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Rural Utilities Service's Water and Waste Disposal Loan and Grant Program and its Contribution to Small Public Water System Improvements in New York State

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ABSTRACT*

Throughout the debate over re-authorization of the Safe Drinking Water Act (SDWA), it has been clear that members of both Houses of Congress are keenly aware of the financial burden facing the owners of small water systems in their efforts to comply with the 1986 and future amendments to the SDWA. The most reliable source of funds for drinking water and wastewater improvements for small systems has been the Water and Waste Disposal Loan and Grant Program administered through the Rural Utilities Service (RUS) of the USDA's Rural Development mission area. This report provides some background of the RUS loan and grant program. Specific attention is directed towards New York's Rural Development efforts where we develop small system cost models related to treatment and distribution improvements.

Over the past 50 years, RUS has been the primary source of low-cost financing to rural water and waste disposal systems, providing over 35,000 loan and grant funding packages totaling nearly $18 billion. Despite the recent increases in obligations in nominal terms, the real purchasing power of these funds has yet to rebound to pre-1980 levels. Due to EPA's efforts to enforce the 1986 and later amendments to the SDWA, combined with the aging of water system infrastructure, the demand for these funds consistently outweighs available obligation levels.

Data from nearly 150 small water system improvement projects in New York State receiving RUS funding are evaluated to determine the extent of improvements related to SDWA regulations. Operating revenues and expenses are relatively similar across the state; however residual funds for future capital improvements after reducing net incomes by principle and interest payments are nonexistent. While public water systems should not accumulate large surplus funds, the small residuals remaining are surely insufficient to support any major capital improvements in the future.

The costs of treatment varied widely by treatment technology and system size. An indirect cost function was specified regressing annualized treatment and operating costs on system population, water source, and treatment variables. While the economies are substantial for very small systems, for some technologies, they are nearly exhausted at service populations of around 3,300. An indirect cost function for distribution and transmission improvements was specified. These models are useful in comparing the tradeoff between economies of size of treatment to the associated diseconomies of distribution and transmission.

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INTRODUCTION

Throughout the debate over re-authorization of the Safe Drinking Water Act (SDWA), it has been clear that members of both Houses of Congress are keenly aware of the financial burden facing the owners of small water systems in their efforts to comply with the 1986 Amendments to the Act. These problems potentially affect a substantial majority of the 57,000 community water systems nationwide. An estimated 93% of them serve fewer than 10,000 people, a size below which many systems are unable to take advantage of economies of size in production and management and have insufficient resources to finance increased monitoring and treatment at a reasonable cost to customers (Boisvert and Schmit, 1996 and EPA, 1993b). The financial concerns can only increase as governments at all levels attempt to shrink their budgets and curtail the growth in state and federal aid.

According to the Environmental Protection Agency (EPA), the small and medium-sized public systems in the most trouble are those: a) whose budgets are commingled with other local government activities, b) with an inability to implement full cost pricing, c) that lack professional management, and d) that are in need of infrastructure repair. These problems are compounded by a limited set of financing options. The bond market is particularly thin for this group of local governments. Many must purchase insurance in order to sell their general obligation bonds, and the use of revenue bonds as the primary source of funding has increased in recent years.

As of 1993, 29 states have established state loan programs, bond pools, and revolving loan funds to increase access to financing for small publicly owned water systems. According to a recent study on alternative funding mechanisms for drinking water programs conducted by the National Conference of State Legislatures (NCLS), 14 states are operating revolving funds (SRF's) generating over $240 million in funding for drinking water projects this year, with another 11 states authorized to operate such programs, but awaiting federal capitalization grants (AWWA, 1995). However, states and federal authorities need to develop these revolving funds so that funds are accessible to small communities.[1] In prior efforts for the reauthorization of the SDWA, Congress proposed setting aside 15% of the amount credited to any revolving fund solely for systems that regularly serve fewer than 10,000 people. The funds were also to be available to private systems having the greatest public health or financial need. Even so, lobbyists and drinking water personnel continued to experience difficulties in their efforts to push for reauthorization of the SDWA.

Finally, after more than five years of reauthorization efforts, President Clinton signed the SDWA amendments of 1996 (PL-104-182) into law on August 6, 1996. In addition to provisions giving regulators more flexibility with regards to small system variances and assistance and requiring annual reports to water utility customers on existing contaminant levels and potential health effects, the law provides for a federally funded state revolving loan fund.

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[1] For example, the SRF's under Title VI of the Clean Water Act (CWA) to assist in financing wastewater projects have been in place for several years, but there is growing evidence that small communities are experiencing problems gaining access to funds. The affordability of many SFR loans is increasingly in question even at low interest rates (EFAB, 1991).

The fund provides $9.6 billion in grant and loan funding, capitalized over the years 1994 to 2003, for local water system facility improvements (AWWA, 1996). In addition, 15% of the capitalization grant funds must be made available for systems serving less than 10,000 people and individual states may use up to 30% of their fund allocation for special assistance to small disadvantaged systems.

These additional sources of financing are essential if small and medium-sized systems are to have access to the resources needed to comply with the 1986 Amendments to the SDWA.[2] Without them, the existing sources of financing already available--including funds from EPA, HUD's Small Cities Community Development Block Grants (CDBG), EDA's Administration Grants, the Farm Credit System's CoBank Rural Utility Small Loan Program, and the Rural Utility Service's (RUS) Water and Waste Disposal Loan and Grant Program--will come under increasing pressure.

While all these programs provide significant funding to small and rural communities, most resources are directed toward projects other than public drinking water and wastewater system improvements.[3] Without doubt, the most accessible and reliable source of funds for drinking water and wastewater improvements for communities of under 10,000 people has been the Water and Waste Disposal Loan and Grant Program administered through the Rural Utilities Service (RUS) of the USDA's Rural Development mission area.[4] In one form or another, this program has been in operation since the 1940s, and although loan and grant applications always exceed its resources, Rural Development has made available between $500 million and $1 billion (in 1992 dollars) annually for water and wastewater projects since the mid-1980s. Furthermore, since 1989, the funds obligated have risen each year, from about $500 million to $1.1 billion by

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[2] According to a recent EPA study, compliance with the SDWA standards for the 84 contaminants initially regulated is expected to cost public water systems about $1.4 billion per year, not including monitoring and reporting costs (EPA, 1993b). Furthermore, EFAB reported that small communities alone (those with under 2,500 people) would need $5.5 billion in capital spending during the 1990s, of which 40% would be directly related to SDWA compliance. An additional $4.5 billion would be needed for improvements to wastewater treatment and solid waste management facilities. (EFAB, 1991).

[3] Throughout the 1980s, for example, EPA provided annual construction grants for wastewater treatment facilities of varying amounts, ranging from nearly $4 billion in 1981 to about $1 billion in 1990 (EFAB, 1991). Since 1990, no appropriations have been made, but the SRF capitalization grants of $2 billion in 1991 have absorbed some of the slack. HUD's block grant programs for small cities has provided between $700 and $900 million annually since 1984 to benefit low income communities, but only a small proportion of the funds have been used for water and wastewater projects. Similarly, only a fraction of the $100 to $220 million annually in grants through EDA's Public Works and Development Facilities Program go for water and wastewater projects. The Appalachian Regional Commission's (ARC) supplemental grants have provided between $18 and $35 million annually since 1981 in support of other federal programs for community development, and CoBank, a federally chartered and regulated bank and part of the Farm Credit System, serves rural utilities and agricultural cooperatives. The latter's authority was expanded under the 1990 Farm Bill to help finance water and wastewater improvements in communities with populations under 20,000; loans can range from $50,000 to $500,000.

[4] USDA's Rural Development mission area (formerly Rural Economic & Community Development RECD) and Farmer's Home Administration (FmHA) prior to RECD encompasses three agencies that aid rural America: Rural Utilities Service (RUS), Rural Business-Cooperative Service, and Rural Housing Service.

1994. In that year, nearly $700 million was specifically for improvements to drinking water facilities.

The purpose of this report is to gain a better understanding of Rural Development's contribution to financing small public water systems and the extent to which these funds are used for system repair, extension, or the installation of new treatment facilities. The overall contribution of Rural Development's activity to financing small public water systems can be assessed through an examination of trends in loan and grant activity over the past 25 years. It is much more difficult to obtain detailed data on the nature of the individual loan and grant requests. For this reason, an analysis of the kinds of water system extensions, repairs, and new treatments being financed by Rural Development is based on an examination of loan files from the state of New York. This represents a good start toward understanding the role of Rural Development mission area in financing small water system improvements. In addition, we have been able to use the detailed information to gain a better understanding of the costs of distribution extensions and of water treatment processes. A statistical analysis of these individual cost components provides estimates of the per unit costs of extending service, as well as the economies of size in various water treatment technologies. This information is important for understanding the actual costs of compliance with the 1986 Amendments to the SDWA, as well as for understanding the implications for system consolidation.

The report continues with some background of the RUS loan and grant program, along with a description of the national and regional trends in program funding. This is followed by a discussion of procedures for collecting data from New York's Rural Development regional offices. The data are summarized as a convenient point of departure for the statistical analysis. Once the results of the analysis are presented, some general conclusions and policy implications are articulated.

SOME BACKGROUND ON THE RUS GRANT AND LOAN PROGRAMS

For more than half a century, the FmHA, and now the Rural Development mission area, has been the credit agency for agriculture and rural development of the U.S. Department of Agriculture (USDA). One of the agency's primary concerns is with credit and counseling services that have supplemented private resources for building stronger family farms, and as late as the mid-1980s, farm credit still accounted for almost half the resources administered by FmHA. Since its inception, FmHA also administrated other non-farm programs to benefit families and communities in rural areas. These programs have been expanded dramatically for the past three decades and have helped to provide safe housing, modern water and sewer systems, essential community services, and jobs and other economic development in rural areas.

One of the agency's oldest non-farm programs for financial assistance to rural communities is its Water and Waste Disposal Loan and Grant Program (WWD), now operated by the RUS branch of Rural Development. During the program's first 50 years of operation, over 35,000 loan and grant funding packages totaling nearly $18 billion have been obligated to more than 14,000 rural water and waste disposal systems. As rural water systems continue to upgrade their facilities in response to requirements under the SDWA, the demand for financing from the WWD is likely to continue to exceed available funds. Regardless, this program, combined with other non-farm programs, will continue to account for an increasing share of the agency's activity.

Partly in recognition of this expanding rural, non-farm orientation, the Rural Development Administration (RDA) was created by the 1990 Farm Bill to administer the Water and Waste Disposal Program, mainly through FmHA's network of state and district offices. More recently, the entire agency has been restructured to form the Rural Development mission area of USDA, and the RDA has been made part of its RUS. It is the RUS that is coordinating a USDA initiative called Water 2000--a blueprint for delivering clean, safe, affordable drinking water into all rural homes that seek it by the turn of the century (RUS, 1995). Clearly the WWD is a cornerstone to this national initiative. RUS continues to encourage joint funding packages with other federal and state agencies whenever possible.

Eligibility and Application Requirements

The WWD is administered by the RUS, and it provides loans, grants, and loan guarantees for water and wastewater systems primarily serving rural areas or communities of less than 10,000 people, including municipalities, counties, special purpose districts and authorities, associations, cooperatives, and nonprofit organizations. Funds obtained through the WWD may be used for the installation, repair, improvement, or expansion of water systems, wastewater collection and treatment systems, and solid waste disposal facilities. Applicants must demonstrate that they are unable to finance the proposed project from their own resources or through commercial credit at reasonable rates and terms. Public bodies and non-profit corporations can also be eligible applicants.

Through this program, funds are allocated to individual states by formula based on the state's proportion of the national rural population, as well as the proportion of the rural population living below the poverty level. Efforts are made to take explicit account of a community's financial capability in determining levels and types of assistance to provide. This includes no matching requirements and assistance in the form of loans, grants, and loan guarantees.[5] Funds can be used for construction, land acquisition, legal fees, engineering fees, capitalized interest, equipment, initial operation and maintenance costs, project contingencies, and any other costs determined necessary by RUS. Projects must be primarily for the benefit of rural residential-size users.

Loans are provided at market, intermediate, and "poverty" loan rates; intermediate rates are halfway between the other two. "Poverty" loan rates are set quarterly, and as of the fourth quarter of FY 1995, the rate was 4.5%, while market and intermediate rates are at 5.75% and

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[5] Loan guarantees were added in FY 1990 for RUS financial assistance, whereby the agency can guarantee loans of other lenders for between 80 and 90% of eligible project costs. These guarantees are similar in nature to the farm loan guarantees FmHA has provided for a number of years. Eligibility requirements are similar to those under the loan program. Loan guarantees of $75 million were appropriated for FY 1990 but none were obligated; similarly, $35 million were appropriated for FY 1991 but less than $6 million were actually obligated. Since then, loan guarantees have not been used.

5.125%, respectively. Applicants qualify for the "poverty" rate in cases where the loan is needed to meet a health or sanitary standard and the median household income (MHI) of the service area is below 80% of the state's non-metropolitan median income or below the federal poverty level ($15,150 for 1995). The intermediate rate is available when the MHI of the service area is less than or equal to the MHI for the state. The market rate, for those not qualifying for "poverty" or intermediate rates, is based on the average bond buyer index. Loan terms may not exceed the useful life of the facility, up to a maximum of 40 years.

Outright grants are available to some communities in conjunction with the loans; but grant funds cannot be used to pay interest or project costs related to refinancing, to the purchase of existing systems, or to initial operation and maintenance. Eligibility for a grant of up to 75% of eligible project costs requires the service area's MHI to be below the poverty income level for the state or nation, whichever is higher. Because of the program's rural orientation, somewhat smaller grants (up to 55% of eligible project costs) are also available for communities which fail to qualify for funds based on poverty status, but for which the community's median household income is below the national MHI for non-metropolitan areas.[6] In both these situations, the final amount of the grant awarded to any community is based on the additional user charge that would be required to cover project costs (including the project's annual debt service). The final amount of the grant depends on whether the annual debt service costs per capita for the project exceeds a specified percentage of the MHI in the service area--exceeding 0.5% and 1.0% of MHI to be elgible for maximum grants of 55% and 75%, respectively (EFAB, 1991).

Since applications for RUS loan and grant funding persistently exceed funds available for new obligations, a rating system has been designed to help ensure that projects of the highest priority are funded first (Water Sense, 1995). The rating system scores applicants based on: a) Population--smaller communities being given funding priority; b) Income--priority being given to projects benefiting low-income residents; c) Health and Sanitation--communities with pressing health problems receiving higher priority; and d) Other Criteria--such as priority given to the "truly rural" system.

Funding History of the Water and Waste Disposal Loan and Grant Program

To better understand the significance of RUS funding for public water system improvements to meet the 1986 amendments to the SDWA, it is useful to compare the past lending history and trends with current obligation levels. For this purpose, data for the national and state-level loan and grant obligations under RUS's water and waste disposal program were obtained for fiscal years 1979 through 1995.[7]

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[6] In 1990, the MHI for non-metropolitan areas was $39,417 according to the Census, but the non-metropolitan MHI for individual states varied substantially. It was lowest in Louisiana ($23,075) and highest in Alaska ($39,641), but highest in Connecticut ($37,657) if we consider only the continental United States.

[7] Unpublished data for 1979 through 1994 were provided by the office of the RUS in Washington, DC. Data on obligations (e.g. the amount available for loans and grants) for 1995 are from Water Sense (1995). For fiscal years 1984 to 1994, the national office also had available at the national level the loan and grant obligations, separated into their respective water and waste disposal components.

The total obligations for WWD at the national level since 1979 are given in Figure 1, in both nominal dollars and constant 1992 dollars so that the trends are adjusted for changes in purchasing power over the 15-year period.[8] Beginning in 1979 nominal funding was about $1.2 billion, but was consistently lower throughout the 1980s. In seven of the ten years during that decade, funding was closer to half a billion dollars. Since 1990, obligations have risen dramatically and were just over $1.3 billion in 1995.

Overall, the trend in the real value of obligations (measured in constant 1992 dollars) is similar to that in nominal dollars (Figure 1). However, despite the recent increases in obligations in nominal terms, the real purchasing power of these loans and grants has yet to rebound to pre-1980 levels. In constant 1992 dollars, for example, the $1.2 billion of obligations in 1979 would have had the purchasing power of $2 billion, whereas the $1.3 billion of obligations in 1995 would have the purchasing power of only $1.2 billion. Put differently, the constant dollar purchasing power of obligations in 1995 is only 61% of what it was in 1979.

It is difficult to explain why funding levels dropped so dramatically during the middle 1980s. One might speculate, however, that prior to that time, much of the funding for water systems was for distribution infrastructure and low level treatment improvements, with little emphasis being given to extensive treatment facilities.[9] Once many of these initial investments were in place, the need for funds could well have been reduced by the mid-1980s. Currently, under EPA's efforts to enforce the 1986 amendments to the SDWA, combined with the aging of water system infrastructure, funds both for treatment and infrastructure repair are again on the rise.

Lobbying efforts by formal and informal organizations have also helped increase funding obligations over the past several years. Since 1989 the annual percentage rate increases in obligations have varied widely, ranging from a high of 40% between 1990 and 1991 to a low of 3% between 1993 and 1994. In part because of these recent lobbying efforts, obligation levels in 1995 reflect a 13% increase over the 1994 levels.

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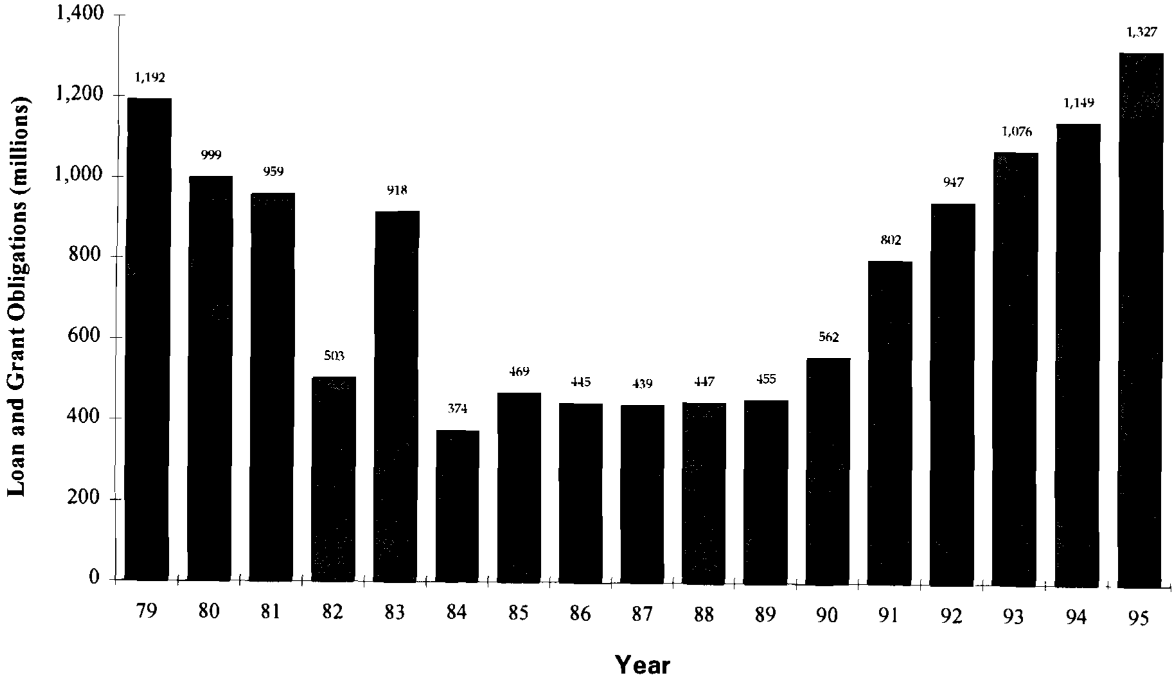
[8] Data are converted into constant 1992 dollars using the construction cost index reported in the Engineering News Record (1995).

[9] According to the Congressional Budget Office (1995), federal capital spending on infrastructure for water supply and wastewater treatment peaked in the late 1970s at nearly $8 billion (1990 dollars) and has declined steadily since then, to a low of $2.5 billion in 1995. Over this period spending for wastewater was dominant, reaching a peak in 1977 of $7 billion and falling to $2.2 billion by 1995. Spending for water supply infrastructure peaked in 1980 at nearly $980 million, with current outlays for 1995 estimated at $320 million. For the most part, water supply related outlays for infrastructure are from RUS's WWD program and the Water and Sewer Basic Grants Program operated by HUD. Spending for wastewater is from EPA grants for the construction of municipal wastewater treatment plants, plus wastewater related outlay from the other sources mentioned above.

Figure 1. RUS WWD Program Loan and Grant Obligations by Year

A. Nominal Dollars



B. Constant 1992 Dollars

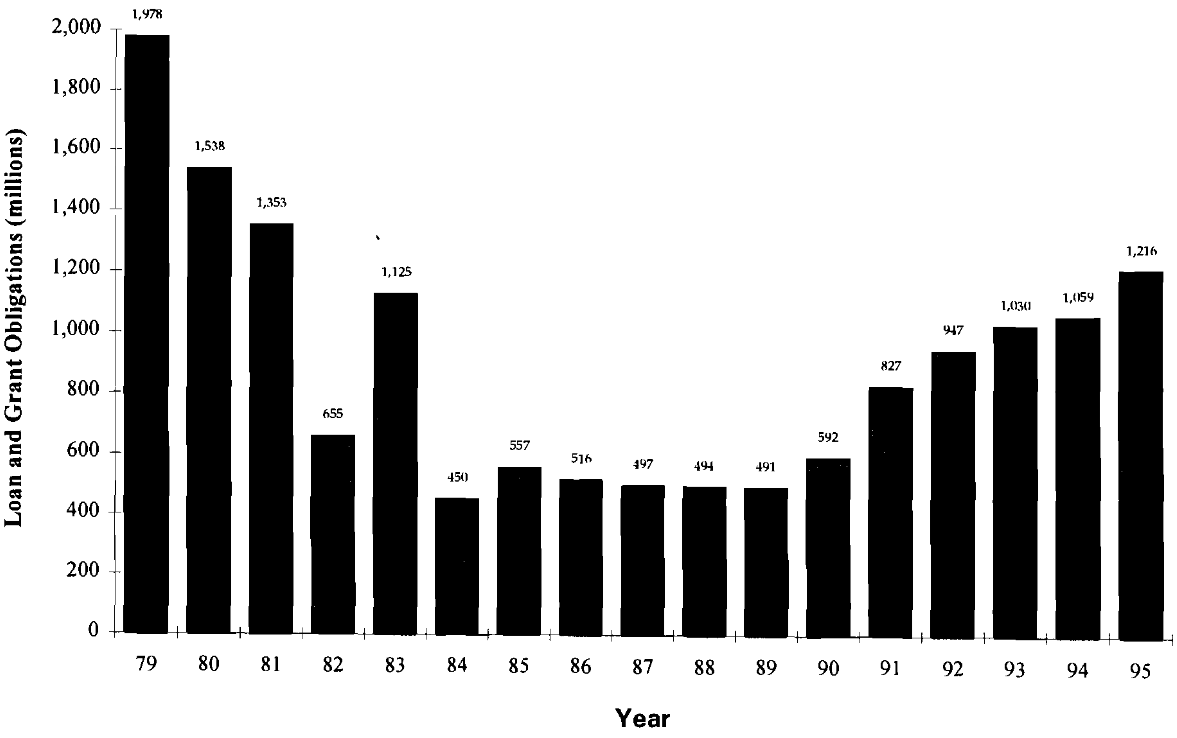


Figure 2 contains the allocation of loans and grants from total obligations for the years 1979 through 1994. Until 1989, loans generally represent about 70% of total obligations, but since then, this proportion is closer to 60%. This shift toward a higher proportion of funding in the form of grants is undoubtedly appealing to small communities needing additional funds, but may also just reflect the difficult financial situations where more communities may now qualify for grants.

Figure 3 shows the trend in RUS's financing since 1984, disaggregated by water and waste disposal financing. Although drinking water obligations are higher in each year (ranging from $300 million to $700 million), waste disposal financing remains a significant portion of total allotments, ranging from over 30% to just under 50% of combined obligations for both drinking water and waste disposal programs annually. Data for individual states or regions exhibit similar relationships since amounts of available funding are tied to rural population and MHI levels.

Regional Distribution and Trends

To provide some perspective on the regional distribution and trends in funding levels, Figure 4 contains the percentages of total RUS loan and grant obligations by EPA region, as defined in Table 1. Clearly, the largest shares of the total national allocations consistently go to Regions IV, V, and VI. This is as one would expect, given the nature of the RUS's criteria for funds allocation. Table 2 provides some insight into allocation levels through a comparison of regional rural population and MHI levels with their corresponding RUS obligation levels for two census years, 1980 and 1990.[10] Region IV, located in the southeast, was allocated over 25% of total program funds throughout the decade; not surprisingly this region has the highest percentage of the nation's rural population in both 1980 and 1990. Rural MHI, as a proportion of the national average was among the lowest in Region IV as well. Regions V and VI, with approximately a 15% share of the funds, are somewhat different. On the one hand, Region V has about 20% of the nation's rural population, but rural MHI is above the national average. In contrast, Region VI contains only about 11% of the nation's rural population, but rural MHI is well below the national average.

One might also expect to see the highest proportion of RUS obligations in those regions with the largest share of the nation's small water systems. To shed some light on the relationship between the number of water systems and RUS obligations, EPA's FRDS-II data system was used to estimate proportions of small (less than 10,000 population served) systems by EPA Region (EPA, 1993a). Table 3 contains these distributions and demonstrates a strong correlation between obligation levels and the number of small water systems. As seen in the first column, the share of all systems that are small is high for all regions. Over 94% of all systems nationally are small by this definition, and the regional averages range from 84 to 97%. In terms of funding shares, Regions IV, V, and VI are ranked one, two, and three, respectively. Combined, these three regions received nearly 56% of RUS obligations in 1990; they contain just under 50% of the small water community systems.

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[10] Since the rural MHI levels were not available for 1980, total MHI is used as the reference income variable.

Figure 2. RUS WWD Obligation Percentages for Loans and Grants.

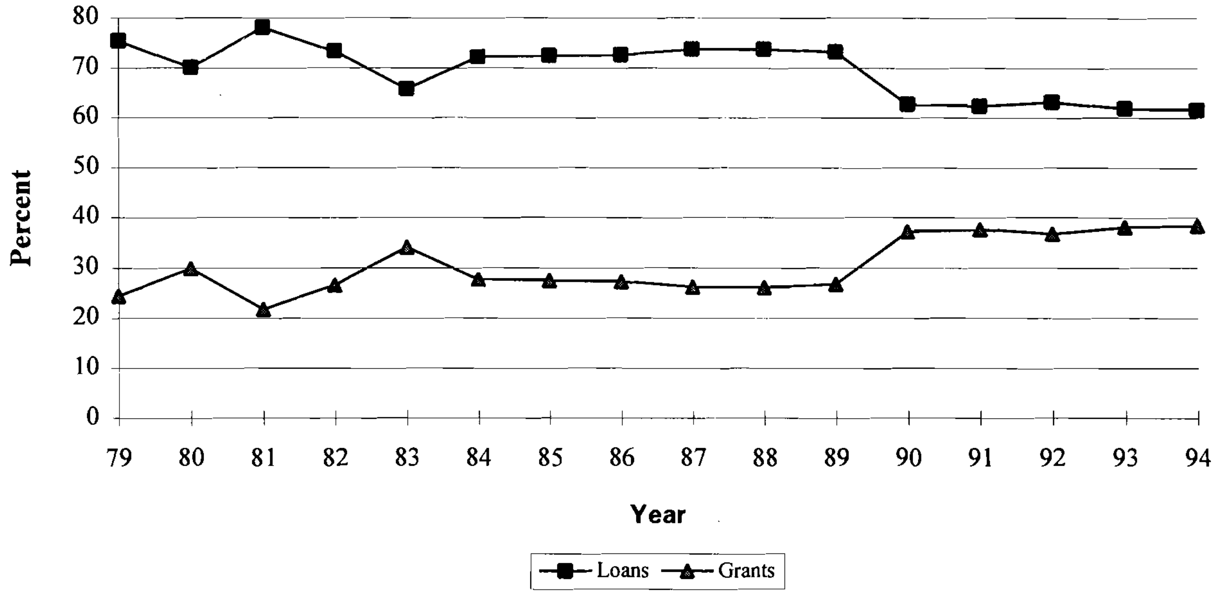


Figure 3. RUS WWD Obligation Percentages for Water and Waste Disposal.

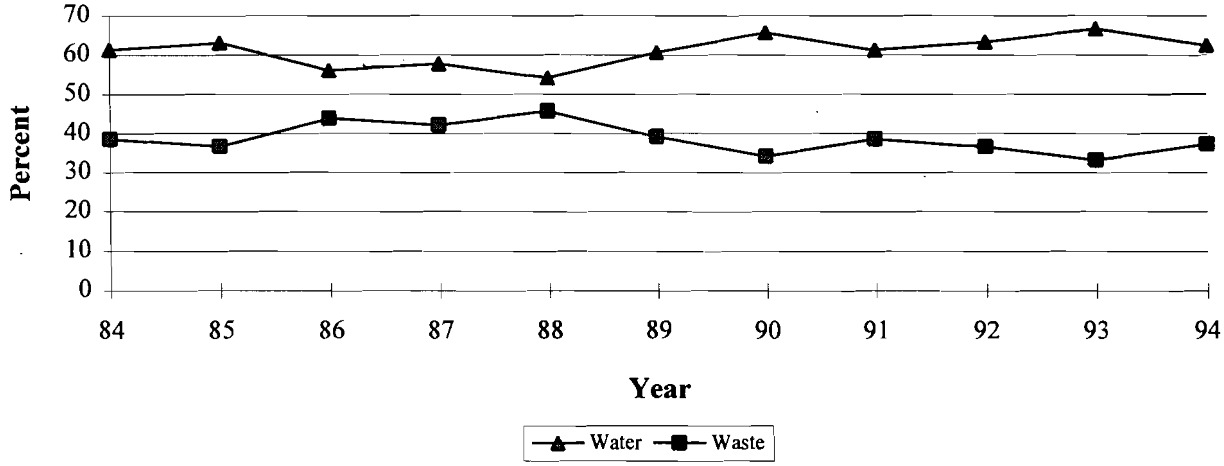
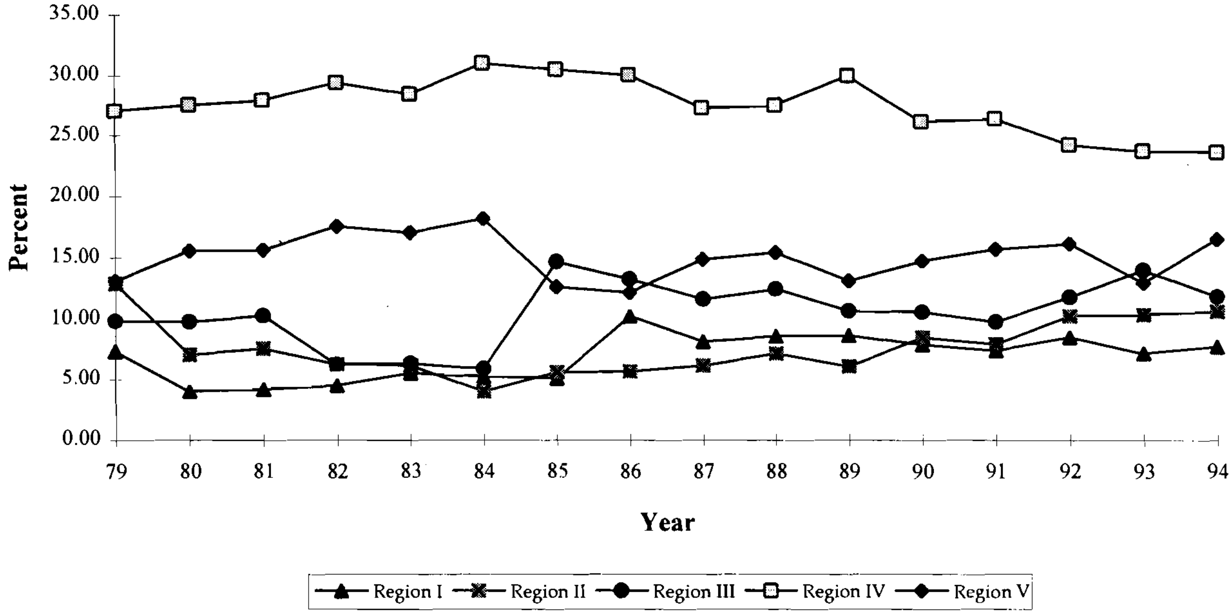


Figure 4. Percent of National RUS Loan and Grant Obligations, EPA Regions I through V



EPA Regions VI through X

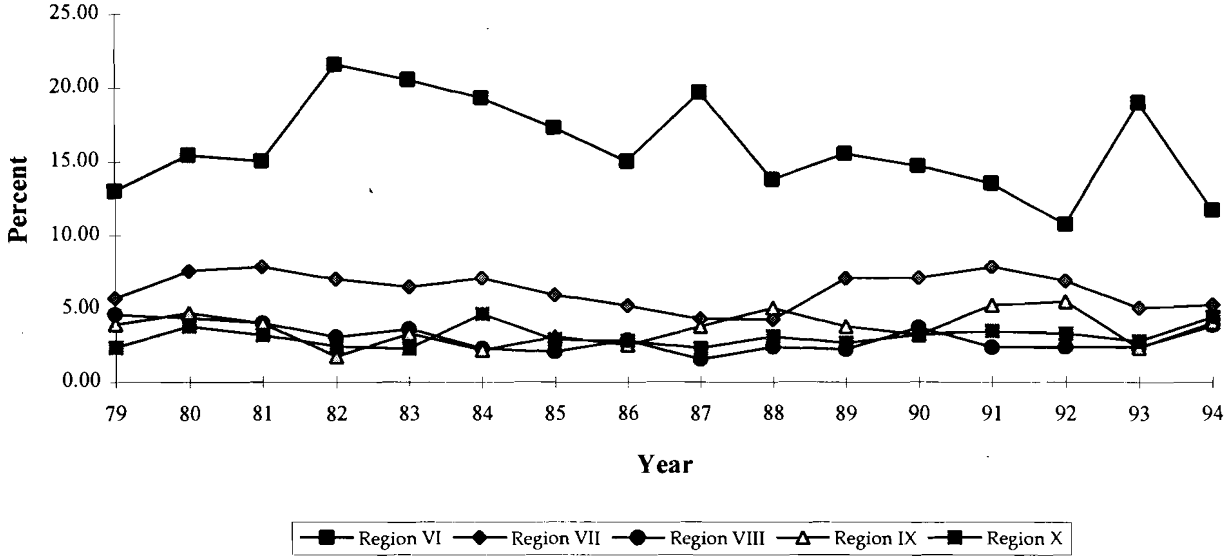


Table 1. EPA Regions, Regional Office Location, and States Included.

EPA Region	Regional Office	States in Region
I	Boston	CT, ME, NH, RI, VT
II	New York	NJ, NY
III	Philadelphia	DC, DE, MD, PA, VA, WV
IV	Atlanta	AL, FL, GA, KY, MS, NC, SC, TN
V	Chicago	IL, IN, MI, MN, OH, WI
VI	Dallas	AR, LA, NM, OK, TX
VII	Kansas City	IA, KS, MO, NE
VIII	Denver	CO, MT, ND, SD, UT, WY
IX	San Francisco	AZ, CA, HI, NV
X	Seattle	AK, ID, OR, WA

Regions as outlined in EPA (1993a).

Table 2. EPA Region Rural Population, MHI Percentages, and RUS Obligations Relative to National Levels.

		1990				1980			
EPA Region		Rural	Rural	RUS		Rural	Total	RUS	
No.	Name	Population	MHI	Obligations		Population	MHI	Obligations	
		%	%	$ mill	%	%	%	$ mill	%
I	Boston	5	142	47	8	5	104	62	4
II	New York	6	128	50	8	6	104	109	7
III	Philadelphia	13	104	63	11	13	103	151	10
IV	Atlanta	26	87	155	26	25	84	424	28
V	Chicago	20	108	87	15	21	109	239	16
VI	Dallas	12	82	87	15	11	93	238	15
VII	Kansas City	6	87	42	7	7	95	117	8
VIII	Denver	3	90	22	4	3	101	67	4
IX	San Francisco	5	110	19	3	5	107	73	5
X	Seattle	4	105	19	3	4	105	59	4

Source: United States Census of Population and Housing, 1980 and 1990.

Note: Population percentages reflect the percent of total rural population, while MHI percentages reflect the percent of national average rural MHI for 1990 and total MHI for 1980, rural breakdowns not available for 1980.
RUS obligations indexed to 1992 dollars by ENR Construction Cost Index, with the percent equal to the percent of total national obligations.

Although none of these general relationships is overly surprising, there are several factors that affect the distribution of RUS obligations by state and region. In an attempt to disentangle the relative importance of each factor, state level obligations in 1990 were combined with rural population and MHI levels to estimate this relationship econometrically. This relationship should serve to verify RUS procedures and goals aimed at helping those smaller, rural community water systems without ability to repay such financing at market rates. Furthermore, elasticities with respect to population and income levels can help determine differential effects of changes in these variables for different areas of the country.

The linear relationship estimated is:

$$POBL_i = \beta_0 + \beta_1 PRPOPNAT_i + \beta_2 POPMHI_i + \alpha_1 REGNE_i + \alpha_2 REGME_i + \alpha_3 REGSED_i + \omega_i \ ,$$

where *POBL* is the 1990 percentage of national obligations for each state *i*, $i = 1$ to 50, *PRPOPNAT* is the state percentage of the national rural population, *POPMHI* is an interaction variable multiplying *PRPOPNAT* with the state rural MHI percentage relative to the nation (*PRMHINAT*), *REGNE*, *REGME*, and *REGSED* are the three RUS regional dummy variables for the Northeast, Mideast, and Southeast and Delta regions, respectively, to reflect any inherent differences across regions above and beyond those in the rural population and income criteria. The term ω_i is the random error component.

Table 3. FRDS Distribution of Small Community Water Systems by EPA Regions.

EPA Region		Region	Region	Nation
No.	Name	Systems	Population	Systems
		%	%	%
--	Nation	94	21	--
I	Boston	96	19	3
II	New York	93	13	8
III	Philadelphia	95	18	10
IV	Atlanta	93	25	21
V	Chicago	93	24	12
VI	Dallas	96	32	16
VII	Kansas City	97	34	9
VIII	Denver	96	26	6
IX	San Francisco	84	9	6
X	Seattle	97	28	9

Source: EPA FRDS-II Data System (EPA, 1993a).

Note: Small Community Water Systems refer to those systems serving under 10,000 people. Regional system and population percentages refer to the percent of systems and population served within that region. National system percentages refer to the region's number of small systems relative to the national total.

Some descriptive statistics for the variables used in the regression are in Table 4. Average state obligations were nearly \$11 million in 1990, ranging from \$245,000 (0.4%) in Delaware to over \$27 million (5%) in Kentucky.[11] State rural population shares ranged from 0.2% in Rhode Island to nearly 6% in Pennsylvania. State MHI levels varied widely around the national average of \$28,600, with Mississippi having the lowest level at \$19,152 (67% of the national average) and Connecticut having the highest level at \$51,695 (181% of the national average).

The regression results are quite encouraging (Table 5) with 79% of the variation in state obligation allocation explained by the independent variables, and the standard errors on the estimated coefficients are relatively low. The coefficients on variables for rural population and income exhibit the expected signs. As a state's proportion of total rural population increases, RUS obligation levels increase as well. Furthermore, as a state's rural MHI level increases relative to the national average, *ceterus paribus*, obligation levels decrease. By including the interaction variable, the combined effects of population and income levels are accounted for both directly and indirectly.

Table 4. Descriptive Statistics for Variables in RUS Obligation Regression Equation.

Variable	Description	Mean	Std. Dev.	Minimum	Maximum
pobl	State's percentage of total RUS Obligaions 1990.	2.00	1.45	0.00	4.97
prpopnat	State's percentage of the nation's rural population 1990.	2.00	1.53	0.20	5.99
popmhi	Interaction variable prpopnat*prmhinat.	195.88	154.09	21.90	616.83
prmhinat	State's percentage of nation's rural median household income 1990.	100.00	24.88	66.97	180.76
regne	RUS Region Northeast Dummy Variable.	0.24	0.43	0.00	1.00
regme	RUS Region Mideast Dummy Variable.	0.14	0.35	0.00	1.00
regsed	RUS Region Southeast or Delta Dummy Variable.	0.14	0.35	0.00	1.00
regsw	RUS Region Southwest Dummy Variable.	0.08	0.27	0.00	1.00
regnc	RUS Region North Central Dummy Variable.	0.24	0.43	0.00	1.00
regwp	RUS Region Western Pacific Dummy Variable.	0.16	0.37	0.00	1.00

Source: Unpublished data provided by Rural Utilities Service, Washington, D.C.

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[11] Hawaii did have zero obligations in 1990 compared with over \$1.4 million in 1980.

Table 5. Regression Results for RUS Obligation Percent Allocation Equation.

Regressors	Description	Coefficients	Standard Error	t-ratio
Intercept		0.243	0.177	1.371
prpopnat	State's percentage of the nation's rural population 1990.	1.786	0.360	4.954
popmhi	Interaction variable prpopnat*prmhinat.	-0.011	0.004	-3.089
regne	RUS Region Northeast Dummy Variable.	0.802	0.319	2.512
regme	RUS Region Mideast Dummy Variable.	0.677	0.319	2.124
regsed	RUS Region Southeast or Delta Dummy Variable.	0.727	0.338	2.149
R-square =		0.8870		

Source: Unpublished data provided by Rural Utilities Service, Washington, D.C.

Equally interesting is the significance of several RUS regions in determining the proportion of RUS obligations by state. The three regional dummy variables, all for parts of the eastern United States, have positive coefficients ranging from 0.68 to 0.80, thus shifting the relative obligation levels upwards in all states in those regions accordingly. These differences could be explained by a relatively larger number of funding requests from these regions for FY 1990, a greater incidence of emergency or pressing health problems, or just increased political power and lobbying efforts in these regions. Without additional information it is impossible to account for the differences explicitly, a fact that is complicated by the availability only of cross-sectional data for the one year, 1990.

This regression equation not only provides a way to estimate states' proportions of national RUS obligations, but it can also be used to calculate elasticities of state obligation percentages with respect to the explanatory variables. In this way, we can capture the incremental (or marginal) effects of the population and income variables on the distribution of funds. For purposes here, it makes little sense to articulate these elasticities by state, but elasticities for the several RUS regions are reported in Table 6, along with rural population shares and MHI levels. For the nation (i.e., averaged across the 50 states), the elasticity of the share of RUS obligations with respect to the share of rural population is 0.71, relatively inelastic. In other words, a 1% increase in a state's rural population relative to the nation's resulted in a 0.71% increase in its share of obligations, *ceterus paribus.*[12]

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[12] Elasticities whose absolute value are greater than one are defined as elastic, those less than one are inelastic, and those equal to one are unitary elastic.

Table 6. RUS Rural Population and MHI Levels and Obligation Elasticities.

				Elasticity Levels	
RUS Region	Rural Population	Rural MHI	RUS Obligations	Rural Population	Rural MHI
	---------------	---%---	---------------		
Northeast	29.54	115.95	26.76	0.57	-1.57
Mideast	17.98	90.32	20.29	0.70	-0.98
Southeast	12.22	89.43	11.73	0.71	-0.93
Delta	6.17	70.49	10.70	0.68	-0.54
Southwest	8.49	83.41	7.43	0.90	-1.02
North Central	17.06	93.22	16.61	0.83	-1.24
West & Pacific	8.55	107.56	6.48	0.77	-1.69
National Average				0.71	-1.23
Minimum Rural Population Elasticity:					
Connecticut	1.11	180.76	0.40	-0.36	
Maximum Rural Population Elasticity:					
Texas	5.43	87.98	4.76	0.95	
Minimum Rural MHI Elasticity:					
Connecticut	1.11	180.76	0.40		-2.94
Maximum Rural MHI Elasticity:					
Delaware	0.29	106.04	0.05		-0.32

Source: Unpublished data provided by Rural Utilities Service (RUS), Washington, D.C.

Note: MHI = Median Household Income.

Rural population and RUS obligation percentages represent regional (or state) percentage of national totals, while rural MHI percentages reflect regional (or state) rural MHI levels as a percentage of the national average rural MHI.

National elasticities represent weighted average state elasticities by respective rural population levels; regional elasticities were calculated in the same manner, but based on total regional rural populations.

What is perhaps more interesting is the range of elasticities over the seven RUS regions. The Northeast region has the lowest rural population elasticity (0.57), while the largest is in the Southwest region (0.90). Although the regions in the eastern United States received higher shares of total obligations on average than do the remaining regions, their elasticities with respect to rural population shares are lower. Therefore, equivalent percentage increases in rural population shares in the central and western United States would result in higher obligation percentage increases than for their counterparts in the east.

In contrast, the elasticities of the proportion of RUS obligations with respect to rural MHI are negative; averaged across the 50 states it is relatively elastic, -1.23. Put differently, a 1% increase in a state's rural MHI relative to the national average results in a 1.23% decrease in its share of RUS obligations, *ceterus paribus*. Furthermore, the same general pattern of elasticities by region exhibited for rural population is not as apparent for the rural MHI. The smallest elasticity (in absolute value) is -0.54 in the Delta region; this substantially smaller and inelastic result is surprising. The elasticities for both the Mideast and Southeast regions are also in the inelastic range, but are much closer to unity in absolute value. In all other regions the elasticities with respect to rural MHI are greater than unity, with those in the Western and Pacific regions being the highest (-1.69).

This review of RUS's role and activities relative to the improvement of our nation's public drinking water systems provides an appropriate backdrop for the research described in the remainder of this report. Given this perspective on the goals, direction, and operation of the RUS's WWD program, we now take an in-depth look at the specific capital improvement projects funded in New York over the past several years. We begin with a description of the data collected from the New York districts of the Rural Development mission area on recent funding packages to assist small, rural communities across the state. Following a descriptive analysis of the data, econometric techniques are applied to the data to develop relationships to help understand the costs of system extensions and consolidation, as well as to estimate average annualized costs and economies of size for the various water system treatment technologies found in the data.

RUS COMMUNITY WATER SYSTEM FINANCING IN NEW YORK

During the summer of 1994, we contacted New York's district offices of the Rural Development mission area to inquire about the availability of data for projects to improve drinking water systems in small communities financed by the RUS's WWD Program. Without exception, we were invited to visit the offices to examine the project files and assemble the available data. Data collection began early in the fall and was completed in early 1995.

The data include numerous financial and operating characteristics of the community water systems; of particular interest are the estimated capital and operating characteristics of the water system expansions or improvements for which the funding was requested. To ensure that the data were representative of the diverse nature of all projects, information from all drinking water system funding applications in process or obligated within the past four years were collected. These diverse system projects were for improvements or expansions to the distribution and transmission capacity, for source development, for water storage, and for new or expanded treatment facilities. The basic types of data collected are shown below:

Water System Characteristics

- System name, type, and location
- Existing facility description
- MHI of service area
- System size characteristics
- Average and maximum daily water demands
- Hook up information by user type
- Primary water source
- Existing RUS and other indebtedness
- Revenue projections and cash flow summary
- Annual operating budget
- Water treatments utilized

Capital Project Funding Details

- Capital project description and specifications
- Date of application, obligation, and closing
- Project type (i.e. distribution, treatment, etc.)
- Estimated funding breakdown
- RUS loan and grant amounts
- Grant determination specification
- Interest rate and repayment period
- Funding security offered
- Annual debt repayment per user
- Annual user costs before and after project
- Project cost classification and contingencies

To assemble these data, specific RUS forms were reviewed, as was additional documentation in project narratives and engineering reports detailing system characteristics and project specifications. The quantitative data were coded in Excel spreadsheets. A brief narrative summary was prepared to capture the more qualitative aspects of each project, and in many cases, copies of important parts of the engineering reports were made as well. This detailed information was used, to the extent possible, to partition total project costs among its various components, particularly treatment costs and costs of water storage, transmission, and distribution. To facilitate statistical analysis, the data were transferred into a SAS data set and were combined with additional information for the water systems available from EPA's Federal Reporting Data System (EPA, 1993a) and with municipal level financial characteristics available from the New York State Department of Municipal Affairs (New York, 1994).

Some Descriptive Statistics of the RUS Data

In total, we obtained 149 loan and grant funding packages, representing 141 unique village water systems or town water districts and encompassing 138 village or town-level municipalities.[13] These systems are distributed throughout New York's five Rural Development service areas (Figure 5). At one extreme, 42 systems (28%) are in the northern New York area served by the Potsdam district office, while at the other, only 19 systems (13%) are in the west-central New York area served by the district office in Ithaca. The remaining systems are distributed somewhat more evenly across the districts, with 25 systems (17%) in the Newburgh district serving southeastern New York, 29 systems (19%) in the Whitesboro district serving central New York, and 34 systems (23%) in the Salamanca district serving the western part of the state.

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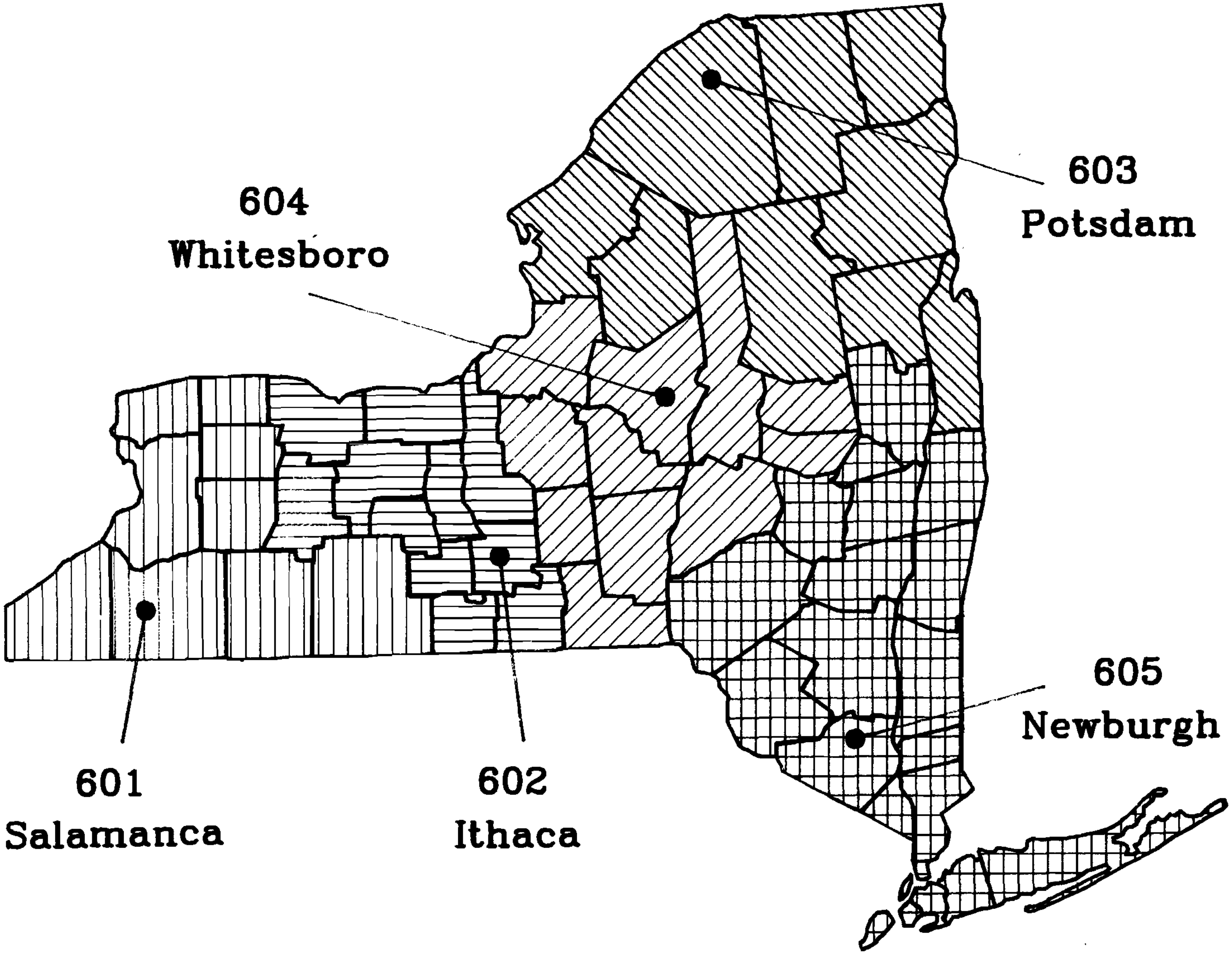
[13] These numbers include one private water system operating as a not-for-profit corporation.

Figure 5. New York Rural Development District Offices and Service Areas



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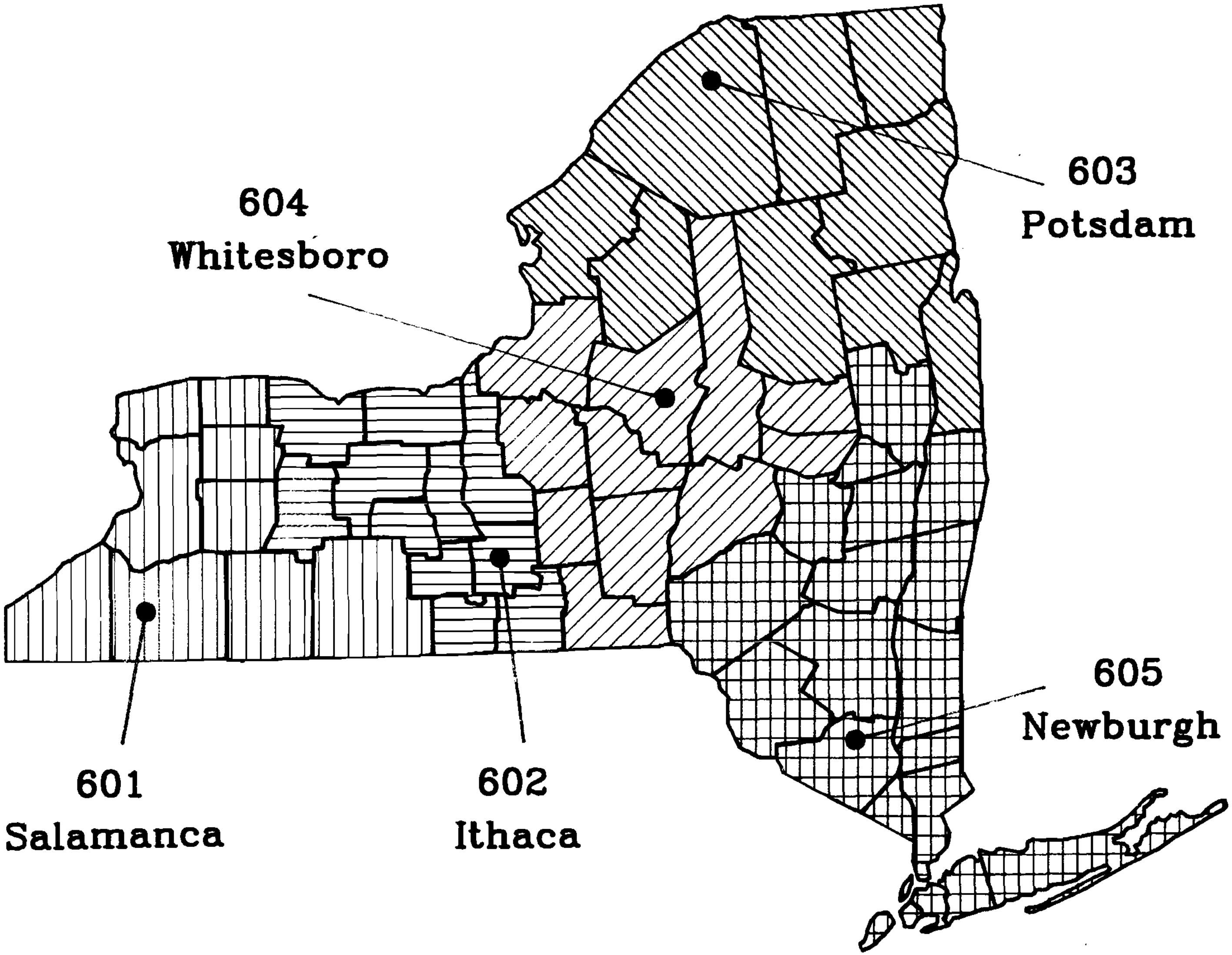


Projects Across New York's Rural Development Districts

Table 7 contains the distribution of projects by major project component for each district. Projects are fairly evenly distributed over the five main categories of distribution, transmission, treatment, storage, and source development. Not surprisingly, most projects involve work in several categories. Distribution improvements are involved in roughly 50% of the projects, while 40% of the systems requested funding for transmission work. Just under 40% are for treatment upgrades; another 50% are for storage; and over 34% are for source development.

In southwestern New York, however, most projects focus on distribution repairs and extensions; there were few involving treatment and source development. One possible explanation is the area's apparent reliance on system consolidation to comply with mandated improvements (i.e. SDWA regulations). In addition, over three-quarters of the projects are town-level water districts (Figure 6) where newly formed water districts would simply tie into the neighboring district system rather than form an entirely new source and treatment system.

The projects in the remaining regions are more homogenous. Typically, one-half to two-thirds of the systems perform some type of distribution or transmission improvement. Less than half of the systems wanted to finance treatment improvements, while one-third to two-thirds needed storage upgrades, and between 20 and 60% requested funding for source development. Those systems receiving funding for treatment upgrades are of particular interest, because they enable us to estimate the costs of water system improvements needed to comply with the 1986 amendments to the Safe Drinking Water Act. However, it would be helpful, before describing project funding levels across districts, to learn more about the nature of the systems, in terms of size, as measured by population served and average daily water demand, water source, and MHI levels of the water system service areas.

Population and Household Income

Since part of the RUS's mission is to assist small rural communities with water and waste disposal financing, only those communities with populations of fewer than 10,000 are eligible for assistance. The characteristics of the systems by size of population served (i.e. in village or city municipality, or town water district) are in Table 8. The average population served is nearly 1,800 people, ranging from under 1,100 in the Salamanca district to nearly 2,800 in the Newburgh district. Over three-quarters of the systems serve populations under 2,500 people, and over 90% serve populations under 5,000. These proportions are similar across districts, with some notable exceptions. For the southwestern district, virtually all systems serve populations below 5,000, and over 60% serve populations of fewer than 1,000 people. In southeastern New York, on the other hand, there is a relatively higher proportion of larger systems, with only 60% serving populations 2,500 and just over 70% serving populations under 5,000. Much of the difference is explained by the geographic location of the respective districts and proximity to larger metropolitan areas.

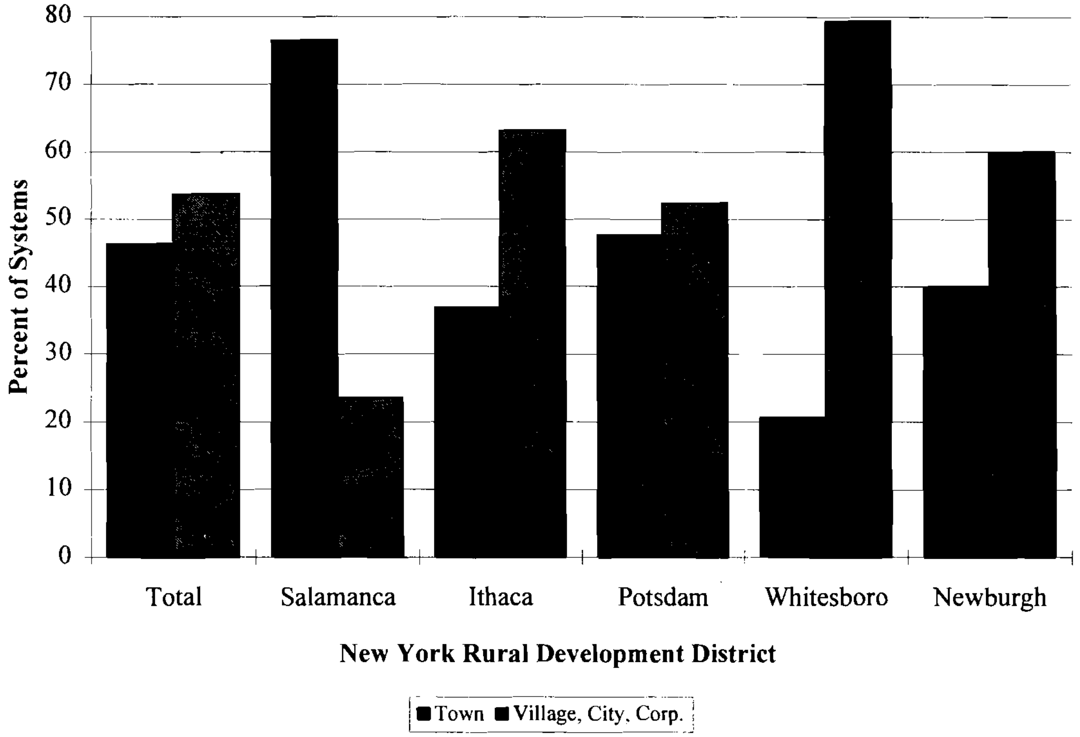
Table 7. Distribution of Drinking Water System Projects by Project Component.

	All Districts		Salamanca		Ithaca		Potsdam		Whitesboro		Newburgh	
Project Component	Frequency	Percent	Frequency	Percent	Frequency	Percent	Frequency	Percent	Frequency	Percent	Frequency	Percent
Distribution Extension	33	22	19	56	3	16	4	10	3	10	4	16
Distribution Repair	49	33	8	24	6	32	11	26	13	45	11	44
Transmission New	18	12	1	3	2	11	6	14	4	14	5	20
Transmission Repair	41	28	5	15	6	32	16	38	9	31	5	20
Treatment New	45	30	4	12	6	32	15	36	13	45	7	28
Treatment Repair	10	7	1	3	2	11	3	7	1	3	3	12
Storage New	64	43	9	26	7	37	26	62	11	38	11	44
Storage Repair	13	9	3	9	4	21	1	2	2	7	3	12
Source Development	51	34	6	18	4	21	17	40	10	34	14	56

Source: Primary data obtained from New York Rural Development district offices.

Note: Individual data observations may contain more than one project type, thus the percent summed in any one region may be greater than 100%.

Figure 6. Distribution of Municipal Water Systems by Community Type.



Household income levels are a crucial component for allocating RUS loan and grant fund obligations, as well as for setting priorities for approving applications awaiting obligation. Thus, we include in Table 8 the average MHI levels for the sample communities within each district. These data are from the Census of Population and so are available only for 1980 and 1990. For those project funding requests close to 1990, the 1980 MHI levels were used, and are included in the table for completeness. The average 1990 MHI level over the entire sample was $27,175 compared to the statewide rural MHI of $32,557.[14] The Rural Development district located in northern New York has the lowest MHI level at $25,647. However, all districts are closely grouped near the mean with the maximum average MHI of just $29,180 in the Ithaca district. Since these income levels are important criteria when evaluating average assistance levels and proportions of loans to grants awarded, they are referred to in later sections of this report.

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[14] Since 1980 and 1990 MHI levels follow similar patterns, only 1990 averages are discussed. Interested readers can consult Table 8 for additional information. MHI for 1980 in New York was $16,647; no rural classification was available. MHI for 1990 in New York was $32,965.

Table 8. Median Household Income and Population Distributions by Rural Development District.

	All Districts	Salamanca	Ithaca	Potsdam	Whitesboro	Newburgh
Median Household Income 1980	13,321	14,505	14,554	13,101	13,343	11,756
Median Household Income 1990	27,175	28,366	29,180	25,467	26,553	26,631
Number of Systems	149	34	19	42	29	25
Average Population Served	1,756	1,073	2,073	1,446	1,893	2,777
% of Systems by Population Category:						
Less than 101	5	15	0	5	0	0
101 to 500	34	41	37	36	28	28
501 to 1,000	12	6	5	14	10	24
1,001 to 2,500	27	29	26	26	41	8
2,501 to 3,300	8	3	5	12	14	4
3,301 to 5,000	5	3	11	5	0	8
5,001 to 7,500	6	3	16	0	0	20
7,500 to 10,000	3	0	0	2	7	8

Source: Primary data obtained from New York Rural Development district offices.

Primary Source of Water

It is well known that the kinds of treatment needed by the nation's public water systems depend on whether the systems rely primarily on ground or surface water. Nationally, we know that 69% of all publicly owned water systems rely, at least to some extent, on ground water sources; the percentage is slightly higher (73%) for systems serving under 10,000 people (Boisvert and Schmit, 1996). In contrast, only 37% of New York's publicly owned water systems utilize water primarily from ground water sources, with the proportion being relatively unchanged for those systems serving under 10,000 people. The reliance on ground and surface water is split evenly in our sample of about 150 New York water systems (Table 9). In three of the five Rural Development districts, these proportions are nearly the same as the overall average, but this was not the case for the other two districts. Nearly 65% of the systems in our sample in western New York rely on surface water, while the systems in the central part of New York have the highest proportion of ground water systems, over 65%. Although it would be impossible to draw any conclusions from this distribution of systems in the sample, it is not surprising that slightly more than half (56%) of the systems requesting funding for new or improved treatment facilities use primarily surface water.

Table 9. Primary Water Source Distributions by New York Rural Development District.

Primary Water Source	Total		Salamanca		Ithaca		Potsdam		Whitesboro		Newburgh	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Ground, nonpurch.	71	48	12	35	8	42	19	45	19	66	13	52
Ground, purchased	4	3	0	0	1	5	2	5	0	0	1	4
Surface, nonpurch.	44	30	5	15	6	32	20	48	5	17	8	32
Surface, purchased	30	20	17	50	4	21	1	2	5	17	3	12
Ground	75	50	12	35	9	47	21	50	19	66	14	56
Surface	74	50	22	65	10	53	21	50	10	34	11	44

Source: Primary data obtained from New York Rural Development district offices.

Water Connections and Water Demand

Before reviewing the financial characteristics of water systems in the sample, a brief review of the demand for water is warranted (Table 10). For the systems in the sample, the average number of connections is nearly 600 and ranges from a district average of 444 to nearly 825. To standardize the demand for water, RUS estimates the number of equivalent dwelling units (EDU) for a water system as a way of combining household use with that from commercial and industrial establishments.[15] As one would expect for these smaller systems that serve primarily residential communities (with 92% and 59% of the hookups and water demand, respectively, due to residential use), the distribution of EDUs follows a similar pattern to the distribution of connections. There is an average of 800 EDUs across the entire sample, with the Salamanca district having the lowest average number of EDUs (649) and the highest (over 1,000 EDUs) in the Newburgh district.

For all systems, average daily demand was just over 260,000 gallons per day (gpd), which translates into 135 and 366 gpd on per capita and per hookup bases, respectively (Table 10). On a per capita basis, the range is from an average of 108 gpd in the western New York district to 162 gpd in northern New York. For all systems, average per capita water demand is slightly higher than the national and state averages of 126 gpd and 111 gpd, respectively (Boisvert and Schmit, 1996).

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[15] EDU is determined by measuring the average household water demand and extrapolating the number of these households it would take to consume the same amount of water as a higher or excessive user, such as an apartment complex or industrial/commercial user. For example, if the average household consumption were 300 gallons per day (gpd) and an industrial user demanded 3,000 gpd, this would be equivalent to 10 EDUs.

Table 10. Average Water System Connection and Demand Characteristics.

System Descriptor	All Districts	Salamanca	Ithaca	Potsdam	Whitesboro	Newburgh
Equivalent Dwelling Units	808	649	951	647	929	1,032
Total Hookups	608	444	732	495	678	823
% Residential	92	94	95	90	93	89
% I/C/B (a)	5	5	4	6	4	7
% Excessive I/C/B (b)	3	1	1	4	3	4
Average Daily Demand (c)	261,819	132,646	259,049	270,650	316,494	356,114
% Residential	59	78	66	57	57	56
% I/C/B	4	4	4	4	2	5
% Excessive I/C/B	37	18	30	39	41	39
Per EDU (d)	291	239	275	336	313	271
Per Hookup	366	282	380	417	386	361
Per Capita	135	108	129	162	141	122

Source: Primary data obtained from New York Rural Development district offices.
(a) Industrial, commercial, or business hookups at or near residential levels.
(b) Industrial, commercial, or business hookups with excessive user rates above residential levels.
(c) Average daily demand expressed in gallons per day (gpd).
(d) Equivalent Dwelling Units, see text for definition.

An estimated 60% of water use is for residential purposes, but this percentage ranges by district from 56% to 78%. This percentage is lowest for systems in Rural Development districts nearest metropolitan areas where there is also likely to be more commercial and industrial activity.

Annual Operating Budgets

With this descriptive background, we now extend the discussion to the financial operating characteristics of the sample water systems. These diverse characteristics, including type of municipality, system size, and primary water source, give rise to some of the differences in operating schedules and costs, but the number and types of treatments applied affect costs as well. These are discussed below in greater detail, and their effects are isolated with the help of the indirect cost functions estimated from the data.

To begin to understand the differences across districts, schedules for operating income and expenses by district are shown in Table 11, and reported on a per capita and per hookup basis in Tables 12 and 13, respectively. To be consistent with the data on system characteristics and the application instructions, these schedules should contain any adjustments in income and expenses necessary for the funded water system improvements. Further, the income and expense categories are dissaggregated into categories normally used for accounting and auditing purposes. On average, these systems have a total income of nearly $221,000, with operating expenses estimated at just over $192,000. Net income averages $28,000. Not surprisingly, total income and expenses are related to population served and other measures of system size, so for purposes of analysis, it makes sense to focus the discussion on the per capita or per hookup data.

Table 11. Annual Average Operating Schedules by New York Rural Development District.

	All Districts	Salamanca	Ithaca	Potsdam	Whitesboro	Newburgh
Operating Income:						
Metered Sales	$146,609	$111,440	$219,830	$71,213	$171,201	$245,122
Unmetered Sales	10,955	2,077	947	6,102	1,628	50,981
User Fees/Service Charges	37,323	15,154	26,187	49,582	56,792	26,069
Water Penalties	1,275	682	3,353	46	535	3,559
Other/Miscellaneous	1,400	822	2,265	641	3,660	100
Total Optg. Income	197,562	130,175	252,582	127,584	233,816	325,831
Operating Expenses:						
Administration	23,067	7,380	25,766	10,558	31,503	54,005
Source Supply/Pumping	25,276	32,192	33,228	20,160	19,263	27,491
Purification	12,494	8,230	17,468	3,026	9,395	35,757
Distribution/Transmission	19,820	21,636	32,543	12,985	16,419	24,446
Employee Benefits	13,012	8,710	22,247	5,559	9,950	28,811
Taxes and Insurance	7,958	4,539	10,905	1,467	24,999	1,475
Salaries/Labor	7,188	6,341	1,270	7,329	7,887	12,027
Interest	53,849	31,477	67,156	34,803	74,853	81,468
Other O & M	23,293	7,929	513	17,360	51,800	37,751
Other Miscellaneous	6,277	0	16,223	2,446	1,136	19,390
Total Optg. Expenses	192,234	128,434	227,319	115,693	247,205	322,621
Net Operating Income	5,328	1,741	25,263	11,891	-13,389	3,210
Non-Operating Income:						
Interest	2,639	9,153	2,070	338	891	1,683
Tax Assessments	14,335	5,160	8,093	11,604	40,838	3,670
Front Footage Charge	49	250	0	0	0	0
Capital Charges	2,781	0	0	0	8,636	6,751
Other Miscellaneous	3,431	2,273	2,253	91	1,222	15,019
Total Non-Optg. Income	23,235	16,836	12,416	12,033	51,587	27,123
Total Income	220,797	147,011	264,998	139,617	285,403	352,954
Net Income	28,563	18,577	37,679	23,924	38,198	30,333
Depreciation	522	1,196	480	0	1,136	0
Loan Principal Payments:						
FmHA	18,464	16,255	37,361	16,414	14,586	15,082
Other	7,747	919	6,608	9,574	11,700	8,924
Net Income - Principle Payments	2,352	1,403	-6,290	-2,064	11,912	6,327

Source: Primary data obtained from New York Rural Development district offices.

Table 12. Annual Average Operating Schedules Per Capita by New York Rural Development District.

	All Districts	Salamanca	Ithaca	Potsdam	Whitesboro	Newburgh
Operating Income:						
Metered Sales	$83.49	$103.86	$106.04	$49.25	$90.44	$88.27
Unmetered Sales	6.24	1.94	0.46	4.22	0.86	18.36
User Fees/Service Charges	21.25	14.12	12.63	34.29	30.00	9.39
Water Penalties	0.73	0.64	1.62	0.03	0.28	1.28
Other/Miscellaneous	0.80	0.77	1.09	0.44	1.93	0.04
Total Optg. Income	112.51	121.32	121.84	88.23	123.52	117.33
Operating Expenses:						
Administration	13.14	6.88	12.43	7.30	16.64	19.45
Source Supply/Pumping	14.39	30.00	16.03	13.94	10.18	9.90
Purification	7.12	7.67	8.43	2.09	4.96	12.88
Distribution/Transmission	11.29	20.16	15.70	8.98	8.67	8.80
Employee Benefits	7.41	8.12	10.73	3.84	5.26	10.37
Taxes and Insurance	4.53	4.23	5.26	1.01	13.21	0.53
Salaries/Labor	4.09	5.91	0.61	5.07	4.17	4.33
Interest	30.67	29.34	32.40	24.07	39.54	29.34
Other O & M	13.26	7.39	0.25	12.01	27.36	13.59
Other Miscellaneous	3.57	0.00	7.83	1.69	0.60	6.98
Total Optg. Expenses	109.47	119.70	109.66	80.01	130.59	116.18
Net Operating Income	3.03	1.62	12.19	8.22	-7.07	1.16
Non-Operating Income:						
Interest	1.50	8.53	1.00	0.23	0.47	0.61
Tax Assessments	8.16	4.81	3.90	8.02	21.57	1.32
Front Footage Charge	0.03	0.23	0.00	0.00	0.00	0.00
Capital Charges	1.58	0.00	0.00	0.00	4.56	2.43
Other Miscellaneous	1.95	2.12	1.09	0.06	0.65	5.41
Total Non-Optg. Income	13.23	15.69	5.99	8.32	27.25	9.77
Total Income	125.74	137.01	127.83	96.55	150.77	127.10
Net Income	16.27	17.31	18.18	16.54	20.18	10.92
Depreciation	0.30	1.11	0.23	0.00	0.60	0.00
Loan Principal Payments:						
FmHA	10.51	15.15	18.02	11.35	7.71	5.43
Other	4.41	0.86	3.19	6.62	6.18	3.21
Net Income - Principle Payments	1.34	1.31	-3.03	-1.43	6.29	2.28

Source: Primary data obtained from New York Rural Development district offices.

Table 13. Annual Average Operating Schedules Per Hookup by New York Rural Development District.

	All Districts	Salamanca	Ithaca	Potsdam	Whitesboro	Newburgh
Operating Income:						
Metered Sales	$262.74	$265.97	$316.30	$161.12	$271.75	$333.95
Unmetered Sales	19.63	4.96	1.36	13.81	2.58	69.46
User Fees/Service Charges	66.89	36.17	37.68	112.18	90.15	35.52
Water Penalties	2.28	1.63	4.82	0.10	0.85	4.85
Other/Miscellaneous	2.51	1.96	3.26	1.45	5.81	0.14
Total Optg. Income	354.05	310.68	363.43	288.65	371.14	443.91
Operating Expenses:						
Administration	41.34	17.61	37.07	23.89	50.00	73.58
Source Supply/Pumping	45.30	76.83	47.81	45.61	30.58	37.45
Purification	22.39	19.64	25.13	6.85	14.91	48.72
Distribution/Transmission	35.52	51.64	46.82	29.38	26.06	33.31
Employee Benefits	23.32	20.79	32.01	12.58	15.79	39.25
Taxes and Insurance	14.26	10.83	15.69	3.32	39.68	2.01
Salaries/Labor	12.88	15.13	1.83	16.58	12.52	16.39
Interest	96.50	75.12	96.63	78.74	118.81	110.99
Other O & M	41.74	18.92	0.74	39.28	82.22	51.43
Other Miscellaneous	11.25	0.00	23.34	5.53	1.80	26.42
Total Optg. Expenses	344.51	306.53	327.08	261.75	392.39	439.54
Net Operating Income	9.55	4.16	36.35	26.90	-21.25	4.37
Non-Operating Income:						
Interest	4.73	21.84	2.98	0.76	1.41	2.29
Tax Assessments	25.69	12.32	11.64	26.25	64.82	5.00
Front Footage Charge	0.09	0.60	0.00	0.00	0.00	0.00
Capital Charges	4.98	0.00	0.00	0.00	13.71	9.20
Other Miscellaneous	6.15	5.42	3.24	0.21	1.94	20.46
Total Non-Optg. Income	41.64	40.18	17.86	27.22	81.88	36.95
Total Income	395.69	350.86	381.29	315.88	453.02	480.86
Net Income	51.19	44.34	54.21	54.13	60.63	41.33
Depreciation	0.94	2.85	0.69	0.00	1.80	0.00
Loan Principal Payments:						
FmHA	33.09	38.79	53.76	37.14	23.15	20.55
Other	13.88	2.19	9.51	21.66	18.57	12.16
Net Income - Principle Payments	4.22	3.35	-9.05	-4.67	18.91	8.62

Source: Primary data obtained from New York Rural Development district offices.

Sources of Revenue

Based on population served, total income for the sample systems averages about $126 per capita, of which 89% is in the form of operating income, including water sales and user fees. The other significant income sources are from non-operating classifications such as interest earned and property tax assessments. Metered and unmetered water sales are by far the most frequently used sources of income to these systems, with metered water sales accounting for two-thirds of all income on average. Unmetered sales, on the other hand, account for less than five percent of all revenues. User fees or other service charges, such as a per connection flat rate charges, accounted for about 17% of all revenues. Any shortfall in revenue needs from these sources is generally made up through tax assessments and capital charges, which combined constitute about eight percent of income. There is some variation about these average figures across districts, but only two worth comment. In the Newburgh district, for example, unmetered sales account for a larger fraction of revenue than do user fees, while in the Whitesboro district, unmetered sales raise less than a dollar per capita, but tax assessments account for over $21 in revenue on a per capita basis.

Operating Expenditures

For all the water systems in the sample, operating expenses, including interest, averaged just over $192,000, or $110 per capita (Table 12). The five main categories used for audit and control purposes, administration (12%), source supply and pumping (13%), distribution and transmission (10%), purification (7%), and interest (28%), account for nearly 70% of all operating expenses, although the exact composition of these categories is hard to disentangle. There seems to be surprising consistency in these data across the several Rural Development districts. Interest expense constitutes the largest share of operating expenses in all districts but western New York, where it is within a dollar of what is spent on source supply and pumping. On a percentage basis, interest expense ranges between 25% and 30% of total expenses. At the other end of the spectrum, purification expenditures account for only 6.5% of operating expenditures on average, and range from 3 to 11% across the districts. In some respects, these percentages seem low although some of the salary, benefits, interest, and other expenditures are directly attributable to purification processes. Furthermore, none of these expenditures reflect the capital costs of acquiring treatment facilities.

Net Incomes and Reserve Residuals

When expenses are subtracted from income from all sources, the average net income of the systems on a per capita basis is just over $16, ranging from $11 in the Newburgh district to about $20 per capita in the Whitesboro district. Put somewhat differently, net income averages about 13% of total revenues and varies little across districts. This residual income represents water system funds available for debt principal repayment or for transfer into existing account reserves for depreciation or for capital improvements. Since the average principle repayment is nearly $15 per capita, there is only about a dollar per capita left annually for capital or depreciation account reserve funds. In fact, only 3 of the 149 systems declared any depreciation fund transfers at all.

From a policy perspective, it is difficult to know exactly how to interpret these small average residual income figures for our sample of water systems. On the one hand, these are public systems and perhaps should not accumulate large revenue surpluses, but the very small or negative cash flow margins certainly are insufficient to support major capital investments needed in the future to move closer to full compliance with the SDWA regulations.[16] This is just further evidence of the continuing need for additional financial assistance from other funds within the already stressed municipal budgets.

Capital Funding Projects by District

This discussion of the net financial position of sample water systems provides an important perspective from which to view the financial demands placed on small water systems needing capital improvement. We begin this discussion with a general overview, and then, to the extent possible, examine the costs by type of project or project component. To the extent that we are able to disentangle costs by component, we gain additional insight into identifying the costs at the margin of adding various components to water system projects.

RUS Loan and Grant Funding

As explained above, the data used in this analysis relate to RUS grant and loan obligations for drinking water system improvements for the years 1990 through 1995. Over this period, the total funding for these 149 projects is about $196 million, of which 91% or $179 million is from RUS sources (Table 14). The remaining nine percent is from other grants. These projects account for an estimated 75% of all obligations for the state of New York under RUS's Water and Waste Disposal Loan and Grant Program.[17]

The average size of the RUS loan and grant funding packages is nearly $1.2 million. There is some variation about this average level across districts, ranging from a low of just over $800 thousand in the Salamanca district to over $1.6 million down near New York City. Funding from sources other than RUS is nearly twice as large on a percentage basis in the Salamanca and Whitesboro districts as in the Newburgh district. Obviously, because of the origin of the data, these systems tend to rely on RUS for the lion's share of the financing, but despite the fact that RUS encourages municipalities to combine funds from a variety of sources if possible, only 33 (or 22%) of the 149 projects includes funds from other outside sources. These funds are predominantly in the form of HUD grants bound by maximum levels usually far below estimated project costs. In a few cases, EDA grants were available, but were generally at levels below those for HUD grants.

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[16] It is possible that some of the small or negative cash flow margins are due to reporting errors, such as the inclusion of interest payments when reporting principle amounts (especially for non-RUS financing), or the failure to update all operating schedule information on the loan or grant application. It seems unlikely, however, that problems of this kind in the data are sufficient to alter the major conclusions.

[17] This percentage is based on actual obligations for New York for the years 1990 through 1994 (as obtained from unpublished data provided by RUS's Washington D.C. office). Obligations for New York in 1995 are set at four percent of estimated 1995 national obligations, reflecting the average proportional allocation to New York over the past 25 years.

Although grants can be awarded up to 50 or 75% of eligible project costs, some municipalities do not qualify for grant money because the income levels in the service areas are too high. This explains why only about one-third of all RUS funding is in the form of grants. Interestingly, the proportion of funds in the form of grants is higher in the Newburgh district than in any other district. This is somewhat surprising in that the Newburgh district serves an area of the state within commuting distance of New York City, where incomes are affected accordingly. Clearly, there are some communities in this area where this is not the case, and it is these communities that appear to make the most use of RUS funding. The more affluent suburbs may either be too large to qualify for RUS loans, or have other sources of funds.

Table 14 also contains data on the average loan and grant approval levels for drinking water system improvements in each of the districts. Loan repayments are consistently amortized over a 38-year period, with average interest rates at or near 5.5%. Average interest rates in the respective districts seem representative of the municipal economic conditions, based on income levels, economic activity, and proximity to larger metropolitan areas. To some degree, average interest rate levels are correlated with MHI levels mentioned earlier. Procedures for interest rate determination are detailed above.

Table 14. Average New York RUS Drinking Water Loan and Grant Financing Characteristics.

Funding Information	All Districts		Salamanca		Ithaca		Potsdam		Whitesboro		Newburgh	
	$ 000	%	$ 000	%	$ 000	%	$ 000	%	$ 000	%	$ 000	%
Total Funding	195,997	100	31,446	16	29,266	15	46,066	24	45,169	23	43,307	22
RUS Funding	178,534	100	27,511	15	27,788	16	42,304	24	39,626	22	40,873	23
Loans	118,584	100	18,575	16	23,218	20	29,920	25	25,061	21	21,027	18
Grants	59,950	100	8,936	15	4,571	8	12,383	21	14,566	24	19,846	33
Other Grant Funding	17,463	100	3,935	23	1,478	8	3,762	22	5,543	32	2,434	14
Average Project Funding	1,315	100	925	100	1,540	100	1,097	100	1,558	100	1,732	100
RUS Funding	1,198	91	809	87	1,463	95	1,007	92	1,366	88	1,635	94
Loans	796	66	546	68	1,222	84	712	71	864	63	841	51
Grants	402	34	263	32	241	16	295	29	502	37	794	49
Other Grant Funding	117	9	116	13	78	5	90	8	191	12	97	6
Total Funding per Capita	$749		$862		$743		$759		$823		$624	
Total Funding per Hookup	$2,164		$2,083		$2,104		$2,216		$2,297		$2,105	
RUS Interest Rate (%)	5.38		5.34		5.66		5.35		5.20		5.48	
Repayment Period (years)	38		38		38		38		38		38	

Source: Primary data obtained from New York Rural Development district offices.

Note: Total funding percentages reflect the individual district fund proportion of total funding. Average funding percentages reflect the individual fund component proportion of total average funding.

Given the variation in population served and water demand in projects across districts, the variation in average project funding by district described above is to be expected. The type of project also affects the level of financing, but abstracting from these differences for the moment, it is instructive to examine funding levels on a per capita or per hookup basis. Average total project financing was nearly \$750 per capita or \$2,200 per connection (Table 14). And, despite the fact that average population served and funding levels per project are lowest in the Salamanca district, project costs in this district on a per capita basis are the highest (\$862). At the other end of the spectrum, projects in the Newburgh district are more costly and serve more people, but on a per capita basis the funding needs are only \$624, or only 72% of those in the Salamanca district.[18] Since many capital costs can be spread over larger service areas or populations, these data certainly support the hypothesis that substantial economies of size exist in water system improvements. A more formal test of this hypothesis, which accounts for different project and treatment objectives, is described below.

Breakdown of Capital Costs by Component

It is important, before evaluating specific components of the construction costs of the various types of projects, to gain some sense of the distribution of capital costs, and Table 15 contains this distribution for the seven major components.[19] Of the nearly \$1.3 million average capital costs, it is hardly surprising that construction and equipment costs account for the lion's share (75%) of the costs of system improvements. This percentage is quite stable across districts, as are the relative percentages in the other major categories as well. An estimated 12% are for engineering and project inspection, another 4% are for administration and legal fees, another 6% are for construction contingencies, and just over 2% are for other miscellaneous expenditures. Total costs in the various categories are also highly correlated with system size, population served, and water demand levels across districts. Any variation is largely due to differences in project type. For example, in a large project for the extension or improvement of a water distribution system, funds for construction may be the largest single component of total cost, whereas if the project is for a treatment facility a larger proportion of total cost may be accounted for by equipment. In addition, projects for repairs or improvements are likely to require less engineering work and inspection than projects involving new treatment plant construction or new distribution extensions. Construction contingencies are often estimated to be from 10 to 20% of construction costs, depending on the type of project and the expected accuracy of the project cost breakdowns.

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[18] Project financing per hookup varies much less across regions, ranging narrowly from nearly \$2,100 to under \$2,300.

[19] Capital costs as defined here are not exactly the same as the project financing totals discussed above. These minor discrepancies can be explained by the fact that the data in this section: a) fail to account for municipality contributions towards project costs; b) include contingency allowances which may or may not be realized; and (3) reflect the most current project estimates after construction has begun, while final financing levels may not be adjusted until total construction has been completed. Regardless it is the distribution of costs that is most important here, and these differences have little effect on this distribution.

Table 15. Drinking Water Project Capital Costs by New York Rural Development District.

Average Project Capital Costs	All Districts		Salamanca		Ithaca		Potsdam		Whitesboro		Newburgh	
	$	%	$	%	$	%	$	%	$	%	$	%
Total Capital Costs	1,279,859	100	888,231	100	1,468,337	100	1,074,572	100	1,688,892	100	1,507,545	100
Administration/Legal	52,939	4	34,122	4	51,344	3	50,078	5	74,244	4	58,854	4
Engineering/Inspection	151,055	12	83,328	9	159,132	11	140,526	13	203,835	12	189,939	13
Construction/Equipment	964,355	75	706,917	80	1,149,938	78	778,917	72	1,254,470	74	1,123,299	75
Site Development	10,774	1	2,961	0	268	0	9,405	1	25,492	2	14,186	1
Land/Right of Way	8,249	1	3,035	0	2,221	0	5,878	1	13,997	1	16,840	1
Miscellaneous	10,489	1	5,755	1	16,012	1	8,671	1	13,234	1	12,265	1
Contingencies	81,998	6	52,113	6	89,422	6	81,097	8	103,620	6	92,162	6
Number of Systems	146		33		19		40		29		25	

Construction and Equipment Cost Breakdown	All Districts		Salamanca		Ithaca		Potsdam		Whitesboro		Newburgh	
	$	%	$	%	$	%	$	%	$	%	$	%
Total	934,832	100	698,803	100	1,240,112	100	753,285	100	1,190,190	100	1,085,594	100
Distribution	277,382	30	328,074	47	164,163	13	192,881	26	329,704	28	389,334	36
Transmission	183,291	20	185,681	27	163,600	13	141,958	19	177,388	15	300,894	28
Treatment	276,836	30	22,300	3	800,560	65	183,266	24	488,348	41	130,769	12
Storage	154,828	17	141,235	20	92,977	7	192,214	26	128,713	11	198,738	18
Source Development	42,494	5	21,513	3	18,813	2	42,966	6	66,037	6	65,859	6
Number of Systems	129		32		16		37		27		17	

Source: Primary data obtained from New York Rural Development district offices.

Note: Percentages equal to zero represent percentages less than 0.5%, construction cost breakdowns are based on a smaller number of systems due to data limitations.

The lower section of Table 15 contains a breakdown of the construction and equipment costs into the project type classifications, for those systems where the disaggregation was specified.[20] As expected, expenditures for distribution, transmission, and treatment dominated all other expenditure categories. Of the nearly $1 million average costs for construction and equipment, distribution, transmission, and treatment accounted for 30, 20, and 30% shares, respectively. This is true across all districts, with a couple of notable exceptions. In the Salamanca district, with its reliance on connections to existing systems, the project emphasis was on distribution and transmission extensions and improvements, and on storage structures. A

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[20] Nearly all, 146 of the 149 systems, provided capital cost breakdowns for their projects. These data are summarized in the upper portion of Table 15. The lower portion of the table contain details about construction costs for the 129 systems for which these costs were broken out separately.

smaller share of the funds were requested for treatment or source development. In both the Ithaca and Whitesboro districts, expenditures for treatment were considerably higher than average on a percentage basis.

Some Concluding Remarks on the Descriptive and Financial Data

Up to this point, we have developed a detailed descriptive picture of the 149 water systems in the data set which includes information about the size of the systems, the demand for water, as well as the financial data and the associated operating margins. We have also examined the nature of the funding requirements for the various capital improvement projects funded by RUS. The analysis of the operating schedules and cash flow requirements over all Rural Development districts identified the very small or negative cash flow residuals characteristic of all systems. Systems with negative cash flow residuals will be unable to support themselves under existing or proposed operating and financial structure unless additional sources of revenue are found. For those systems where the cash flow residuals are positive, the residuals remain small and generate insufficient additions to capital fund reserves for future improvements or additions. The financial uncertainty and inadequate operating margins of municipal drinking water systems puts additional strain on the already strapped municipal resources.

In the overview of the financial data for the capital projects, it is clear that these systems face substantial costs not only to make the necessary improvements for drinking water systems to remain potable, but also to attempt to comply with ever increasing drinking water mandates. Not surprisingly, the major financial requirements are related to new or improved treatment facilities and improvements or extensions in distribution and transmission. It is now important to examine the costs in greater detail in an attempt to isolate in a systematic way the effects of various factors on the costs of distribution and treatment.

Econometric Models to Estimate Distribution and Treatment Costs

This statistical analysis begins with an examination of the transmission and distribution costs. A discussion of the rationale for understanding the factors affecting these costs is followed by the specification and estimation of the regression model. Finally, we examine the performance of the model in estimating these costs.

Transmission and Distribution Cost Estimation

Although there is much written about the financial benefits of small system consolidation to take advantage of economies of size in water treatment, it is also well known that as the service territory expands to exploit this advantage, it is possible to experience diseconomies of size in transmission and distribution, particularly in sparsely populated areas where many small systems are located.

In another report for this project, Boisvert and Tsao (1995) estimate the economies of size for a number of water system treatment technologies, as well as the simulated annual cost savings for consolidated systems compared with treatment by the individual small systems. The extent to which these annualized cost savings can be realized depends in large measure on whether they are offset by the added costs of distribution and transmission as the systems are consolidated. For this reason, it is imperative that we understand the factors affecting the costs of distribution and transmission. In addition to providing the basis on which to estimate the net savings due to consolidation, this type of relationship can provide existing municipal systems with a quick and convenient way to estimate the costs of extending service to new areas.

In order to specify and estimate the regression equation to identify the factors affecting distribution costs, data for 72 of the 149 systems were combined into a single data set. For a system to be retained, it was necessary that the project include distribution or transmission installation or improvement and for there to be in the loan file enough detailed information to identify the following items:

- System size and water flow demand
- Costs of excavation, backfill, restoration, and boring
- Transmission and distribution line specifications and cost
- Costs of pipe fittings, valves, and existing system connection
- Costs of water service and meter installation
- Number and per unit costs of hydrant installation
- Costs of specialized altitude, pressure, and other valves
- Construction, administration, and engineering contingency levels

In an attempt to gather as many observations from the original data set as possible, we included all systems that provided a breakdown of distribution and transmission costs, even if some of the overall project costs are for source development or treatment.[21] For the 72 systems in the data set, average distribution costs are nearly $775,000, ranging from $82,000 to over $2.6 million (Table 16). The average number of new service connections is 133, ranging from zero to 928. The number of hydrants installed ranges from zero to 84; the average is about 16. For systems connecting to a neighboring system, water hydrants and service connections may not be necessary. However, for an extension to a new district, service laterals and hydrants for fire protection potentially constitute a large share of total distribution costs. The average length of transmission and distribution main (not including service lateral distances) is almost 15,000 linear feet (lf) or over 2.5 miles.

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[21] Note that "distribution and transmission" and "distribution" are used interchangeably here. For ease of use and fluidity of text "distribution" may be used by itself, even though costs for both transmission and distribution are included.

Table 16. Descriptive Statistics for Use in New York RUS Distribution/Transmission Regression Equations (a).

Variable		Mean	Std. Dev.	Minimum	Maximum
Untransformed Variables (b):					
TDISRCOS	Total distribution costs ($) (c)	774,545	593,890	82,026	2,653,414
DISTRCOS	Distribution construction costs ($)	618,136	476,553	63,096	2,010,161
CELRCOS	Administrative, engineering, & contingency costs ($)	156,409	139,282	0	643,253
CONNECT	Number of service connections made	133	173	0	928
HYDRNTNO	Number of fire hydrants installed	16	17	0	84
TDMAIN	Linear footage of transmission & distribution watermain	14,197	11,213	700	61,000
Regression Variables:					
TDISCOLF	Total distributions costs per linear foot ($)	69.28	47.60	20.60	285.50
CONNPHLF	Service connections made per hundred linear feet	2.72	11.27	0.00	92.80
ADDPHU	Average daily water demand per connection (gpd)	138.93	153.69	34.71	1,243.00
PPIPEU8	Percent of trans. & dist. watermain less than or equal to 8"	78.40	32.54	0.00	100.00
PPIPEO8	Percent of trans. & dist. watermain greater than 8"	21.60	32.54	0.00	100.00
HYDPHLF	Number of hydrants installed per hundred linear feet	0.12	0.12	0.00	0.77
DUM601	Dummy Variable for Salamanca RECD District	0.34	0.48	0.00	1.00
DUM602	Dummy Variable for Ithaca RECD District	0.08	0.28	0.00	1.00
DUM603	Dummy Variable for Potsdam RECD District	0.32	0.47	0.00	1.00
DUM604	Dummy Variable for Whitesboro RECD District	0.14	0.35	0.00	1.00
DUM605	Dummy Variable for Newburg RECD District	0.11	0.32	0.00	1.00

Source: Primary data obtained from New York Rural Development district offices.

(a) All variables displayed in level terms, not logarithms.

(b) These variables consist of variable statistics before conversion to a linear footage basis for the regression equations.

(c) All costs in 1992 Dollars, converted by ENR Construction Cost Index (ENR, 1995).

Specification of the Regression Equation and the Empirical Results

Once the data set containing these items was assembled, the general form of the regression relationship could be specified as:

$$\begin{aligned} TDISCOLF_i = {} & \beta_0 + \beta_1 CONNPHLF_i + \beta_2 CONPHLFS_i + \beta_3 ADDPHU_i \\ & + \beta_4 PPIPEO8_i + \beta_5 HYDPHLF_i + \alpha_1 DUM602_i + \alpha_2 DUM603_i \\ & + \alpha_3 DUM604_i + \alpha_4 DUM605_i + \omega_i \, , \end{aligned}$$

where TDISCOLF is total distribution and transmission costs per linear foot, CONNPHLF is the number of service connections installed per hundred linear feet for i=1 to n observations, CONPHLFS is the quadratic of CONNPHLF, ADDPHU is the average daily demand per hook-up in the service area, PPIPEO8 is the proportion of transmission and distribution water main installed over eight inches in diameter, HYDPHLF is the number of hydrants installed per hundred linear feet, DUM602, DUM603, DUM604, and DUM605 are dummy variables for the New York Rural Development service areas, and ω_i is the random error component.

The results of the regression analysis are reported in Table 17 for three forms of the equation. Model 1 differs from a linear model only in that there is a squared term for the number of connections per linear foot. In model 2, the dependent variable is transformed into its natural logarithm, while in model 3, all variables (with the exception of the service area dummy variables) are transformed into their natural logarithms.

Table 17. Regression Results for Total Distribution Costs per Linear Foot. (a)

	Model 1 (b)			Model 2			Model 3		
Regressors	Estimate	t-ratio	Elasticity	Estimate	t-ratio	Elasticity	Estimate	t-ratio	Elasticity
INTERCEPT	8.768	1.20		3.279	33.60		2.988	7.171	
CONNPHLF	7.149	5.47	0.27	0.080	4.56	0.21	0.205	5.125	0.12
CONPHLFS (c)	-0.053	-3.64		-0.001	-3.42		0.019	4.990	
ADDPHU	0.027	1.14	0.05	0.001	1.71	0.07	0.167	1.788	0.17
PPIPEO8	0.407	3.67	0.13	0.003	2.28	0.07	0.004	2.769	0.00
HYDPHLF	122.794	4.24	0.22	1.490	3.84	0.18	0.036	2.610	0.04
DUM602	34.351	2.80		0.543	3.31		0.394	2.030	
DUM603	27.853	3.37		0.447	4.04		0.434	3.337	
DUM604	40.994	3.96		0.631	4.55		0.527	3.390	
DUM605	24.311	2.18		0.483	3.23		0.524	3.290	
R-square	0.733			0.646			0.583		

Results of Within Sample Prediction:

		Model 1		Model 2		Model 3	
	Actual	Estimate	Avg % Error	Estimate	Avg % Error	Estimate	Avg % Error
Avg Cost per lf	69.29	74.492	7.51	73.641	6.28	61.831	-10.76
Std Deviation	47.60	41.199	--	46.151	--	41.010	--

Source: Primary data obtained from New York Rural Development district offices.

(a) Total distribution costs per linear foot include construction, administration and legal, engineering and inspection, and contingency allowances.

(b) Model 1 provides a linear specification with the exception of the quadratic term on the number of connections; in Model 2 the dependent variable is transformed to its natural logarithm; and in Model 3, all variables with the exception of the district dummy variables are converted to their natural logarithms.

(c) CONPHLFS = CONNPHLF squared for the linear form and is equal to [ln(CONNPHLF)] squared for the natural logarithm form.

The estimated equations are quite good, particularly for the linear model where about 73% of the variation is explained, and the signs on the estimated coefficients for the variables are as expected. The standard errors on the coefficients are generally quite low. Costs per linear foot of main increase with the average daily demand per connection, as well as with the proportion of main that is greater than eight inches in diameter. The number of hydrants adds importantly to cost per foot, as does the number of connections per 100 linear feet. However, as the number of connections increases, the cost rises, but at a decreasing rate. This is reflected in the negative sign on the coefficient for the number of connections squared.

The dummy variables on the New York service areas, given all other variables held constant, dictate the incremental difference in costs relative to the omitted service area, the Salamanca district. The positive values for all four districts were expected, given the lower average transmission and distribution cost expenditures per linear foot relative to the remaining districts.

To facilitate comparison of the results based on these three equations, the changes in distribution costs due to an incremental change in one of the dependent variables are put on a percentage basis. These elasticities, as they are called, are also reported in Table 17. On this basis, the effects of changes in the explanatory variables on distribution and transmission costs are much more similar in models 1 and 2 than in model 3, although in all models elasticities are positive and less than unity. The percentage change in cost is much greater for a one percent change in the number of hydrants or connections than for percentage increases in either water demand or the amount of pipe of a larger size. For example, a one percent increase in the number of connections increases transmission and distribution cost per linear foot by nearly three-tenths of one percent based on model 1 and about two-tenths of one percent according to model 2. Increasing the number of hydrants by one percent leads to a increase in cost by about two-tenths of one percent in both of the first two models.

Although the regression results are particularly encouraging, and we can place a great deal of confidence in the magnitude of the individual coefficients, it is important also to determine the extent to which these equations can be used to predict accurately the cost of distribution over a wide range of conditions. This is particularly critical given the logarithmic nature of two of the three equations. In these cases, the R^2 value reflects the amount of variation in the logarithm of cost explained by the model. It is a much less accurate indicator of how well the model predicts cost itself because cost is a nonlinear transformation of the dependent variable in these final two regressions.

For this reason, it would be helpful to have sufficient information for other systems so that the performance of the equation could be tested on systems not used in the estimation. Unfortunately such data do not exist, and the best that can be done is to use the within sample predictions as a measure of the model's performance. These results are again quite encouraging, with average percentage errors (in the prediction verses the actual) ranging from 6.3% for model 2 to -10.8% for model 3 (Table 17). In general, the lower levels of distribution costs tend to be under-predicted slightly, while relatively high distribution costs in the data are predicted much more accurately. Although model 1 produced a slightly higher R^2, its percentage error in prediction is slightly higher than that of model 2. Given the expected use and applicability of the model estimated here, it would be difficult to choose between the first two models, but either seems preferable to model 3.

Estimating the Cost of Water Treatment Technologies

We now turn our attention to estimating indirect cost functions reflecting the several types of water treatment technologies represented in our sample of water systems. These cost functions provide quantitative estimates of any economies of size associated with each treatment technology, as well as the means to forecast average system costs by treatment and system size.

Of the 149 observations in the data set, 45 of them (30%) are capital projects funded, at least in part, for the purpose of installing new water treatment technologies. Of these 45 systems, 37 had adequate detailed information on major components of project costs to disentangle those due to treatment from those due to other project objectives such as new or improved storage or transmission and distribution. These systems are the primary focus of this section of the report.

Water Treatment Processes Used by All Systems. It is important to point out first that most of the 141 distinct water systems represented by the 149 RUS files do engage in some type of water treatment. Therefore, for completeness, and to put this analysis into proper perspective, we begin with a brief discussion of the range in treatments undertaken by all 141 water systems. In those cases where the water treatments being used are not reported in the files, the FRDS-II data base provided the needed information. Since 25 of these water systems purchase treated water from neighboring systems, we also used both the RUS and FRDS-II data sources to track down which treatments the sellers conducted prior to the water transfer.

The frequencies with which the 141 water systems use 20 different types of water treatment are summarized in Table 18, where systems are grouped according to the primary source of water and whether treated water is purchased from neighboring systems. Since over 70% of all the systems employ more than one type of treatment, the column totals in the table add to well over 100%. Several patterns are readily apparent from the table. First, for those systems purchasing treated water, the frequency with which nearly every type of treatment is used is substantially higher than for those systems treating their own water. This is easily explained because the systems selling water are likely to be larger and are also likely to insist on a generally higher level of treatment both for their own customers and to avoid any problems with systems to which they sell water. Second, with the exception of chlorine disinfection, which is used by virtually all systems in the sample, and nationally as well (Boisvert and Schmit, 1996), the relative frequency of use for each type of treatment is much higher for systems relying primarily on surface water rather than on ground water.

Compared with chlorination, filtration, at least for surface water systems, is the next most commonly used treatment process. Nearly 60% of all systems have some type of water filtration process, whereas this is true for over 90% of all water systems relying primarily on surface water. To ensure the efficient operation of their filtration processes, these same systems commonly use methods of coagulation, sedimentation, flocculation, and rapid mixing in conjunction with one another. Algae control and sludge treatment also may be grouped in the same category, but are used to lesser degrees.

Table 18. New York RUS Data Set Treatment Use for Own and Purchased Treated Water Systems. (a)

	All Water Sources			Ground Water			Surface Water		
Treatment Type	Owned	Purchased	Total	Owned	Purchased	Total	Owned	Purchased	Total
					%				
Algae Control	16	44	21	10	33	11	23	45	30
Sludge Treatment	4	48	12	1	33	3	9	50	22
Sequestration	1	0	1	1	0	1	0	0	0
Coagulation	12	80	24	4	67	7	23	82	42
Sedimentation	10	64	20	6	33	7	17	68	33
Flocculation	11	76	23	4	67	7	21	77	39
Rapid Mix	9	76	21	3	67	6	17	77	36
Aeration	17	32	20	17	0	17	17	36	23
Activated Carbon	2	56	11	0	33	1	4	59	22
Ion Exchange	3	4	4	4	33	6	2	0	1
Diatomaceous Earth Filtration	5	12	6	0	33	1	13	9	12
Slow Sand Filtration	16	12	15	3	33	4	34	9	26
Pressure Sand Filtration	4	0	4	6	0	6	2	0	1
Rapid Sand Filtration	16	36	19	7	33	8	28	36	30
Other Filtration	5	52	13	4	33	6	6	55	22
Chlorination	98	100	99	99	100	99	98	100	99
Fluoridation	21	64	28	22	33	22	19	68	35
pH Adjustment	16	52	23	12	100	15	23	45	30
Inhibitors	9	0	7	6	0	6	13	0	9
Permanganate	3	0	3	1	0	1	6	0	4

	All Water Sources			Ground Water			Surface Water		
Number of Treatments	Owned	Purchased	Total	Owned	Purchased	Total	Owned	Purchased	Total
					%				
0	1	0	1	1	0	1	0	0	0
1	34	0	28	46	0	44	17	0	12
2	30	4	26	30	0	29	30	5	22
3	11	0	9	12	0	11	11	0	7
4	6	8	6	0	33	1	15	5	12
5 or more	17	88	30	10	67	13	28	91	48

Source: Primary data obtained from New York Rural Development district offices.

Note: Percentages equal to zero represent percentages less than 0.5%.

(a) Of the 141 unique water systems, 116 perform their own treatment (69 ground water and 47 surface water), including one ground water system currently applying no treatment. The remaining 25 systems (3 ground water and 22 surface water) purchase treated water from neighboring systems. The treatments performed by those sellers are used to calculate the above percentages. The overall average number of treatments applied is 3.72 (2.33 for ground water and 5.17 for surface water).

Aeration is another common treatment for both surface and ground water systems and is used by 20% of the systems, nearly double the rate for New York State and the nation. Other specialized treatments, such as activated carbon and ion exchange processes, were used minimally, with shares of only 11% and 4%, respectively, compared with national and state averages of about five percent for each category.

Other additives for corrosion control, softening, fluoride, or pH control were relatively common, but the use of these types of treatments are source specific and tend not to be directly related to compliance with SDWA. Chemical addition for pH adjustment was used on 23% of the systems, 15% for ground water and 30% for surface water systems, in both cases slightly higher than national and state averages. Inhibitors follow a similar pattern and are used by nearly 7% of the systems. This is identical to the national proportion of 7%, but much higher than the overall state proportion of under 1%. Closely following national (24%) and state (19%) levels, fluoride is used in 28% of the systems in the sample. Finally, the addition of permanganate is found in just 3% of the systems.

Projects Funding New Treatments. The data, from the 37 observations for which adequate capital and operating cost information are available, needed for the econometric estimation of the indirect cost functions are summarized in Table 19. In this table, the means on the treatment dummy variables provide the proportions of these systems requesting funds to install the various treatment processes. Because of the relatively small sample size, some types of treatments are combined into single categories for purposes of estimation. In this sample, about 65% of all new treatments are related to some type of filtration. All but five of these systems were surface water systems, directly tied to filtration requirements for compliance with the SDWA Surface Water Treatment Rule (SWTR).[22] In addition, ground water sources under the direct influence of surface waters also would fall under the SWTR mandate. The limited number of ground water sources implementing filtration use smaller direct filtration technologies for turbidity reductions, iron removal, microbe removal, or removal of some inorganic (IOC) or synthetic organic chemicals (SOC).

It is interesting that those smaller municipal water systems subject to filtration requirements under the SWTR choose predominantly slow sand filtration; this technology is an excellent choice for small systems that want low maintenance requirements, but also have access to a surface water source of high quality. While annual maintenance requirements are quite low, this technology does require a large amount of land for the needed filter area. Membrane technologies such as microfiltration, ultrafiltration, and reverse osmosis are also available for SWTR compliance, but are not implemented here, primarily because of the high operating costs, maintenance requirements, and additional treatment requirements.

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[22] The SWTR (54 FR 27486) was promulgated in June 1989 and requires surface water source systems to apply disinfection and may require filtration unless some 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.

Some Economic Theory for Cost Function Estimation. Our intent is to use data from these 37 systems to estimate the economies of size for water treatment technologies, and to quantify the marginal cost of adding new alternative treatment options to existing systems. To do this, indirect cost functions are estimated econometrically on the basis of annualized capital plus operating costs for these systems. Thus, before reporting the results, it is essential that we recall a bit about the theory of cost and identify some properties of the translog indirect cost function used in the analysis below. This particular form of the cost function is selected for its more flexible qualities, including the allowance for economies of size to vary with output.[23]

Table 19. Descriptive Statistics for New Treatment Annualized Cost Function Estimation.

Variable Name	Variable Definition	Mean	Std. Dev.	Minimum	Maximum
Project and Operating Costs:					
TCAP	Total capital cost ($)	2,048,874	1,619,653	176,982	7,938,883
CAPTRT	Treatment capital cost ($)	1,363,646	1,556,858	22,232	7,938,883
ANCAPTRT	Annualized treatment capital cost ($)	138,891	158,570	2,264	808,597
OM	Annual system operation and maintenance cost ($)	169,146	193,916	5,475	902,145
TOTCOST	Total system annualized cost ($)	308,037	335,699	16,122	1,710,742
Size and Demand Characteristics:					
ADD	Average daily demand (gpd)	393,658	512,202	15,000	2,700,000
POPN	System population served	2,475	2,281	143	9,470
HSHLDS	System households served	890	790	46	3,266
SURFACE	Dummy variable for surface water system	0.76	0.43	0.00	1.00
GROUND	Dummy variable for ground water system	0.24	0.43	0.00	1.00
Capital Cost Treatments Installed:					
CHLOR	Chlorination dummy variable	0.65	0.48	0.00	1.00
AERAT	Aeration dummy variable	0.11	0.31	0.00	1.00
DIRFILT	Direct filtration dummy variable	0.14	0.35	0.00	1.00
SSFILT	Slow sand filtration dummy variable	0.35	0.48	0.00	1.00
DEFILT	Diatomaceous earth filtration dummy variable	0.08	0.28	0.00	1.00
RSFILT	Rapid sand filtration dummy variable	0.08	0.28	0.00	1.00
COAGFILT	Coagulation/Filtration dummy variable	0.08	0.28	0.00	1.00
OFILT	Other filtration = DEFILT+RSFILT+COAGFILT	0.24	0.43	0.00	1.00

Source: Primary data obtained from NY RECD district offices.

Note: All costs are in 1992 dollars, capital costs are converted by the ENR Cost Construction Index and operation and maintenance costs are converted by the ENR Wage History Index (ENR, 1995). Households and water demands are included for reference here, but are not included in the cost function estimation. Treatment dummy variables are equal to one if the treatment was included in the capital project, zero otherwise.

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[23] For a more detailed discussion of the economic relations of production, input demand, and cost theory for the water supply industry, one is referred to Boisvert and Tsao (1995).

Other studies related to rural utility or municipal financing have also used the translog function (Boisvert and Tsao, 1995; Christensen and Greene, 1976; Bhattacharyya *et al.*, 1994; and Deller and Halstead, 1994).

The generalized form of the translog cost function can be written as

$$\ln C = \ln \beta_0 + \alpha \ln q + \delta (\ln q)^2 + \sum_i \beta_i \ln P_i + \tfrac{1}{2}\sum_i \sum_j \gamma_{ij} \ln P_i \ln P_j + \sum_i \phi_i \ln P_i \ln q \,,$$

where P_i is the price of the i^{th} input, q is the output, and $\gamma_{ij} = \gamma_{ji}$ by Young's Theorem.[24] To make the cost function homogeneous of degree one in prices the following restrictions are imposed

$$\sum_i P_i = 1,\ \sum_i \phi_i = 0,\ and\ \sum_j \gamma_{ij} = 0\ for\ i = 1\ to\ n.$$

Since the underlying production function is not necessarily translog (i.e. not self-dual), the translog function can also be thought of as a local second-order approximation to an arbitrary cost function. In logarithmic form, this cost function is linear in parameters and can then be estimated using ordinary least squares (OLS). Under the assumption that prices are uncorrelated with output, parameter estimates for the above cost function remain unbiased (Judge *et al.*, 1988).

Since prices do not vary in this analysis, the translog cost function reduces to

$$\ln C = S_o + \alpha^* \ln q + \delta (\ln q)^2,$$

$$where\ S_o = \ln \beta_0 + \sum \beta_i \ln P_i + \tfrac{1}{2}\sum \sum \gamma_{ij} \ln P_i \ln P_j \ ,\ and$$

$$\alpha^* = \alpha + \sum \phi_i \ln P_i \,.$$

Thus, the function reduces to the logarithm of cost being a quadratic function of the logarithm of some suitable measure of system capacity or output. Christensen and Greene (1976) point out that in this restricted form the underlying production function is homothetic but not homogeneous, and therefore economies of size can vary with output levels.[25] Hanoch (1975) has

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[24] Specifically, Young's Theorem states that: suppose $y = f(x_1, x_2, \ldots, x_n)$ is twice continuously differentiable on an open region J ε $\Re^n$. Then, for all x ε J, and for each pair of indices i, j, $\frac{\partial^2 f}{\partial x_i \partial x_j}(x) = \frac{\partial^2 f}{\partial x_j \partial x_i}(x).$

[25] Boisvert and Tsao (1995) clearly explain the distinction between economies of scale and economies of size "the economies of scale measure the proportional change in output due to a one percent change in all inputs. The returns to size relates to the proportional change in output as factors are expanded in least-cost proportions along an expansion path. Only in the case of homothetic [production functions], or homogeneous production functions such as the Cobb-Douglas is the expansion path a linear ray out of the origin. In this case, returns to scale are equal to returns to size. In the case of non-homothetic functions, the two concepts are not equivalent. When referring to average costs declining (increasing or constant) as factors are increased in least-cost proportions, the correct term to use is really increasing (decreasing or constant) returns to size."

this way, the economies of size vary with output, as well as type of treatment. Further, the coefficients on the treatment regressors provide the incremental annualized cost for the associated treatments at a particular size of system.

Table 20. Regression Results for New Treatment Annualized Cost Function Estimation.

Regressors	Description	Coefficient	Std. Error	t-ratio
INTERCEPT	Intercept term	8.49	0.32	26.94
SURFACE	Surface water dummy variable	0.27	0.24	1.13
LPOPNSQ	[Ln (Population)] squared	0.04	0.01	5.16
LPOPAERA	[Ln (Population)] * AERAT	0.10	0.05	1.93
LPOPDIR	[Ln (Population)] * DIRFILT	0.15	0.05	3.05
LPOPSSF	[Ln (Population)] * SSFILT	0.20	0.04	4.59
LPOPOFIL	[Ln (Population)] * OFILT	0.18	0.04	3.94
R-square =	0.89			

Results of Within Sample Prediction of Average Costs Per Capita:

Treatment Type	Average Population	Average Cost Per Capita Actual	Average Cost Per Capita Predicted	Average Cost Per Capita % Error
		$	$	%
Chlorine	441	73.05	68.85	-5.75
Aeration	3,348	61.65	54.36	-11.82
Direct Filtration	2,478	113.18	111.20	-1.75
Slow Sand Filtration	2,806	169.64	162.24	-4.36
Other Filtration	2,963	150.57	133.24	-11.51
All Treatments	2,475	130.03	121.48	-6.58

Source: Primary data obtained from New York Rural Development district offices.

Note: The translog functional form was used; hence, the dependent variable is the natural logarithm of total system annualized costs, and population levels are converted into their natural logarithms. The level population regressor was not included due to its high collinearity with the quadratic term and less favorable results, however, it is included with the treatment interaction terms.

As expected, the coefficient on the logarithm of population squared is positive and depicts increasing annualized costs with increases in size. In terms of annualized costs, including both annual capital and operating costs, slow sand filtration is shown to have the largest incremental effect on cost, population held constant. Other filtration is the next largest, with direct filtration providing the lowest marginal increase of the filtration types included. Although slow sand filtration's annual operating requirements are relatively low, the capital costs, and most notably the size of land area required for operation, increase total annualized costs above that of the remaining treatments. Direct filtration, which is generally used only when the water quality is high, requires potentially more operation and maintenance but the capital requirements are smaller. The aeration technologies exhibit the lowest marginal increase in annualized costs for all treatments included. Again, the costs of chemicals and operation are relatively low, and capital requirements are modest as well. In fact, the highest average capital cost is for slow sand filtration, nearly $98 per capita and well above the $84 per capita cost for other filtration (Appendix Table A1). Average operating cost as a proportion of total cost is lowest for slow sand filtration as well (44%). On a percentage basis, O&M costs were highest for aeration (85%) and chlorine disinfection (70%).

Although the amount of explained variation and significance of the parameter estimates is appealing, it is also important to look at this estimation in terms of its ability to predict costs for individual systems or for more general policy cost estimation analyses. The bottom of Table 20 displays the results of the within-sample prediction procedure. Ideally, additional data would be used to test the predictive ability of the model; however, due to the limited number of observations and concern for degrees of freedom, a within-sample prediction procedure was warranted.

Over all treatment categories, for an average system of nearly 2,500 people, the average actual cost per capita is over $130 compared with the average predicted value of approximately $121, for an average prediction error of under 7%. Given the limited amount of data and the nonlinear tranformation of annualized costs, this error level is minimal. Since the model is estimated in double logarithmic form, the antilog of predicted annualized costs is necessary to return to level dollar terms. Furthermore, all treatment categories resulted in average percent errors of under 12%, with the lowest occurring for direct filtration at under -2%. While individual system predictions may vary more widely, the average prediction errors are well within an acceptable range. Individual operating and cost data are displayed in Appendix Table A1 for all 37 systems. Both annualized costs on a level and per capita basis are included to identify similarities and differences in the cost data, and point to reasons for any potential outliers. Generally, costs tend to be slightly under-predicted at high population levels and slightly over-predicted at relatively low population levels.

Estimates of the economies of size that can be derived from this equation are of particular interest. Heretofore, the only available estimates of economies of size for water treatment technologies applied to small systems have been based on "pseudo-data" derived from the engineering equations found in EPA's small public water system Best Available Technology (BAT) recommendations (Malcolm Pirnie, Inc., 1993). These estimates are reported by Boisvert and Tsao (1995), but they have been received cautiously because they are based on data generated from these engineering equations that go somewhat beyond the system size for which the engineering equations were designed.[27] Thus, in addition to providing new information on the economies of size, these results based on RUS data can serve to validate earlier estimates.

The estimated economies of size from this study are given in Table 21, along with similar estimates using procedures by Boisvert and Tsao (1995) based on the BAT engineering equations model results.[28] In order to reflect as closely as possible the capital and operating costs inherently included in the RUS data, the BAT simulations were run by including the "additional costs" for site development, building, fence, road, and land acquisition capital costs, and distribution operation and maintenance costs. In the table, the economies of size are reported for the several points reflecting the range in the level of population served for the RUS data.[29]

Based on a comparison of these different estimates of economies of size, the conclusions are both largely consistent and encouraging. In the case of slow sand and direct filtration, economies of size based on the RUS data lie consistently below those based on the BAT data, whereas for aeration and other filtration, the aggregate estimates based on RUS data lie consistently in between those for the separate techniques based on the BAT data. In contrast, with the exception of the very small systems, BAT estimates of economies of size for chlorine are consistently lower than those based on the RUS data. If it can be argued that the results based on the RUS data are more representative of the true situation, then this suggests that estimates of economies of size based on the BAT data are generally biased, but systematically so. This consistency is good news and provides an important guide to the interpretation and proper use of these kinds of characteristics generated from these kinds of engineering relationships. RUS estimates suggest that any economies of size for filtration are nearly exhausted as population exceeds 10,000, while for aeration economies of size still exist for systems of this size.

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[27] See Boisvert and Tsao (1995) for a detailed discussion of the BAT document (Malcolm Pirnie, Inc., 1993) and the simulation model from which it was developed.

[28] The regression equations estimated from the BAT data are in Appendix Table A2. The simulation model can be run for both "small" and "large decentralized" water systems whereby small systems generally represent those systems in isolation, maintaining their own systems, and servicing under 1,000 people. Large decentralized systems are those same sizes of systems but were part of a much larger overall system structure, and therefore the treatment would not only be for that small system, but also for other smaller systems within its service area. For this exercise, only chlorine (i.e. no additional treatment) was assumed "small," while the remaining treatments followed the "large decentralized" classification. The major differences between the cost factors for "small" and "large decentralized" systems are related to engineering, site work, allowances for contingencies, and labor rates, all of which are much higher for "large decentralized" applications. These differences reflect higher aesthetic standards and local codes imposed on the larger systems, and the fiscal resources larger systems have for financing them (Malcolm Pirnie, Inc., 1993). As such, one would expect that estimates of economies of size for any given treatment based on the BAT data for "large decentralized" systems should be larger than for those based on BAT data for the "small" systems.

[29] For this analysis, there were insufficient observations to treat the various types of aeration and other types of filtration separately. However, to the extent possible, estimates for separate types of aeration and other filtration are provided for comparison purposes.

Table 21. Economies of Size, RUS Estimation versus BAT Simulation Model (a).

	System Population				
	Minimum	Midmin	Mean	Midmax	Maximum
Technology	143	1,309	2,475	5,972	9,470
Chlorine:					
BAT	0.68	0.32	0.22	0.09	0.02
RUS	0.59	0.41	0.36	0.28	0.25
Aeration:(b)					
BAT Packed Tower	0.64	0.47	0.42	0.34	0.31
BAT Diffused Air	0.44	0.18	0.10	0.00	-0.06
RUS	0.49	0.31	0.26	0.19	0.15
Direct Filtration:					
BAT	0.75	0.44	0.35	0.23	0.17
RUS	0.44	0.26	0.21	0.14	0.10
Slow Sand Filtration:					
BAT	0.39	0.25	0.21	0.15	0.12
RUS	0.39	0.21	0.16	0.09	0.05
Other Filtration:(c)					
BAT Diatomaceous Earth	0.46	0.10	0.00	-0.14	-0.22
BAT Coagulation/Filtration	0.73	0.37	0.27	0.13	0.06
RUS	0.42	0.23	0.18	0.11	0.07

Source: Primary data from New York Rural Development district offices, BAT results based on Boisvert and Tsao (1995).

(a) All BAT costs are based on the large decentralized assumptions, with the exception of chlorine. RUS estimation assumes chlorine and aeration as ground water source systems and all filtration treatments as surface water systems, based on the original data sources.

(b) RUS aeration includes packed tower aeration and diffused air stripping.

(c) RUS other filtration includes diatomaceous earth, rapid sand, and coagulation/filtration.

Comparisons of these estimates of economies of size with those from other studies are difficult because there have been no attempts to focus on systems of this very small size. However, Feigenbaum and Teeples (1993) used 1970 data on large water systems to estimate general economies of size of 0.15. Bhattacharyya *et al.* (1994) used similar data for 1989 and derived a similar measure of 0.14. In both cases, there was no clear indication of the range in system size embodied in the data, but the fact that most of the estimates here lie at or above these estimates is appealing (especially at mean levels). *What is needed to reconcile these alternative measures of economies of size is an analysis of data which includes systems of a wide range in size, from the smallest to the largest. The most recent national survey of public water systems conducted by EPA may be such a source of data.*

Whereas economies of size levels are crucial in evaluation of small system compliance to SDWA mandates and possible consolidation with larger systems, a comparison of average cost is important in assessing the potential use of any of these models for prediction purposes. Figure 7 displays curves for average annualized costs per capita (from regression equation estimates) for the five water treatment technologies. Not surprisingly, average costs decline consistently as population served increases. However, consistent with the estimates of economies of size, average cost curves become relatively flat once population served exceeds 3,000.

A comparison of the average costs of treatment implied by the cost functions based on RUS and the BAT data helps place these results in proper perspective (Figures 8 through 10). As one would expect, the average costs are lowest for chlorine, and are highest for slow sand filtration, regardless of which data are used to estimate the cost functions. In contrast, the average costs of aeration based on the BAT data ranked second only to slow sand filtration, whereas average costs based on the RUS data ranked just above chlorination. And it is only in the case of aeration that average costs based on BAT are above those based on RUS data.

While these comparative results are not as encouraging as one would have hoped, there are several possible explanations. One of the most important factors is the fact that operation and maintenance costs in the BAT model are probably more narrowly defined than in the RUS data. Further, average labor rates assumed in the BAT model are underestimated relative to those in RUS files for which that information is available.[30] In addition, BAT cost estimates account only for the minimum equipment needed to provide treatment for the design flow with no back-up components (Malcolm Pirnie Inc., 1993). Since this is not consistent with most state design standards, the cost estimates are also low relative to those found in the New York RUS data.

GENERAL CONCLUSIONS AND POLICY IMPLICATIONS

A number of important conclusions and policy implications can be drawn from the analyses in this report. To begin, it is clear that the RUS's WWD program operated by the Rural Development mission area (formerly RECD) has been, for the past five decades, the primary source of low-cost financing for small community water and wastewater improvements. More than 35,000 funding packages, totaling nearly $18 billion, have been obligated to assist water and wastewater systems in over 14,000 small rural communities throughout the country.

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[30] The fact that labor and operation and maintenance requirements, in general, are relatively low probably explains why RUS cost estimates are below those from BAT data throughout the size range for aeration and for larger systems in the case of chlorine.

Figure 7. RUS Average Cost Curves For Alternative Treatment Technologies

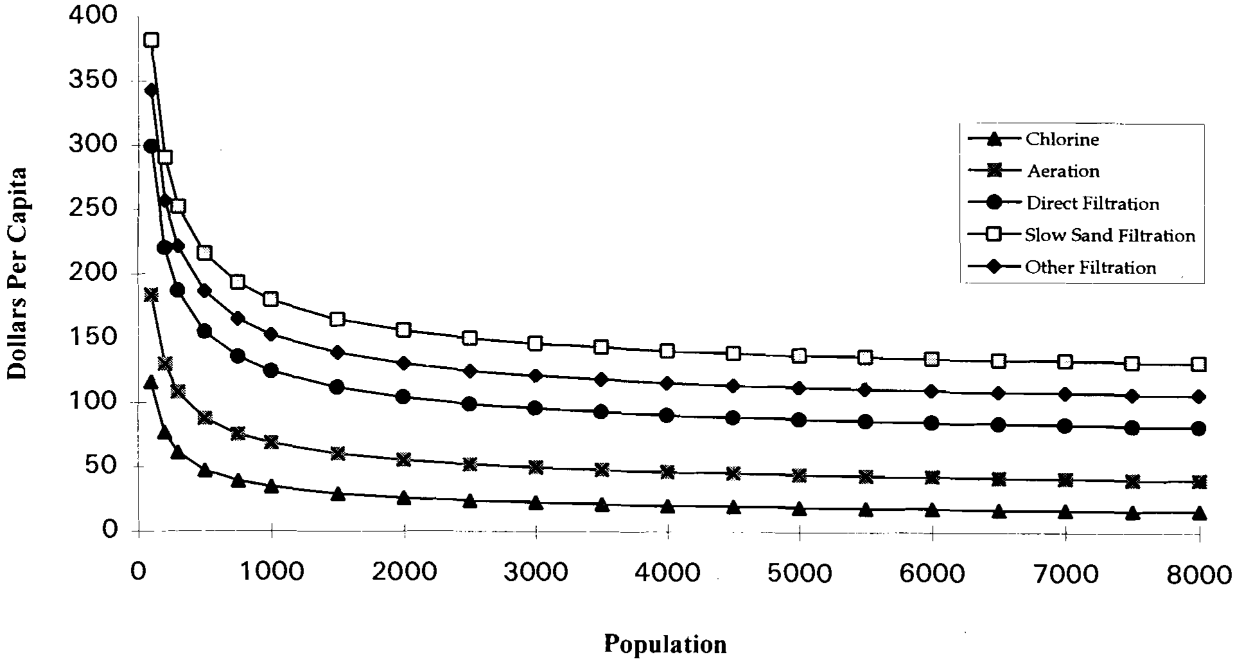


Figure 8. Average Cost Comparison, Chlorine and Aeration

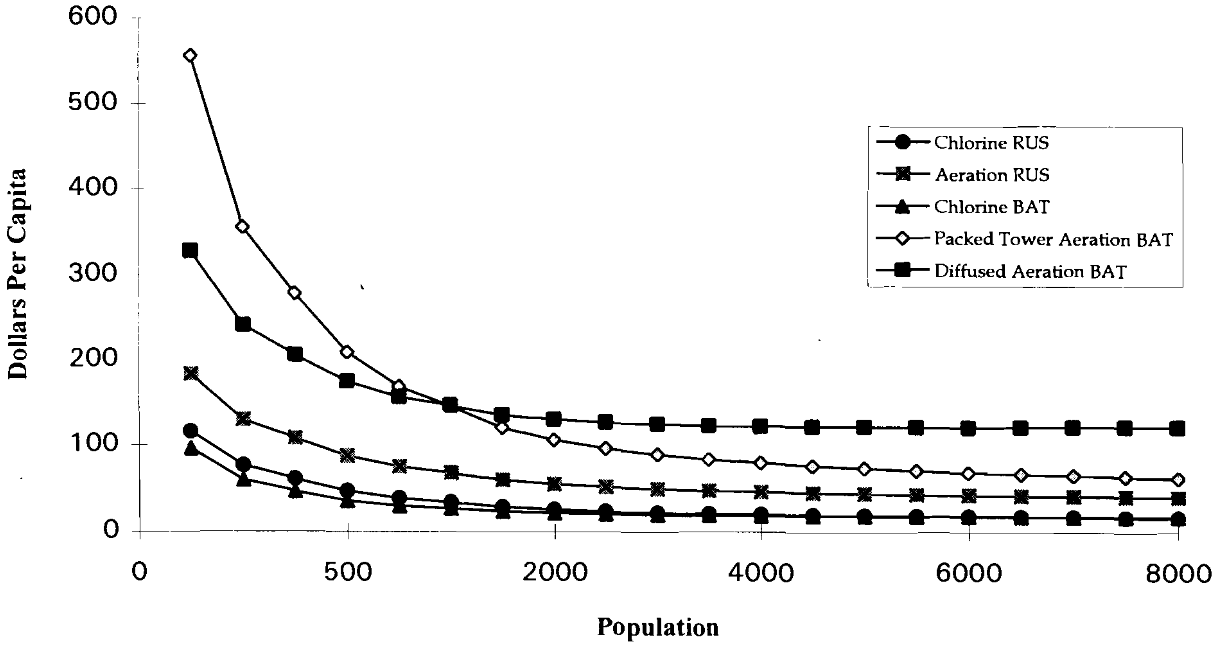


Figure 9. Average Cost Comparison, Direct and Slow Sand Filtration

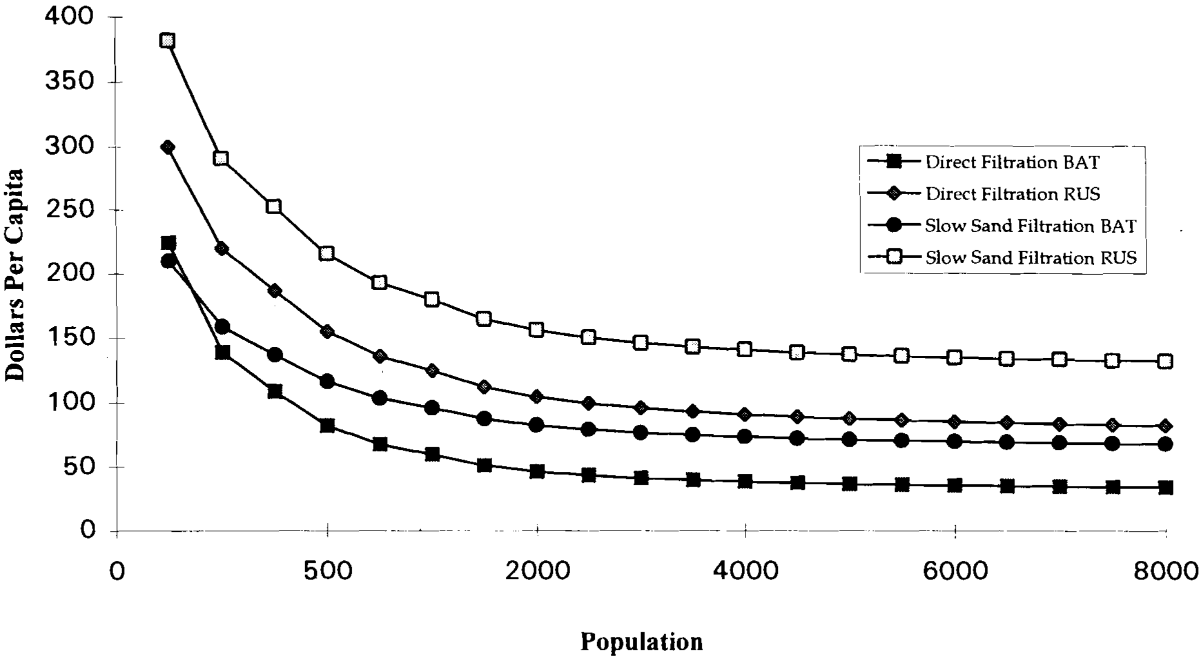
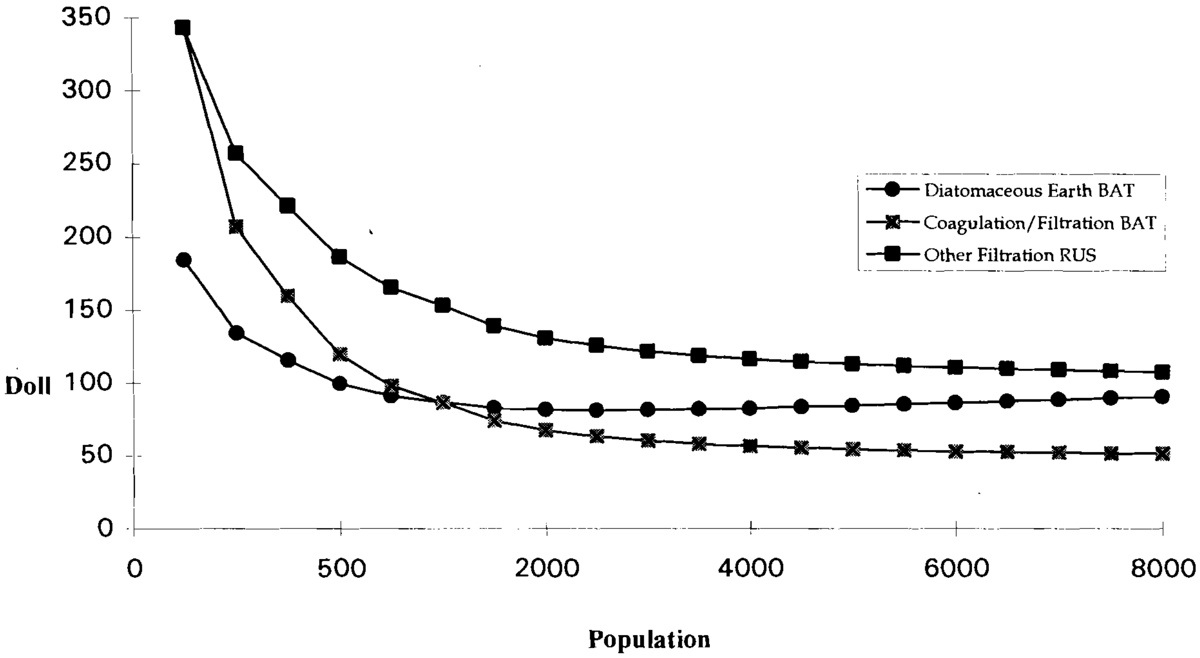


Figure 10. Average Cost Comparison, Other Filtration



Today, the program continues as an integral part of funding support for public water systems faced with increasing SDWA regulations and aging water system infrastructure. After a period of relatively high funding during the late 1970s, obligations dropped considerably in the 1980s before rebounding in the 1990s to levels above $1.3 billion in 1995. However, in real dollars the purchasing power of the recent obligation levels have yet to rebound to pre-1980 levels. The relative funding shortages, compounded by increased monitoring and treatment requirements and the need for improvements in infrastructure have placed added pressure on RUS to allocate available funds in the most efficient and effective way possible. While RUS encourages cooperative funding packages with other state and federal agencies, the number of actual cooperative arrangements of this kind has been small.

In an attempt to assist those communities most in need of funds, RUS funds are allocated to individual states based on the relative size of the rural population and MHI levels, while priorities for individual project obligations are based on household income relative to user charge increases, emergency health and sanitation considerations, and other rural-based criteria. The importance of rural population and median income levels in allocations to states is easily verified through an estimated regression equation on 1990 RUS allocations to individual states. On average, RUS allocations rise with rural population, but less than proportionately, whereas they fall more than proportionately to increases in rural MHI. The fact that RUS regions in the eastern United States received funding above that determined solely by these rural population and income criteria is strong evidence that other factors are important as well. Whether this additional funding is due to a higher incidence of pressing health problems or increased political power and lobbying efforts is impossible to determine without additional and more specific data.

Due to RUS's rural orientation, financial assistance is available only to those communities serving populations under 10,000 people. To gain a more detailed perspective on the nature of RUS's lending activities for community drinking water improvements, we examined actual loan files from the several New York Rural Development district offices. Of the 149 water systems receiving RUS funding, the average number of people served is just under 1,800, ranging from fewer than 100 to nearly 9,500. On average, there are about 600 connections, 92% being designated residential. The average daily water flow is over 250,000 gpd, or 135 gpd per capita.

The size of the operating revenues compared with expenses for these systems has important policy implications. In general, revenues and expenses for these systems are relatively similar across the state with most of the variability coming from the income sources. Metered and unmetered water sales combined with user charges provided the lion's share of operating revenue, while property tax assessments were a distant third. Total income averages nearly $221,000, or $125 per capita. While this may seem substantial, it was largely offset by operating expenses of $192,000 on average ($110 per capita), consisting largely of interest expenses for capital improvements. After subtracting principal payments from net income there is a modest average residual of only $2,400, or $1.34 per capita. While it is difficult to interpret such small, or in some cases, negative residuals, it is these amounts that are inherently available for future capital improvements. Although these are public systems and perhaps should not accumulate large surplus funds, the small residuals remaining are surely insufficient to support any major capital improvements in the future, putting additional pressure on available low or no-cost funding sources such as those from RUS.

Most of the 149 systems for which loan files were available sought funding for a combination of purposes, including distribution, transmission, treatment, storage, and source development improvements. Not surprisingly, the most common requests for funding are for distribution and transmission improvements and treatment technology upgrades. Average project funding for the systems is about $1.3 million ($750 per capita), for which RUS provided over 90% of the total, two-thirds as loans and one-third as grants. What is perhaps most interesting is that for those communities with larger populations, total project costs were higher as well, but were lower on a per capita basis. This is initial evidence supporting the existence of economies of size in the provision of water treatment.

Three-quarters of project costs went for construction and equipment. About 30% of all construction and equipment costs went for distribution, another 30% for treatment, and 20% for transmission. Storage and source development accounted for the remaining 20% of capital and equipment expenditures.

Average distribution costs were nearly $775,000, ranging from as low as $82,000 to over $2.6 million. Projects varied considerably by the number of service laterals and hydrants provided and the proportion and length of transmission line installed. For this reason, we were able to estimate the relationship between distribution costs and major components of the distribution system. In related research, this estimated relationship is being used to help compare the cost savings through system consolidation with the added cost of distribution needed to effect the consolidation. The results suggest that distribution costs associated with system consolidation are increased more on a percentage basis through an increased need for hydrants and connections than for overall increases in water demand or the need for larger sized distribution pipe. The implications as well for how fast costs rise as an existing system extends its distribution network to take advantage of economies of size in water treatment are obvious since the need for these various types of equipment in extending service clearly depends on the nature of the new customers.

About 30% of the 149 communities requested funds from RUS for the construction of new treatment facilities. In these communities, the types of treatment being put in place are similar to those already in use by other small systems across New York and the nation. Based on this experience, it appears that technologies such as chlorine disinfection, aeration, and slow sand filtration are most suitable for small system operation, with some change to rapid sand and membrane filtration technologies as system size increases.

As one would expect, the cost of treatment varied widely by treatment technology and system size. For analytical purposes, it was convenient to translate these costs onto an annual basis by amortizing capital costs and adding the annual operating costs. Treatment capital costs over all treatments averaged $1.4 million, or about $140,000 annually. Combined with system operation and maintenance expenditures, annualized costs totaled nearly $309,000.

To understand the policy significance of these treatment cost data, it was convenient to regress these costs on system population, water source, and treatment variables, thus estimating a simplified indirect cost function which explains nearly 90% of the variation in annualized costs. In general, the implied economies of size based on these cost functions are substantial for all treatments, but varied considerably across technologies. At the upper end of the range for population, economies of size for all filtration technologies are nearly exhausted for populations nearing 10,000. For aeration, economies of size are still substantial at populations near 10,000. These estimates of economies of size are either higher or lower than equivalent estimates implied in the engineering equations from the very small system BAT document, depending on the technology, but for a given technology the bias is consistent by system size. Average costs of treatment based on the BAT engineering equations are consistently lower than those based on RUS data.

This consistency, as well as the consistency with previous estimates of economies of size that are not technology-specific, is encouraging and provides some effective guidelines as to how to use information such as that contained in the BAT document. In large measure, the differences both in economies of size and in average costs based on these two sources of data can be reconciled on the basis of differences in assumptions and in major cost components such as the wage rate. However, in closing it must be reemphasized that these results are based on a small sample of water systems and that *what is needed to reconcile these alternative measures of economies of size is an analysis of data which includes systems of a wide range in size, from the smallest to the largest. The most recent national survey of public water systems conducted by EPA may be such a source of data.* When such an analysis is complete, our understanding of the nature of the cost savings in water treatment due to system consolidation will be enhanced dramatically. It is only then that we can begin to compare those savings with the added cost of distribution for a range of geographic and demographic situations.

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Table A1. Individual System Operation and Cost Characteristics.

System	Water	System	Avg. Daily	Treatment	Annualized Costs			Annualized Costs Per Capita			O & M	RUS Predicted Annualized Costs			BAT Predicted Annualized Costs		
Number	Source	Population	Production	Capital Cost	Capital	O & M	Total	Capital	O & M	Total	Cost %	Total	Per Capita	% Error	Total	Per Capita	% Error
			gpd	$	$	$	$	$	$	$	%	$	$	%	$	$	%
New Chlorine Treatment:																	
1	Ground	143	18,000	63,134	6,430	10,008	16,438	44.97	69.99	114.95	61%	13,394	93.66	-18.52	10,824	75.69	-34.16
2	Ground	200	15,000	104,538	10,647	5,475	16,122	53.24	27.38	80.61	34%	15,432	77.16	-4.28	12,206	61.03	-24.29
3	Surface	210	20,000	34,367	3,500	18,198	21,698	16.67	86.66	103.33	84%	20,670	98.43	-4.74	12,440	59.24	-42.67
4	Ground	400	217,000	22,232	2,264	14,032	16,296	5.66	35.08	40.74	86%	21,295	53.24	30.67	16,576	41.44	1.72
5	Surface	600	67,600	124,754	12,707	20,620	33,327	21.18	34.37	55.54	62%	34,331	57.22	3.01	20,556	34.26	-38.32
6	Ground	1,091	170,000	54,204	5,521	41,500	47,021	5.06	38.04	43.10	88%	36,403	33.37	-22.58	29,632	27.16	-36.98
Average		441	84,600	67,205	6,845	18,306	25,150	24.46	48.58	73.05	69%	23,588	68.85	-2.74	17,039	49.80	-29.12
Aeration Treatment:																	
7	Ground	1,000	170,000	150,000	15,278	47,000	62,278	15.28	47.00	62.28	75%	68,642	68.64	10.22	129,825	129.83	108.46
8	Ground	1,800	221,000	99,553	10,140	64,517	74,657	5.63	35.84	41.48	86%	103,078	57.27	38.07	190,899	106.06	155.70
9	Ground	2,995	1,348,000	560,693	57,108	287,523	344,631	19.07	96.00	115.07	83%	150,004	50.08	-56.47	275,899	92.12	-19.94
10	Ground	7,596	400,000	96,399	9,818	201,251	211,069	1.29	26.49	27.79	95%	314,685	41.43	49.09	589,412	77.60	179.25
Average		3,348	534,750	226,661	23,086	150,073	173,159	10.32	51.33	61.65	85%	159,102	54.36	10.23	296,509	101.40	105.87
Slow Sand Filtration Treatment:																	
11	Surface	307	54,000	708,066	72,118	14,209	86,327	234.91	46.28	281.20	16%	76,975	250.73	-10.83	63,064	205.42	-26.95
12	Surface	850	187,100	2,360,400	240,413	42,994	283,407	282.84	50.58	333.42	15%	159,040	187.11	-43.88	127,288	149.75	-55.09
13	Surface	1,200	242,000	1,072,720	109,259	44,990	154,249	91.05	37.49	128.54	29%	207,313	172.76	34.40	163,968	136.64	6.30
14	Surface	1,500	265,000	873,193	88,937	107,677	196,614	59.29	71.78	131.08	55%	247,391	164.93	25.83	193,965	129.31	-1.35
15	Surface	1,615	142,000	642,000	65,389	152,000	217,389	40.49	94.12	134.61	70%	262,534	162.56	20.77	205,202	127.06	-5.61
16	Surface	1,855	769,000	1,206,298	122,865	87,603	210,468	66.23	47.23	113.46	42%	293,836	158.40	39.61	228,295	123.07	8.47
17	Surface	1,974	360,000	1,593,963	162,349	19,899	182,248	82.24	10.08	92.32	11%	309,230	156.65	69.68	239,584	121.37	31.46
18	Surface	2,452	426,000	1,800,241	183,359	208,443	391,802	74.78	85.01	159.79	53%	370,429	151.07	-5.46	284,064	115.85	-27.50
19	Surface	2,600	753,500	2,296,398	233,894	460,615	694,509	89.96	177.16	267.12	66%	389,215	149.70	-43.96	297,622	114.47	-57.15
20	Surface	2,900	750,000	1,711,799	174,351	153,390	327,741	60.12	52.89	113.01	47%	427,117	147.28	30.32	324,771	111.99	-0.91
21	Surface	4,500	400,000	2,200,000	224,076	276,300	500,376	49.79	61.40	111.19	55%	626,954	139.32	25.30	465,210	103.38	-7.03
22	Surface	5,257	570,400	2,778,806	283,029	552,751	835,780	53.84	105.15	158.98	66%	720,902	137.13	-13.75	529,906	100.80	-36.60
23	Surface	9,470	2,700,000	7,938,883	808,597	902,145	1,710,742	85.39	95.26	180.65	53%	1,245,237	131.49	-27.21	880,047	92.93	-48.56
Average		2,806	586,077	2,090,982	212,972	232,540	445,512	97.76	71.88	169.64	44%	410,475	162.24	7.75	307,922	125.54	-16.96

Table A1. Individual System Operation and Cost Characteristics (continued).

System	Water	System	Avg. Daily	Treatment	Annualized Costs			Annualized Costs Per Capita			O & M	RUS Predicted Annualized Costs			BAT Predicted Annualized Costs		
Number	Source	Population	Production	Capital Cost	Capital	O & M	Total	Capital	O & M	Total	Cost %	Total	Per Capita	% Error	Total	Per Capita	% Error
			gpd	$	$	$	$	$	$	$	%	$	$	%	$	$	%
Other Filtration Treatment:																	
24	Surface	683	103,350	1,377,812	140,334	95,681	236,015	205.47	140.09	345.56	41%	116,068	169.94	-50.82	62,617	91.68	-73.47
25	Surface	1,265	270,000	788,731	80,334	75,586	155,920	63.51	59.75	123.26	48%	175,106	146.66	18.98	94,805	74.95	-39.20
26	Surface	1,397	200,000	335,713	34,193	51,989	86,182	24.48	37.21	61.69	60%	155,530	152.48	147.17	101,953	72.98	18.30
27	Surface	1,565	310,000	2,304,456	234,715	66,829	301,544	149.98	42.70	192.68	22%	215,686	137.82	-28.47	111,021	70.94	-63.18
28	Surface	2,207	370,000	2,422,000	246,687	231,379	478,066	111.77	104.84	216.61	48%	283,526	128.47	-40.69	145,596	65.97	-69.54
29	Surface	2,750	349,000	1,501,428	152,924	127,331	280,255	55.61	46.30	101.91	45%	339,478	123.45	21.13	174,955	63.62	-37.57
30	Surface	3,000	200,000	1,048,907	106,834	90,897	197,731	35.61	30.30	65.91	46%	364,947	121.65	84.57	188,565	62.86	-4.64
31	Surface	5,800	1,300,000	5,013,055	510,593	496,050	1,006,643	88.03	85.53	173.56	49%	644,261	111.08	-36.00	346,376	59.72	-65.59
32	Surface	8,000	1,614,000	1,521,334	154,952	436,532	591,484	19.37	54.57	73.94	74%	861,201	107.65	45.60	478,320	59.79	-19.13
Average		2,963	524,039	1,812,604	184,619	185,808	370,427	83.76	66.81	150.57	48%	350,645	133.24	17.94	189,357	69.17	-39.34
Direct Filtration Treatment:																	
33	Surface	462	52,500	123,750	12,604	51,500	64,104	27.28	111.47	138.75	80%	73,769	159.67	15.08	53,241	115.24	-16.95
34	Surface	1,556	108,000	293,127	29,856	50,000	79,856	19.19	32.13	51.32	63%	172,921	111.13	116.54	97,172	62.45	21.68
35	Surface	2,270	355,246	673,302	68,578	187,593	256,171	30.21	82.64	112.85	73%	231,024	101.77	-9.82	122,194	53.83	-52.30
36	Surface	3,102	900,000	2,865,650	291,874	176,500	468,374	94.09	56.90	150.99	38%	296,163	95.48	-36.77	149,951	48.34	-67.98
37	Surface	5,000	1,500,000	1,692,986	172,435	387,377	559,812	34.49	77.48	111.96	69%	439,730	87.95	-21.45	210,450	42.09	-62.41
Average		2,478	583,149	1,129,763	115,069	170,594	285,663	41.05	72.12	113.18	65%	242,721	111.20	12.72	126,602	64.39	-35.59
All Treatment Average		2,475	483,722	1,363,646	138,891	169,146	308,037	65.35	64.68	130.03	57%	283,338	121.48	9.47	206,175	88.67	-13.61

Source: Primary data obtained from New York Rural Development district offices.

Note: Other filtration includes rapid sand filtration, diatomaceous earth filtration, and coagulation/filtration, while aeration includes both packed tower and diffused aeration treatments.

Table A2. BAT Regressions for Estimated Annual Translog Cost Functions for Selected Water Treatment Technologies (a)

	Intercept		Log Population (b)		Log Population Squared (b)		
Process	Coefficient	Standard Error	Coefficient	Standard Error	Coefficient	Standard Error	R-squared
Chlorine Feed System	9.644	0.119	-0.474	0.043	0.081	0.004	0.999
Aeration:							
Packed Tower	10.262	0.023	-0.041	0.008	0.037	0.001	1.000
Diffused Air	9.310	0.068	-0.040	0.025	0.058	0.002	1.000
Direct Filtration	10.995	0.085	-0.447	0.031	0.070	0.003	0.999
Slow Sand Filtration	8.370	0.021	0.280	0.008	0.033	0.001	1.000
Other Filtration:							
Coagulation/Filtration	11.141	0.086	-0.521	0.031	0.081	0.003	0.999
Diatomaceous Earth	9.279	0.059	-0.245	0.022	0.076	0.002	1.000

Source: Derived from BAT Simulation Model developed by Boisvert and Tsao (1995).

(a) The dependent variable is the logarithm of annual cost, C.

(b) Logarithm of population.

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