	3	0.3	46	4.7
ACFHP	1	0.1	54	5.5
ACFI	1	0.1	55	5.6
ACFIN	3	0.3	58	5.9
ACFL	1	0.1	59	6.0
ACFN	2	0.2	61	6.2
ACHI	3	0.3	64	6.5
AFHP	21	2.1	85	8.7

Medium Surface Water Systems (continued)

Treatment Combination	Frequency	Percent	Cumulative Frequency	Cumulative Percent
ACFHLP	2	0.2	48	4.9
ACFHN	4	0.4	52	5.3
ACFHNP	1	0.1	53	5.4
AFP	7	0.7	92	9.4
C	194	19.8	286	29.2
CE	2	0.2	288	29.4
CEF	3	0.3	291	29.7
CEFH	1	0.1	292	29.8
CEFHL	3	0.3	295	30.1
CEFHLN	2	0.2	297	30.3
CEFILN	1	0.1	298	30.4
CEFINP	2	0.2	300	30.6
CEFL	1	0.1	301	30.7
CEFLNP	4	0.4	305	31.1
CEH	1	0.1	306	31.2
CEHP	1	0.1	307	31.3
CF	168	17.1	475	48.5
CFH	128	13.1	603	61.5
CFHI	25	2.6	628	64.1
CFHIL	2	0.2	630	64.3
CFHIN	13	1.3	643	65.6
CFHL	14	1.4	657	67.0
CFHLN	6	0.6	663	67.7
CFHN	35	3.6	698	71.2
CFHNP	1	0.1	699	71.3
CFHP	2	0.2	701	71.5
CFHR	1	0.1	702	71.6
CFI	33	3.4	735	75.0
CFIL	3	0.3	738	75.3
CFILN	1	0.1	739	75.4
CFIN	9	0.9	748	76.3
CFINP	1	0.1	749	76.4
CFL	17	1.7	766	78.2
CFLN	8	0.8	774	79.0
CFN	31	3.2	805	82.1
CFO	1	0.1	806	82.2
CH	23	2.3	829	84.6
CHI	6	0.6	835	85.2
CHL	4	0.4	839	85.6
CHN	1	0.1	840	85.7
CHNP	1	0.1	841	85.8
CI	9	0.9	850	86.7
CIL	2	0.2	852	86.9
CILP	1	0.1	853	87.0
CIN	1	0.1	854	87.1
CINP	1	0.1	855	87.2
CL	9	0.9	864	88.2
CLP	2	0.2	866	88.4
CN	2	0.2	868	88.6
E	1	0.1	869	88.7
ECAP	4	0.4	873	89.1
F	63	6.4	936	95.5
FH	4	0.4	940	95.9
FHL	1	0.1	941	96.0
FHN	1	0.1	942	96.1
FHNP	17	1.7	959	97.9
FI	2	0.2	961	98.1
FL	1	0.1	962	98.2
FNP	5	0.5	967	98.7
H	6	0.6	973	99.3
HN	3	0.3	976	99.6

Medium Surface Water Systems (continued)

Treatment Combination	Frequency	Percent	Cumulative Frequency	Cumulative Percent
HP	2	0.2	978	99.8
I	1	0.1	979	99.9
L	1	0.1	980	100.0

Large Ground Water Systems

Treatment Combination	Frequency	Percent	Cumulative Frequency	Cumulative Percent
A	1	0.1	1	0.1
AC	76	10.3	77	10.4
ACE	2	0.3	79	10.7
ACEF	2	0.3	81	11.0
ACEFH	1	0.1	82	11.1
ACEFIP	3	0.4	85	11.5
ACEFL	1	0.1	86	11.7
ACEH	2	0.3	88	11.9
ACEP	1	0.1	89	12.1
ACER	1	0.1	90	12.2
ACF	19	2.6	109	14.8
ACFH	29	3.9	138	18.7
ACFHI	6	0.8	144	19.5
ACFHIN	1	0.1	145	19.6
ACFHL	4	0.5	149	20.2
ACFHLR	4	0.5	153	20.7
ACFHP	1	0.1	154	20.9
ACFHR	1	0.1	155	21.0
ACFI	9	1.2	164	22.2
ACFIL	1	0.1	165	22.4
ACFILN	1	0.1	166	22.5
ACFIN	1	0.1	167	22.6
ACFIP	1	0.1	168	22.8
ACFL	21	2.8	189	25.6
ACFN	1	0.1	190	25.7
ACH	25	3.4	215	29.1
ACHI	2	0.3	217	29.4
ACHL	1	0.1	218	29.5
ACHN	1	0.1	219	29.7
ACHR	4	0.5	223	30.2
ACI	5	0.7	228	30.9
ACIL	1	0.1	229	31.0
ACIN	1	0.1	230	31.2
ACL	3	0.4	233	31.6
ACN	4	0.5	237	32.1
AF	1	0.1	238	32.2
AFHLR	1	0.1	239	32.4
AFHP	2	0.3	241	32.7
AFP	8	1.1	249	33.7
AH	1	0.1	250	33.9
AP	1	0.1	251	34.0
C	300	40.7	551	74.7
CE	5	0.7	556	75.3
CEF	3	0.4	559	75.7
CEFH	2	0.3	561	76.0
CEFHI	1	0.1	562	76.2
CEFI	2	0.3	564	76.4
CEFIR	1	0.1	565	76.6
CEHI	1	0.1	566	76.7
CF	17	2.3	583	79.0
CFH	11	1.5	594	80.5

Large Ground Water Systems (continued)

Treatment Combination	Frequency	Percent	Cumulative Frequency	Cumulative Percent
CFHI	3	0.4	597	80.9
CFHIL	2	0.3	599	81.2
CFHIO	1	0.1	600	81.3
CFHIP	2	0.3	602	81.6
CFHL	4	0.5	606	82.1
CFHN	4	0.5	610	82.7
CFHP	3	0.4	613	83.1
CFI	1	0.1	614	83.2
CFILNP	1	0.1	615	83.3
CFL	19	2.6	634	85.9
CFLN	2	0.3	636	86.2
CFN	1	0.1	637	86.3
CFO	1	0.1	638	86.4
CFP	2	0.3	640	86.7
CH	33	4.5	673	91.2
CHI	4	0.5	677	91.7
CHL	1	0.1	678	91.9
CI	21	2.8	699	94.7
CIL	3	0.4	702	95.1
CL	18	2.4	720	97.6
CLO	1	0.1	721	97.7
CLR	2	0.3	723	98.0
CN	2	0.3	725	98.2
CP	1	0.1	726	98.4
CR	1	0.1	727	98.5
ECAP	1	0.1	728	98.6
F	2	0.3	730	98.9
FH	1	0.1	731	99.1
FHNP	1	0.1	732	99.2
H	1	0.1	733	99.3
HI	1	0.1	734	99.5
HP	1	0.1	735	99.6
I	1	0.1	736	99.7
L	1	0.1	737	99.9
R	1	0.1	738	100.0

Large Surface Water Systems

Treatment Combination	Frequency	Percent	Cumulative Frequency	Cumulative Percent
AC	6	0.6	6	0.6
ACE	1	0.1	7	0.7
ACEFH	1	0.1	8	0.8
ACEFIP	11	1.1	19	1.9
ACEFN	1	0.1	20	2.0
ACEFP	1	0.1	21	2.1
ACEH	1	0.1	22	2.2
ACF	19	1.9	41	4.1
ACFH	12	1.2	53	5.3
ACFHI	1	0.1	54	5.4
ACFHILN	1	0.1	55	5.5
ACFHIN	3	0.3	58	5.8
ACFHIO	1	0.1	59	5.9
ACFHL	1	0.1	60	6.0
ACFHLNP	3	0.3	63	6.3
ACFHN	9	0.9	72	7.2
ACFHOP	1	0.1	73	7.3
ACFHP	1	0.1	74	7.4
ACFI	2	0.2	76	7.6

Large Surface Water Systems (continued)

Treatment Combination	Frequency	Percent	Cumulative Frequency	Cumulative Percent
ACFILNP	1	0.1	77	7.7
ACFIN	2	0.2	79	7.9
ACFL	1	0.1	80	8.0
ACFLN	2	0.2	82	8.2
ACFLO	1	0.1	83	8.4
ACFN	2	0.2	85	8.6
ACH	2	0.2	87	8.8
ACHI	2	0.2	89	9.0
ACHN	1	0.1	90	9.1
AFHP	14	1.4	104	10.5
AFP	6	0.6	110	11.1
AI	1	0.1	111	11.2
AP	1	0.1	112	11.3
C	178	17.9	290	29.2
CE	1	0.1	291	29.3
CEFH	1	0.1	292	29.4
CEFHLP	1	0.1	293	29.5
CEFHN	2	0.2	295	29.7
CEFHNP	1	0.1	296	29.8
CEFINP	21	2.1	317	31.9
CEFLNP	8	0.8	325	32.7
CEFN	2	0.2	327	32.9
CEHI	1	0.1	328	33.0
CELN	1	0.1	329	33.1
CF	114	11.5	443	44.6
CFH	113	11.4	556	55.9
CFHI	38	3.8	594	59.8
CFHIL	3	0.3	597	60.1
CFHILN	3	0.3	600	60.4
CFHIN	25	2.5	625	62.9
CFHIP	1	0.1	626	63.0
CFHL	11	1.1	637	64.1
CFHLN	3	0.3	640	64.4
CFHLP	1	0.1	641	64.5
CFHLR	1	0.1	642	64.6
CFHN	45	4.5	687	69.1
CFHNP	1	0.1	688	69.2
CFHO	3	0.3	691	69.5
CFHP	4	0.4	695	69.9
CFHR	1	0.1	696	70.0
CFI	23	2.3	719	72.3
CFIL	4	0.4	723	72.7
CFILN	5	0.5	728	73.2
CFILNP	1	0.1	729	73.3
CFILP	3	0.3	732	73.6
CFIN	17	1.7	749	75.4
CFIP	1	0.1	750	75.5
CFL	6	0.6	756	76.1
CFLN	10	1.0	766	77.1
CFLNP	1	0.1	767	77.2
CFN	29	2.9	796	80.1
CFO	1	0.1	797	80.2
CH	13	1.3	810	81.5
CHI	4	0.4	814	81.9
CHL	2	0.2	816	82.1
CHN	1	0.1	817	82.2
CI	9	0.9	826	83.1
CIL	1	0.1	827	83.2
CILN	1	0.1	828	83.3
CIN	3	0.3	831	83.6
CINP	3	0.3	834	83.9

Large Surface Water Systems (continued)

Treatment Combination	Frequency	Percent	Cumulative Frequency	Cumulative Percent
CL	17	1.7	851	85.6
CLN	2	0.2	853	85.8
CLP	1	0.1	854	85.9
CN	1	0.1	855	86.0
ECAP	6	0.6	861	86.6
F	84	8.5	945	95.1
FH	1	0.1	946	95.2
FHLP	6	0.6	952	95.8
FHNP	22	2.2	974	98.0
FNP	8	0.8	982	98.8
FO	1	0.1	983	98.9
H	3	0.3	986	99.2
HN	1	0.1	987	99.3
I	1	0.1	988	99.4
N	2	0.2	990	99.6
NP	1	0.1	991	99.7
O	1	0.1	992	99.8
OP	1	0.1	993	99.9
P	1	0.1	994	100.0

Very Large Ground Water Systems

Treatment Combination	Frequency	Percent	Cumulative Frequency	Cumulative Percent
AC	4	9.5	4	9.5
ACFH	1	2.4	5	11.9
ACFHI	1	2.4	6	14.3
ACFHL	1	2.4	7	16.7
ACFHN	1	2.4	8	19.0
ACFI	1	2.4	9	21.4
ACFL	2	4.8	11	26.2
ACH	3	7.1	14	33.3
ACHN	1	2.4	15	35.7
C	12	28.6	27	64.3
CFH	2	4.8	29	69.0
CFHI	1	2.4	30	71.4
CFHL	1	2.4	31	73.8
CFL	4	9.5	35	83.3
CH	1	2.4	36	85.7
CIL	1	2.4	37	88.1
CL	1	2.4	38	90.5
CN	1	2.4	39	92.9
F	3	7.1	42	100.0

Very Large Surface Water Systems

Treatment Combination	Frequency	Percent	Cumulative Frequency	Cumulative Percent
AC	1	0.6	1	0.6
ACF	4	2.5	5	3.2
ACFH	5	3.2	10	6.3
ACFHI	1	0.6	11	7.0
ACFHIN	2	1.3	13	8.2
ACFHINP	1	0.6	14	8.9
ACFHN	1	0.6	15	9.5
ACFLN	1	0.6	16	10.1
ACFN	1	0.6	17	10.8

Very Large Surface Water Systems (continued)

Treatment Combination	Frequency	Percent	Cumulative Frequency	Cumulative Percent
ACFO	1	0.6	18	11.4
ACHI	1	0.6	19	12.0
AFHP	1	0.6	20	12.7
C	10	6.3	30	19.0
CEFHIN	1	0.6	31	19.6
CEFINP	2	1.3	33	20.9
CEFLN	1	0.6	34	21.5
CEFLNP	3	1.9	37	23.4
CF	21	13.3	58	36.7
CFH	20	12.7	78	49.4
CFHI	5	3.2	83	52.5
CFHILNP	1	0.6	84	53.2
CFHIN	4	2.5	88	55.7
CFHINP	2	1.3	90	57.0
CFHLN	2	1.3	92	58.2
CFHLNP	1	0.6	93	58.9
CFHN	11	7.0	104	65.8
CFHP	1	0.6	105	66.5
CFI	1	0.6	106	67.1
CFILN	1	0.6	107	67.7
CFIN	4	2.5	111	70.3
CFL	3	1.9	114	72.2
CFN	7	4.4	121	76.6
CFO	1	0.6	122	77.2
CH	3	1.9	125	79.1
CIL	1	0.6	126	79.7
CIN	1	0.6	127	80.4
CL	2	1.3	129	81.6
EFNO	1	0.6	130	82.3
F	18	11.4	148	93.7
FHLP	1	0.6	149	94.3
FHNP	7	4.4	156	98.7
FILP	1	0.6	157	99.4
FNP	1	0.6	158	100.0

OTHER A.R.M.E. RESEARCH BULLETINS

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