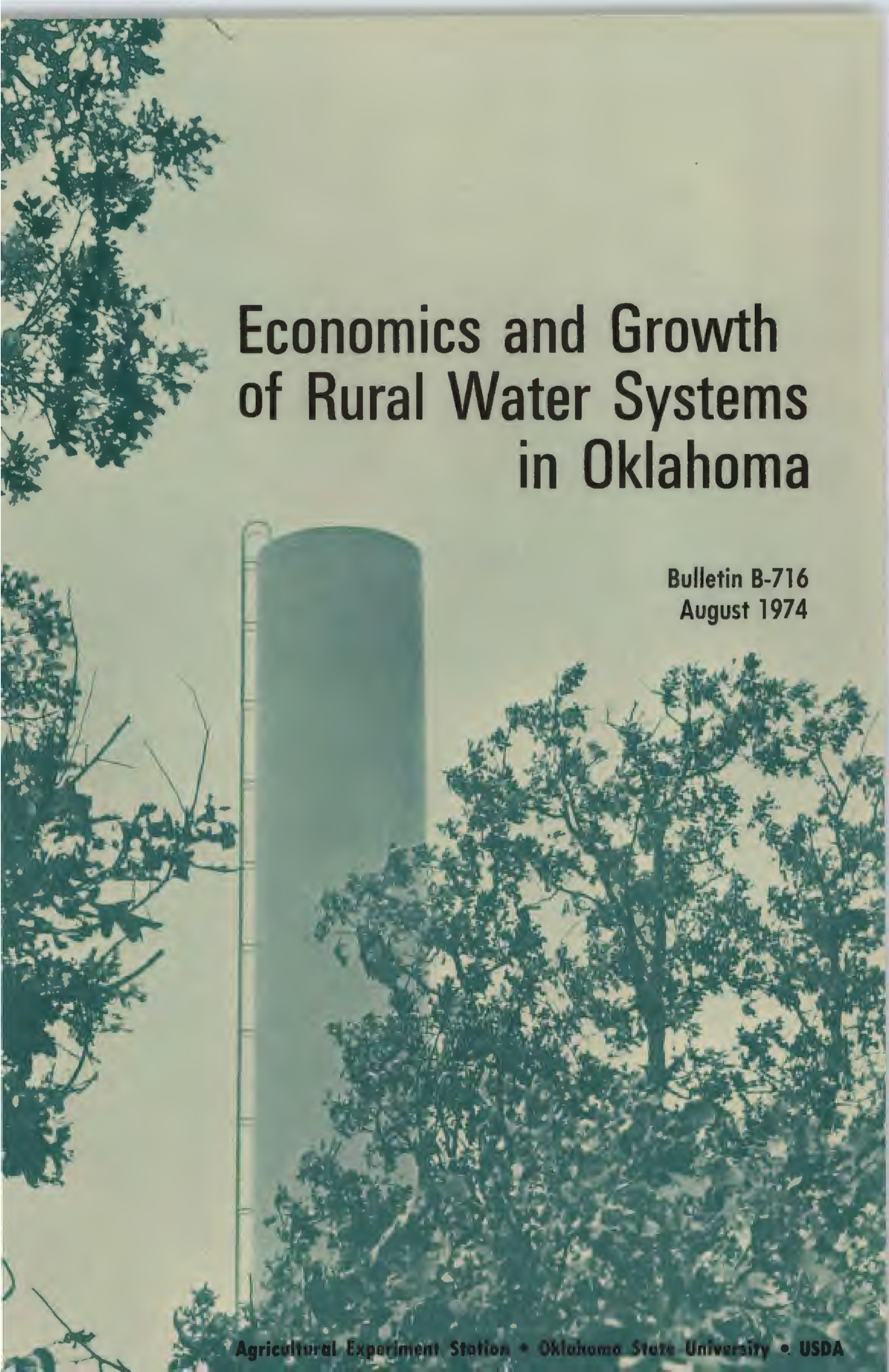
Economics and Growth of Rural Water Systems in Oklahoma



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Economics and Growth of Rural Water Systems In Oklahoma

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Introduction

A persistent problem facing rural residents in many areas of the country is an inadequate supply of good quality water. Individual water wells have provided and continue to provide a plentiful supply of good quality water to many rural residents. Other residents must haul water or rely on limited supplies and/or poor quality water. The passage of the Consolidated Farmers Home Administration Act of 1961 was a major step toward solving this problem. FHA was authorized to make loans and grants to organized groups of rural residents and small communities for the purpose of installing and operating water systems.

Through June 1973, a total of 5,480 water systems, funded under this program, were serving some 2 million families.[2] Nearly 2 billion dollars has been made available, about 90 percent was in repayable loans. Secretary of Agriculture Butz has characterized this program as "one of the bedrock necessities for building a sound, prosperous, fully acceptable standard of life in the great open spaces of America," and indicated that "there is still far to go with this program."[3]

Oklahoma ranks third among the States in the number of rural water systems; 318 had been funded as of August 15, 1973. The first loan in Oklahoma was made in 1964. The systems range in size from about 15 to 1,500 customers. The systems serve small towns, rural areas, and, in some cases, both a town and a rural area.

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[2]USDA "News" No. 2617-73.

[3]"News", p. 3.

The rural water systems obtain water from a variety of sources, including purchasing treated water from nearby communities, drilling wells, and building plants to treat water from reservoirs and streams.

Figure 1 shows the geographical distribution of rural water systems in Oklahoma with approved FHA loans as of August 15, 1973. The number of systems in each county are also shown.

Purpose and Objectives

Despite a very active FHA loan program, many rural areas of Oklahoma still lack an adequate supply of good quality water. Experience gained in building and operating rural systems should be shared with those interested in building new systems and operators of existing systems. The purpose of this study was to provide some insight into costs, system growth, and other relevant information concerning existing rural water systems. More specifically the objectives were:

1. To analyze the annual costs of operating water systems to determine what effect number of customers, density of customers, sources of water, and other factors have on per customer costs;

2. To examine rural water systems with respect to water rates, water consumption, and various operating practices including billing, meter reading, maintenance, and employment; and
3. To analyze growth, measured in number of customers, and to determine what factors affect growth.

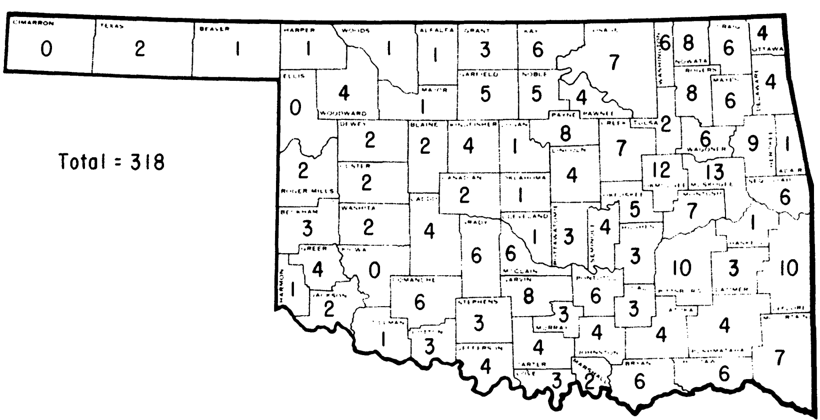

Figure 1. Rural water systems funded by FHA loans in Oklahoma as of August 15, 1973.

Procedure

Sample Selection

A sample of 57 rural water systems in Oklahoma were selected for this study with the assistance of State FHA personnel. Major criteria for selection were as follows: all systems selected must have been in operation for at least two years to assure adequate operating records; all different sizes of systems measured in terms of numbers of customers were included (the range was from 16 to 1,400 customers); systems with different sources of water supply — wells, lakes and streams, purchase of treated water; systems with different densities of customers per mile of line represented by rural only, town only and a combination of town and rural (Table 1).

The systems were also selected to represent approximately the same proportional geographical distribution as all the rural water systems located in the state.

Data Collection

Periodic operating reports are made by each rural water system to the Farmers Home Administration. The FHA State Office made information on these reports available for this study, along with original water system costs and engineering detail. Data on operating and maintenance costs were obtained directly from representatives, bookkeepers, and managers. Data collected included changes in number of customers, additions to distribution lines, water consumption, water rates, wages and salaries, maintenance and billing procedures, and other relevant information. A questionnaire was used to obtain data from FHA and water system representatives.

Table 1. Classification of sample water systems in Oklahoma by number of customers and type of group served, 1972.

Group served	Number of customers (by size category) Under 100	100-199	200-299	300-400	Over 500[1]	Total
	Number of systems					
Rural only	2	6	5	6	4	23
Town only[2]	4	4	2	0	0	10
Town and rural	3	9	6	2	4	24
Total	9	19	13	8	8	57

[1]Largest system in the study had 1,400 customers; only 2 others exceeded 1,000 customers each.
[2]Towns are defined as small communities that have a distinguishable boundary and are laid out in lots and blocks. They may or may not be incorporated but all of them have a place name.

Analytic Procedure and Definitions

Analytic procedures used in this study were primarily comparative analysis and linear regression. Most comparisons were made on a per customer basis, e.g., cost was measured on a per customer basis and growth was measured as a change in number of customers per year. Linear regression analysis was used to determine the effect of one or more variables (such as density of customers or number of customers) on another variable (cost per customer).[4]

Investment cost data collected included the cost of the original system plus any additions made during 1964-72. All costs were adjusted by use of construction cost indices (Table 2).[5] Thus, investment costs used in the study reflect what it would cost to build the systems as they existed at the end of 1972. Annual costs were obtained in the spring of 1973; all data were for 1972 so no adjustment for inflation was necessary. With all costs relating to 1972, it was possible to analyze rural water systems with respect to factors, other than time, that affect costs.

Investment cost was defined as the original construction cost plus the cost of added capital improvements. Major components include: water lines and booster pumps, storage tanks, wells, treatment plants, and buildings and equipment. Annual cost is defined as the amount of money normally paid out by the system each year for salaries, utilities, water

[4]Several different scatter diagrams with costs on the vertical axis and number of customers and density of customers on the horizontal axis indicated that a linear form of the regression equation would be appropriate for this analysis.

[5]Construction costs for water lines decreased from 1966 to 1972. This was due to a lower PVC pipe cost and improved methods of installation.

Table 2. Construction cost indices for rural water systems in Oklahoma

Year	Water lines in place[1]	Treatment plants[2]	Storage tanks, wells, other[3]
		Index numbers	
1964	100	100	100
1965	100	101	102
1966	100	105	106
1967	98	106	110
1968	96	108	118
1969	93	119	129
1970	92	128	137
1971	90	138	155
1972	89	149	171

[1]Index numbers derived from construction bids in Oklahoma for FHA financed Rural Water Systems.

[2]Based on unpublished data furnished by the Environmental Protection Agency, Washington, D. C.

[3]Based on general construction cost index compiled by Engineering News Record, McGraw Hill Publishing Co., Highstown, N.J.

purchases, office expense, maintenance, insurance, legal fees, amortization payments to FHA, and miscellaneous costs. Amortization payments are annual payments for investment cost, including interest, and are not usually included in the definition of annual cost. However, this definition is used because it reflects what rural water system operators generally view as the annual cost of operation.

Because of data limitations, it was difficult to perform any analytical tests relating to water rates, water consumption, billing, meter reading, maintenance, and employment procedures. However, these items are analyzed to the extent possible as they relate to the rural water systems in the study. While gathering data, discussions with representatives of the rural water systems indicated they had considerable interest in other systems with respect to these items.

Water system growth was defined as the change in total number of customers from the end of the water system's first full year of operation to the end of 1972. Growth was determined by dividing the change in number of customers by the number of customers at the end of the system's first year of operation, then dividing that figure by the number of years in which the change took place. This gave an average annual rate of change (measured in percent) for each water system. Since all systems studied were growing, this rate of change is referred to as a rate of growth. Various factors affecting this growth, as suggested in objective 2, were then compared to rates of growth.

Analysis of Costs

Investment costs were obtained primarily from engineering reports made available by the Farmer's Home Administration. The detail and standardization of these reports provided good investment cost data. Annual cost data were obtained from annual audit reports to FHA, and information provided by bookkeepers for the individual water systems. All annual costs were no doubt accounted for. However, records were not standardized and it was difficult to accurately divide all annual costs into separate categories. Annual costs were classified as follows:

Water purchases – cost of treated and/or untreated water purchased for consumption within the water system. Water sales to other systems were deducted.

Salaries – payments on a regularly scheduled basis to employees and managers, including taxes.

Utilities – cost of electricity to operate the system.

Office – costs of items such as telephone, stationery, and postage.

Insurance and bonds — all insurance premiums and payment of bonds for employees.

Legal and Audit — all legal and auditing fees.

Amortization — a factor of .0583 multiplied by investment cost represents an annual payment covering interest and principal, for a 5 percent loan for 40 years. The investment cost used for each system in the study is defined on page 8.[6]

Other — maintenance was included in this category. This was necessary because it was difficult to identify maintenance expenditures from available records. For example, costs of new meters and water line extensions were often included in the maintenance account. These items were removed and added to investment cost if the records were sufficiently detailed to permit this adjustment. Also, in most cases, the amount of labor devoted to maintenance was not available. Miscellaneous items included in "other" were chemicals, billing and collection fees, travel expenses, rent, and equipment repair.

It was decided that the size of the various cost categories relative to total annual costs should be determined first to aid in the analysis of costs (Table 3). Systems with treatment plants, those with wells, and those that purchase treated water were separated because a preliminary review of the cost data indicated there were some rather large differences in costs, especially for water purchases, salaries, utilities, and amortization. A general explanation for the variations is as follows:

Water purchases — systems with wells obviously need not purchase water. Systems with water treatment plants generally purchase low-cost untreated water from the utility controlling the source of supply (usually a reservoir). Systems with no wells or treatment plants must purchase more expensive, treated water — usually from a nearby community.

Salaries — salaries are a lower percentage of total annual costs for systems that purchase treated water because these systems do not have wells or treatment plants requiring constant monitoring by an employee. Wells require less monitoring than treatment plants.

[6]FHA was charging 5 percent interest rate at the end of 1972. Some loans on the systems in the study were made at a lower rate. However, to compare costs among the systems on a 1972 basis it was necessary to amortize the 1972 investment cost with the same interest rate. Otherwise, those systems built with lower interest rate loans would appear in the analysis to have lower annual costs. Thus, by using the same interest rate on all systems, the time factor associated with interest rate differences was eliminated to allow a study of other factors that affect costs.

Table 3. Annual cost items as a percent of total annual costs for 46 sample water systems, Oklahoma, 1972[1]

Number and type of system	Water purchase	Salaries	Utilities	Office supplies	Insurance bonds	Legal and Audit	Amortization[2]	Maintenance supplies, and other	Total
					Percent				
11 with treatment plants	2.7	19.2	5.7	3.0	1.8	1.0	60.2	6.4	100.0
10 with wells	0	17.1	5.7	1.5	2.9	1.2	63.6	8.0	100.0
25 that purchase treated water	23.0	13.0	1.7	1.3	1.2	1.0	53.0	5.8	100.0

[1]Data on 11 of the 57 systems were insufficient for this analysis.
[2]A 5 percent interest rate and 40 year repayment period was applied to each system's investment as of the end of 1972.

Utilities — systems that purchase treated water have lower utility costs because they have less equipment to operate.

Amortization — this item is also lower for systems that purchase treated water because there is no investment in wells or a treatment plant.

Since amortization accounts for over 50 percent of total annual cost for all systems, factors affecting amortization have a considerable impact on total annual costs. Because investment cost is directly related to the annual amortization payment, factors that affect investment costs are analyzed first.

Investment Costs

As was indicated earlier in the report, the source of water supply has a significant influence on the total water system investment cost. Systems with wells or treatment plants have relatively higher investment costs. Of the 57 water systems in the study, 30 purchased treated water, 11 had treatment plants, and 16 had wells. Investments in treatment plants ranged from $33,600 to $243,000; investment in wells ranged from $10,600 to $36,800.

Distribution Systems Investment Costs

Since the investment in treatment plants and wells represent a rather significant share of total water system investment cost, it was necessary to remove this factor from the combined analysis of investment costs in all 57 water systems. This was accomplished by removing the costs of treatment plants and wells, and considering only the investment costs in the distribution system — water lines, storage tanks, meters, booster pumps, equipment, etc. Investment costs of treatment plants and wells are analyzed later in the report.

Density

One factor that affects investment costs per customer is the number of customers for each mile of water line in the distribution system. Water systems with a high density of customers per mile of line have relatively lower distribution system investment costs per customer than low density systems (Table 4). Distribution system investment costs per customer were $539 for systems averaging 30.5 customers per mile of line, and $1,041 for systems averaging 4.1 customers per mile.

Results of the regression analysis indicate that there *is* a statistically significant relationship between investment cost per customer and density of customers per mile of line (Table 5). The results of the regression equation presented in table 5 indicate that an increase of one customer per mile of line would decrease distribution systems investment cost $21.05 per customer.[7] However, density of customers per mile of line explains only about 40 percent ($R^2 = .405$) of the variation. Thus, other factors must be considered.

Number of Customers

Another factor that was considered to have an effect on distribution system investment cost was the number of customers served by the system. Since the density of customers has a significant effect on cost, a division was made of the systems in the study between rural only, town only, and town and rural (Table 6). Customer density per mile of line averaged 7.4, 27.3, and 8.9 respectively for rural, town, and town and rural systems. Investment costs in the town distribution systems were considerably lower

[7]If a system had 10 miles of line, it would take an increase in 10 customers to get an increase of one (1) customer per mile of line.

Table 4. Investment cost per customer relative to number of customers per mile of line for 50 rural water distribution systems in Oklahoma, 1972[1]

System and customers	Customers per mile of line: Under 5	5-9.9	10-14.9	15-19.9	Over 20
			Number		
Number of systems	10	23	9	3	5
Average density of customers	4.1	7.2	12.7	17.4	30.5
			Dollars		
Average investment cost per customer	1,041	902	776	636	539

[1]Data for 7 of the 57 systems were insufficient for this analysis.

Table 5. Regression results for investment cost per customer in the distribution system compared to density of customers per mile of line for 50 rural water systems, Oklahoma, 1972[1]

Item	Regression Coefficient	R^2	Student's t
Density of customers	—21.05	.405	[2]—5.721

[1]Data for 7 of the 57 systems were insufficient for regression analysis.
[2]Coefficient is significant at the 1 percent level.

(line 2, Table 6), reflecting high customer density. However, the number of customers did not appreciably affect distribution investment cost per customer for different size systems.[8] For example, this cost was $818 for rural systems with less than 100 customers and $1,074 for rural systems with over 500 customers.

Four regression equations were computed; investment costs in the distribution system was the dependent variable, and number of customers was the independent variable for (1) rural only, (2) town only, (3) combination town and rural systems, and (4) all the systems combined. Results of these four regressions indicate that the number of customers *does not* have a significant effect on investment costs per customer (Table 7). The R^2's were all very low (.05 or less).

[8]The data in Table 6 are cross sectional. If one traced investment cost per customer for a given water system over time as the number of customers increased, the cost data might look different. Investment cost would go down if customer density went up; but if new lines were added to serve new customers, and customer density remained the same, costs might not go down.

Table 6. Investment cost per customer for water distribution systems with different numbers of customers, 50 water systems, Oklahoma, 1972[1]

	Number of customers (by size category)				
Rural water systems	Under 100	100-199	200-299	300-499	Over 500[3]
			Dollars		
Rural only	818	851	1,008	903	1,074
	[2](22)	(141)	(235)	(341)	(699)
Town only	532	643	520	---	---
	(62)	(140)	(254)		
Town and rural	650	1,000	955	698	833
	(80)	(133)	(243)	(365)	(1,003)

[1]Data for 7 of the 57 systems were insufficient for this analysis.
[2]Numbers in parenthesis are average number of customers in respective size categories.
[3]Largest system in study had 1,400 customers; only 2 others exceeded 1,000 customers.

Table 7. Regression results for investment costs per customer compared to number of customers for 50 rural water systems, Oklahoma, 1972[1]

Rural water systems	Number of systems	Regression Coefficient	R^2	Student's t^2
Rural only	18	.225	.039	.910
Town only	10	—.167	.016	—.366
Town and rural	22	—.060	.011	—.515
All systems	50	.286	.050	1.596

[1]Data for 7 of the 57 systems were insufficient for this analysis.
[2]None of the coefficients were significant at the 10 percent or better level.

Terrain

Terrain was also expected to affect distribution system investment costs. Hilly or mountainous areas require more storage tanks and/or pumps to maintain water pressure than flat to rolling areas; rocky areas result in higher line installation costs because of trenching and backfilling difficulties. If the 57 distribution systems in this study are compared strictly on a terrain basis, investment costs for systems in hilly and/or rocky areas average about 15 percent higher than those in rolling to flat areas.[9]

Investment Costs in Treatment Plants and Wells

Number of customers was the only factor to be analyzed with respect to investment costs in treatment plants and wells. For those rural water systems in the study that have water treatment plants and wells, the number of customers does have an effect on investment cost per customer. This effect can best be demonstrated by comparing investment cost per customer in the treatment plant or well with the number of customers served, excluding distribution system investment cost (Table 8). Average treatment plant investment cost per customer is $431 for plants serving under 200 customers and only $175 for those serving over 500. There is a similar relationship for systems with wells.

Separate linear regression equations were computed for treatment plant and water well investment costs. Regression results for these two equations indicate that treatment plant and water well investment costs

[9]FHA engineers familiar with the terrain of the sample systems categorized the systems to allow this comparison. Investment costs for each distribution system were then placed within the respective categories and compared. No statistical test was applied here because of the subjective placement of the water systems into the terrain classifications.

Table 8. Investment costs in water treatment plants or wells for 26 water systems, Oklahoma, 1972[1]

	Number of customers (by size category)[2]		
Water supply	Under 200	200-499	Over 500
		Dollars per customer	
Treatment plants	431	232	175
	[3](116)	(263)	(909)
Wells	172	107	[4]
	(104)	(231)	

[1]Of the 57 systems, data for analysis were sufficient for 12 systems with treatment plants and 14 with wells.
[2]There were too few treatment plants and wells to divide the systems into more size categories.
[3]Numbers in parenthesis are average numbers of customers in size category.
[4]There were no wells in this size category.

are affected by number of customers. The regression results indicate that an increase in one customer would lead to a decrease in treatment plant investment cost per customer of about $.30 (−.297) and a decrease in water well investment cost per customer of about $.95 (−.951) (Table 9). The results also show that about 40 percent (R^2 = .400) of the variation in investment cost per customer in treatment plants and about 45 percent (R^2 = .454) of the variation in investment cost per customer in water wells are explained by differences in numbers of customers served.

Annual Costs

The preceding analysis of investment costs shows that: (1) density of customers per mile of line affects investment costs per customer in the distribution system; (2) numbers of customers affects investment costs per customer in treatment plants and wells; and (3) number of customers apparently does not affect investment costs per customer in distribution systems. In response to these findings regarding *investment* costs, it was decided to analyze *annual* costs per customer by dividing the system into three categories: those with treatment plants, those with wells, and those that purchase treated water. The systems were then categorized by number of customers served (Table 10). Linear regression analysis was then used to analyze the effect of numbers of customers and density of customers on annual costs (Table 11).

Average annual costs for all systems with treatment plants and all systems that purchase treated water averaged $106 per customer, average annual costs for systems with wells averaged $81 per customer. The lower average annual cost per customer for systems with wells is due largely to the fact that nearly all of these systems serve small towns with high-density populations, and thus lower investment costs per customer.

Six regression equations were computed: two each for systems with treatment plants, systems with wells, and systems that purchase treated water. Annual cost per customer was the dependent variable for the six

Table 9. Regression results for treatment plant and water well investment costs per customer for 26 rural water systems, Oklahoma, 1972

Water supply	Regression Coefficient	R^2	Student's t
Treatment plants	—.297	.400	[1]—2.58
Wells	—.951	.454	[1]—3.16

[1]Coefficients are significant at the 1 percent level.

Table 10. Average annual costs per customers for 45 water systems, Oklahoma, 1972[1]

Source of water	Number of customers (by size category) Under 100	100-199	200-299	300-499	Over 500[2]	Average
			Dollars per customer			
Treatment plants	118	118	102	82	109	106
	[3](1)	(3)	(1)	(1)	(4)	(10)
Wells	83	74	87	0	0	81
	(3)	(3)	(4)			(10)
Purchasing treated water	116	108	110	106	89	106
	(1)	(8)	(5)	(7)	(4)	(25)

[1]Data for 12 of the 57 systems were insufficient for this analysis.
[2]Largest system in the study had 1,400 customers; only 2 others exceeded 1,000 customers.
[3]Numbers in parenthesis are the number of systems in each size category.

regression equations. Number of customers and density of customers were the independent variables.

Regression results indicate that number of customers does not affect annual costs per customer (Table 11). None of the Student's **t** values were significant for the number of customers variable. The regression results do indicate, however, that annual costs are affected by density of customers for systems with wells and systems that purchase treated water but are *not* affected for systems with treatment plants. About 45 percent (R^2 = .450) of the variation in annual costs per customer for systems with wells is explained by density of customers and about 24 percent (R^2 = .239) for systems that purchase treated water.

Interpretation of the regression coefficients (Table 11) indicate that an increase in density of one customer per mile of line would lead to respective reductions in annual costs per customer of \$1.45 (−1.447) and \$2.25 (−2.254) for systems with wells and systems that purchase treated water.

It is commonly assumed that large systems would operate with lower annual costs per customer. However, because only 8 of the 57 systems studied had more than 500 customers (p. 5), it was not possible to draw firm conclusions as to whether there were important economies of size for the systems studied.

Some factors that may help explain the apparent lack of significant economies of size for the systems studied in this report are as follows: (1) the lack of economies of size in investment costs in distribution systems (Table 6) and the large portion of annual costs represented by

Table 11. Regression results for annual costs per customer compared to number and density of customers for 45 rural water systems, Oklahoma, 1972[1]

Systems and customers	Number of systems	Regression coefficient	R^2	Student's t
With treatment plants	10			
No. of customers		—.002	.001	—.109
Density of customers		—1.501	.142	—1.150
With wells	10			
No. of customers		—.010	.003	—.152
Density of customers		—1.447	.450	[2]—2.710
Purchasing treated water	25			
No. of customers		—.022	.113	—1.710
Density of customers		—2.254	.239	[2]—2.690

[1]Data for 12 of the 57 systems were insufficient for this analysis.
[2]Coefficients are significant at the 5 percent level.

amortization (Table 3); (2) utility expenses and water purchases for the size of systems considered herein are largely proportional to the number of customers; (3) the cost of salaries measured in terms of dollars per customer per year average about $14 for the smaller systems and increased to about $18 for the larger systems;[10] (4) the remaining annual costs represented such a small share of total annual costs that they would have little effect on economies of size.

Limitations of Cost Analysis

The results for the preceding cost analysis are applicable only to rural water systems with fewer than 1,400 customers. Another limitation of this cost analysis was then, with the linear regression used, the percent of explained variation in costs (R^2's) never exceeded 50 percent.[11] This indicates that factors other than those included in the regression analysis, such as terrain, have a significant impact on costs.

Caution should be used in comparing costs associated with individual water systems with the average costs presented in this report. In addition to the factors that affect annual costs — density of customers, inflation, terrain, source of water — the interest rate can also affect costs. An interest rate of 5 percent was assumed for all systems in the study. A difference of 1 percent would have a considerable impact on the annual

[10]The salary costs averaged $15 per customer for 100 and under customer systems, $13 from 100-199, $15 from 200-299, $18 from 300-499, and $18 for systems of 500 customers and more. The low salary costs for smaller systems is probably due to voluntary labor, or token salary payments to labor.
[11]Multiple regressions were computed using annual cost as the dependent variable and number of customers and density of customers as two independent variables. Very little improvement in the R^2's was noted.

amortization payment. For example, on a $100,000, 40-year loan the annual amortization payment would be about $5,827 at 5 percent and $5,052 at 4 percent or a 15.3 percent difference in annual payments.

Water Use, Rates, and Selected Operating Procedures

The second major objective of this study was to provide some relevant information on the operation of rural water systems. Items included were water use and consumption, water rates, and operating procedures with respect to meter reading, billing, maintenance, and employment.

Water Use

Rural water systems primarily serve domestic customers. Of the 15,875 customers served by the 57 systems in this study (end of 1972), 96.4 percent were residences. The rest were retail businesses, schools, churches, and a few commercial farm operations, such as feed lots and dairies;[12] feed lots and dairies accounted for less than 1 percent of all customers. There were no industrial customers. Water use by feed lots and dairies was limited in most cases to supplemental water; water from other sources was available.

The quantity of water used per customer per month was divided into four consumption groups (Table 12). The systems were divided among those serving rural areas only, towns only, and rural/town to show differences in water use by place of residence. The percent of customers

[12]One system had about 20 water taps at wheat field locations to water livestock while they were grazing wheat. The owners were charged an annual minimum fee, plus an amount for water use in excess of the minimum. None of these customers had exceeded the minimum as of 1972, so the use of these taps were apparently indeterminant.

Table 12. Water use per month per customer for 28 water systems, Oklahoma, 1972[1]

Rural water systems	Monthly water use (gallons) Under 2,000	2,001-5,000	5,001-10,000	Over 10,000
	Percent of users			
Rural only	27.3	34.3	27.5	10.9
Town only	38.7	32.5	19.5	9.3
Rural/town	36.7	28.8	24.5	10.0
Average of all systems	34.3	31.9	23.8	10.0

[1]October water usage was used for data collection because it was neither a high nor a low usage month. There is no average month for water usage.

using 2,000 gallons or less was relatively higher in town and in the rural/town systems than in the rural systems. This may be partly explained by the fact that many of the very small towns include a relatively large number of retired couples, widows, and widowers. Overall, the largest percentage of customers — 34.3 percent — used 2,000 gallons or less per month; 31.9 percent used between 2,000 and 5,000 gallons. Thus, two-thirds of the customers used less than 5,000 gallons of water per month.

Average monthly water use per customer for the 26 systems reported in Table 8 was estimated at 4,588 gallons.[13] Comparable monthly water use figures for the rural only, town only, and rural/town were 4,899, 4,286, and 4,580 gallons respectively. Water use by rural water customers was highest. Water use for livestock may partly explain this higher use, but sufficient data were not available for such an evaluation.

Water Rates

Water rates for FHA-financed water systems were determined basically as follows. Cost of installing and operating the system, the number of customers that use the system, and the amount of water expected to be used were all estimated. The rate was then determined so that income from the sale of water would amortize the FHA loan and pay operating and maintenance costs. Annual income generated from water rates set in this manner closely reflect actual annual costs. Thus, customers of rural water systems should be very interested in annual costs because these costs have a direct influence on their water bill.[14]

Average monthly water bills for customers of the systems studied can be determined, using the information on consumption estimates and water rates provided by the rural water systems (Table 13). Average monthly consumption for all customers was estimated at 4,588 gallons; at a rate of $.0023 per gallon, the average monthly water bill would be $10.55 per customer ($.0023 × 4,588 gal.). Average monthly water bills determined in a like manner would be $11.27 for rural only, $9.85 for town only, and $10.53 for rural/town systems.

Operating Procedures

Employment, maintenance, meter reading, and billing varied considerably among rural systems included in this study. Some very small systems operated with management by a Board of Directors, a voluntary

[13]Gallons consumed were estimated by multiplying the average percent of customers (line 4, Table 12) in each group by the quantity of water consumed in each group, i.e., (34.3 • 2,000) + (31.9 • 3,500) + (23.8 • 7,500) + (10.000 • 10,000) = 4,588 gallons. These estimates compare favorably with some estimates of consumption that have been made for Oklahoma State Office of FHA.

[14]This does not mean that the water bill for customers of other water systems do not reflect costs. However, in many municipalities, the water bill is subsidized by, or is subsidizing, other municipal functions.

Table 13. Average monthly water rates for 28 water systems, Oklahoma, 1972[1]

Rural water systems	Water use (gallons) Under 2,000[2]	2,001-5,000[3]	5,001-10,000[3]	10,000[4]
	Dollars			
Rural only	8.19	9.34	12.70	14.59
Town only	4.53	6.03	9.41	11.28
Rural/town	6.69	8.47	11.64	13.57
Average total	6.47	7.95	11.25	13.15
Dollars per gallon	.0032	.0023	.0015	.0013

[1]Water rates included in the table are for the same 28 water systems in table 15, These rates reflect the prevailing interest rate and construction costs at the time the loans to the 28 systems were made. Interest rates and construction costs have increased recently, and water rates for recently construction rural water systems are somewhat higher.
[2]Average minimum water bill was used to determine rate.
[3]Average rate for the middle of the range (3,500 gal. and 7,500 gal.) was used.
[4]Average rate for 10,000 gal. was used.

or very low-paid bookkeeper, and a maintenance man. Some of the larger systems had a paid manager, a maintenance man, a bookkeeper, a meter reader, and an "outside" firm to do their billing. A few of the systems hired an outside firm on a contract basis to perform all work – maintenance, bookkeeping, billing, construction of lines, etc.

Operating procedures for about 25 of the systems studied consisted of a board of directors and two employees – a manager and a bookkeeper. The manager's job was to oversee the day-to-day operations, do minor repairs as needed, and install new meters. Major repairs and line additions were usually done by plumbing contractors. The bookkeeper kept all of the books and usually did the billing and bill collection.

Meter reading was accomplished in several ways. In 21 of the 57 systems, customers read the meters monthly, with an annual reading by a system representative. In most of the other systems the manager or maintenance man reads the meter monthly. In a few cases a person is hired to read meters as his only duty. More than 21 of the systems tried having customers read their own meters, but for various reasons they have gone to a different procedure. Those currently having customers read their own meters report the procedure is satisfactory and very economical.

Overall, there did not seem to be a consistent pattern with respect to the various operating procedures just discussed. Rural water systems apparently experiment until they find the procedure that works well for their particular situation. They also apparently adjust their procedures to the growing number of customers they serve.

Water Systems Growth

The third major objective of this study was to determine the rate of growth and the factors affecting growth of rural water systems. No attempt was made in this analysis to determine rates of growth in rural areas without rural water systems. Thus no conclusions may be drawn from this study concerning the contribution of rural water systems to the economic growth of rural areas. Only conclusions about growth of rural water systems may be drawn from this study.

The 57 systems in the study grew from an original 9,943 customers to 15,875 customers at the end of 1972. The rate of growth was defined as the average annual percentage change in the number of customers measured from the end of the system's first year of operation up to the end of 1972. Among the factors that may be expected to affect the rate of growth are: the age of the system, per capita income in the county where the system is located, and distance of the system to the nearest growth center.[15]

Growth Rates

The 57 rural water systems were categorized by their average annual rate of growth. None of the systems studied experienced a decline in number of customers. Thirty-six systems had an average annual growth rate of less than 10 percent (Table 14). However, eight of the systems grew at an average annual rate exceeding 20 percent. The average annual rate for all 57 systems was 10.4 percent, ranging from 1.6 percent to 41.6 percent.

[15]"Growth Center" is a nebulous term; however, growth center in this study included Tulsa, Oklahoma City, Ardmore, Chickasha, Muskogee, Okmulgee, Lawton, Guymon, Claremore, Bartlesville, Miami, Prior, Tahlequah, Poteau, McAlester, Durant, Duncan, Ponca City, Ft. Smith, Arkansas, Hugo, Purcell and Nowata. Rapidly growing residential areas around the lakes in northeastern Oklahoma such as near Disney in Mayes County, were also considered "growth centers." Distance was measured from the edge of the growth center to the edge of the area served by the water system.

Table 14. Average annual rate of growth in numbers of customers for 57 sample water systems, Oklahoma, 1972[1]

	Annual rates of growth (percent)					
Item	Under 4.9	5-9.9	10-14.9	15-19.9	Over 20	Total
			Number			
Number of systems	16	20	9	4	8	57
			Percent			
Percent of systems	28.1	35.1	15.8	7.0	14.0	100.0

[1]Systems are from 2 to 7 years old.

Factors Affecting Growth

With such a wide range in annual rates of growth between rural water systems it is important to look at some factors that affect growth. Table 15 shows factors selected for study. Table 16 shows results of linear regression analysis for these factors.

Age

Age of the system was considered because it was felt that growth might be very rapid at first and then taper off. The systems considered in this study ranged from 2 to 7 years old. The average age of systems with the slowest growth rate was 5.6 years. The average age for systems with the highest growth rate was 4.9 years (line 1, Table 15). Results of the regression analysis indicate that the relationship between age of the system and average annual growth is not statistically significant (Student's t is −.358). It should be pointed out that all of the systems are relatively new, (none are over 7 years old) and the rate of growth could go either way, based on available data, as the systems grow older.

Table 15. Selected factors as they relate to annual rate of growth for 57 water systems, Oklahoma, 1972[1]

Growth factors	Annual rate of growth (percent) 0-4.9	5-9.9	10-14.9	15-19.9	20+
			Years		
Average age of systems	5.6	4.1	5.0	4.5	4.9
			Dollars		
County per capita income	2,333	2,305	2,175	1,936	2,388
			Miles		
Average distance from growth center[2]	16.4	3.6	7.1	6.0	0.9

[1]Systems are categorized by their rates of growth.
[2]Distance was measured from the edge of the growth center to the edge of the area served by the water system.

Table 16. Regression results for selected factors affecting annual rate of growth for 57 rural water systems, Oklahoma, 1972

Growth factors	Regression coefficient	R^2	Student's t
Age of system	—.317	.002	—.358
County per capita income	.001	.001	.194
Distance to growth center	—.385	.151	[1]—3.125

[1]Coefficients are significant at the 1 percent level.

Income

It was also expected that higher incomes would encourage a faster system growth rate. Available data do not support this idea. The regression results indicate there was no statistically significant relationship between these two variables (Student's t is .194). Rather, per capita county income declined for rates of systems growth up to the 20 percent, and then increased (line 2, Table 15). Income in counties with the lowest growth rate system was only $50 less than in the counties with the highest growth rate system. Thus, it would be very difficult to predict a growth rate for water systems on the basis of county per capita income. Average per capita income of present water system customers and potential customers might provide better data for this comparison. However, these data were not available.

Distance

Distance of the system to the nearest "growth center" was also expected to affect growth rates. For the lowest growth-rate system and the highest growth-rate system, distance was definitely a factor (line 3, Table 15), and the regression results indicate a significant statistical relationship (Student's $t = -3.125$). Systems that were adjacent to growth centers (.9 mile average distance) grew at an average annual rate exceeding 20 percent. Those that grew at a rate of less than 5 percent averaged 16.4 miles to a growth center.

Although closeness to a growth center tends to encourage more rapid water system growth, the fact that this is not the only factor affecting growth is obvious by looking at variability in average distances to growth centers in the 5 to 20 percent growth rates, and the small $R^2 = .151$ (Table 16). This coefficient may be interpreted to mean that only about 15 percent of the variability in growth is due to distance from growth centers.

Other Factors Affecting Growth

Some other factors that could affect rates of growth in rural water systems are: characteristics of growth centers near the systems; philosophy of water system management and/or landowners toward growth; availability of water; and physical capacity of the system to serve more customers.

Size and rate of growth of the nearest growth center appears to have an effect on growth of rural water systems. Those systems adjacent or very close to a rapidly growing center such as Tulsa or Ft. Smith, Arkansas, have in most cases, grown faster than those near slower growing centers such as Muskogee or Bartlesville. For example, a system near

Ft. Smith, Arkansas, has grown at an annual rate of 24.8 percent and one near Bartlesville has grown at a rate of only 5.3 percent.

Another factor affecting the growth of rural water systems is the attitude of management and landowners. In discussions with managers while filling out the questionnaires, it became obvious that some were encouraging growth and some were discouraging growth. The attitude of landowners adjacent to water lines toward residential development also affects growth. Some landowners are not interested in subdividing their land. In areas with growth potential, this attitude tends to slow the rate of growth.

Several managers interviewed indicated that the growth was stopped or significantly slowed because the system could not serve more customers. Managers indicated that some of the problems tending to slow growth were: inadequate water supply (15 managers); inadequate distribution system, including either storage tanks, lines, or pressure pumps (20 managers); or treatment plant operating at capacity (6 managers).

Some Consequences of Growth

The rather extensive growth of water systems in rural areas has brought about extension of water lines. The 57 sample systems had 1,778 miles of lines when they were built. At the end of 1972 they had added 414 miles of line, or a 23.3 percent increase. Only 9 of the systems had no line extensions, and 4 of those were serving small towns only. Thus, a very large part of the increase in new customers required water line extensions. These extensions were mainly within the original boundary of the water systems but some systems enlarged their boundaries. New customers paid for necessary line extensions in about 50 percent of the systems. In about 40 percent of the systems, the cost of extensions were shared by new customers and the systems. In the remaining 10 percent, the systems paid for all line extensions.

The Farmer's Home Administration had made additional loans to 8 of the 57 systems in the study to increase the capacity of the systems. These loans were made for line extensions, storage tanks, wells, and other capital improvements. In addition, several systems were in the process of obtaining additional loans to serve customers on a waiting list.

Another consequence of the growth in rural water systems has been the construction or addition of new residences in rural areas. Of the nearly 6,000 customers added to the 57 systems through 1972, 54 percent built new homes and 16 percent moved mobile homes into the area. The remaining 30 percent of the new customers already had homes in the area before the water lines were installed. Existing homes were connected as water lines were extended into areas not served by the original lines.

Summary and Conclusions

The objectives of this study were to provide some insight into costs, operating procedures, and growth of FHA-financed rural water systems in Oklahoma.

FHA has funded some 318 rural water systems in Oklahoma; 57 were selected for study. Information on each system was obtained from State and county FHA offices and representatives of the rural water systems.

For the study, costs were divided into investment costs and annual costs. Investment costs were defined as the original construction costs plus the cost of added capital improvements. Annual costs were defined as normal yearly expenditures for salaries, utilities, water purchases, office expense, maintenance, insurance, legal fees, amortization payments to FHA, and miscellaneous items.

Systems with treatment plants and wells had relatively higher investment costs than systems that purchased treated water. Therefore, in analyzing investment costs, investment in distribution systems was treated separately from investment in treatment plants and wells.

Three factors were analyzed to determine their effect on investment cost per customer in the distribution systems:

1. Number of customers per mile of line. Distribution system investment costs per customer declined from $1,041 for systems averaging 4.1 customers per mile of line to $539 for systems averaging 30.5 customers per mile. Statistical tests of this relationship were significant and indicate that about 40 percent of the variation in this cost is due to the number of customers per mile of line.
2. Number of customers served by the system. The systems in the study were divided among those serving rural customers only, town customers only, and both town and rural customers. Statistical tests indicate that the number of customers served does not significantly affect distribution system investment costs per customer.
3. Terrain. Distribution system investment costs are about 15 percent higher in extremely hilly and/or rocky areas.

For investment costs in treatment plants and wells, only the number of customers served was analyzed. Treatment plant investment cost per customer was $431 for plants serving less than 200 customers and only $175 per customer for plants serving more than 500 customers. There was a similar relationship for systems with wells. Statistical tests of these relationships were significant, and indicate that about 40 percent of the variation in investment costs per customer in treatment plants and about 45 percent of the variation in investment cost in water wells are explained by differences in number of customers served.

Annual costs were analyzed by dividing the systems among those with treatment plants, those with wells, and those that purchase treated water. Number of customers served and number of customers per mile of line were then tested to determine their effect on annual costs.

Statistical tests indicate that the number of customers does not have a significant effect on annual costs per customer. The tests do indicate that annual costs are affected by the number of customers per mile of line for systems with wells and those that purchase treated water but *not* for those with treatment plants. About 45 percent of the variation in annual costs per customer for systems with wells is explained by the number of customers per mile of line, and about 24 percent for systems that purchase treated water.

Of the 15,875 customers served at the end of 1972 by the 57 systems in this study, 96.4 percent were residences. Average monthly water use per customer was estimated at 4,588 gallons, with a monthly water bill of $10.55.

A typical rural water system operates with two employees — a manager and a bookkeeper. Some of the larger systems also employ a helper for the manager. In 21 of the 57 systems, customers read their own meters.

The average annual rate of growth for all systems studied, measured in terms of customers added, averaged 10.4 percent, and ranged from 1.6 to 41.6 percent. Distance to a growth center, age of the water system, and average per capita county income were statistically tested to determine their effect on growth. Distance to a growth center was the only one found to be significant. Other factors that apparently affect growth were attitude of management and landowners toward growth, and the limited physical capacity of systems to supply water to additional customers.

Some consequences of growth were: a 23.3 percent increase in miles of line over the miles of line originally constructed, and the addition of about 6,000 new customers resulting from the construction of about 3,240 new homes and the addition of about 960 mobile homes. The rest of the new customers lived in homes that existed when the lines were constructed.