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ECONOMIES OF SIZE AND SOCIO-ECONOMIC IMPACTS OF RURAL WATER DISTRICTS IN OKLAHOMA

By

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IMPACTS OF RURAL WATER DISTRICTS

IN OKLAHOMA

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CHAPTER I

INTRODUCTION

The need for good quality water cannot be overemphasized because water is a basic essential requirement for all living creatures and it constitutes one of life's most valuable resources. The availability of good quality water in an area helps in improving health conditions especially as water is a vital requirement for a clean and sanitary environment. The progress of sanitation is closely associated with the availability of an adequate good quality water supply. Good quality water, as defined by E. G. Wagner and J. N. Lanoix (1, p. 18), is that which will not yield harmful effects upon consumption. It is free from poisonous substances and from excessive amounts of mineral and organic matter.

An adequate water supply is an important element in community development which can be regarded as an effort aimed at increasing the economic opportunity and quality of living in a given community. Recognizing the role of water in maintaining community health and community development, federal programs have been initiated to assist communities in obtaining adequate water facilities. The Farmers Home Administration (FHA), of the United States Department of Agriculture, makes loans and grants to public and nonprofit organizations primarily serving rural residents to enable them to plan and develop domestic water supply and waste disposal systems. Since 1963 when the program began, public water and sewage systems have become an integral part of community life and the systems have enabled communities to develop adequate supplies of water for domestic and industrial uses and as efficient means of collecting waste materials.

In Oklahoma, under the Rural Water, Sewer and Solid Waste Management Districts Act (820.5. Supp. 1972SS 1324.1 - 1324.26), the FHA made loans and grants totaling more than $60 million for the construction of over 245 completed rural water systems as of December 1, 1972 (Table I). These water systems now provide an adequate supply of good quality water to areas where private wells were costly to construct or were incapable of delivering enough good quality water. They have also saved the users the cost and inconvenience of hauling water, which for all practical purposes was not an adequate source of water supply for domestic uses. When these 245 rural water districts began distributing water, they were serving 49,534 members.

Before the rural water district program was available to rural communities in Oklahoma, many rural residents obtained their water supply requirements from three main sources: (1) wells, (2) hauled water and (3) rain water. Rural residents who are not members of rural water districts today still depend on one or more of these sources for their water supply. Cisterns are used in many cases to collect rain water and hold hauled water.

The decision to join a rural water district is made by the individual but this study shows that this decision is considerably affected by such factors as adequacy of the supplies from the individual's present sources of water, quality of the water from the individual's present sources, the ever present need to maintain the water pumps in good working condition, and the cost of obtaining water from the rural water districts.

TABLE I

RURAL WATER DISTRICTS ESTABLISHED IN OKLAHOMA, 1964-1972

(As of December 1, 1972)

Number of Rural Water Districts in Operation	245
Amount of loans ($)	56,880,640
Amount of grants ($)	3,266,210
Number of members at the start	49,534
Number of Rural Water Districts with Loans Funded but Not Yet in Operation	23
Amount of loans ($)	4,068,500
Amount of grants ($)	179,000
Number of members	2,025
Number of Applications Received by FHA for Funds to Establish Rural Water Districts	43
Amount of loans requested ($)	9,049,200
Amount of grants requested ($)	4,732,300
Number of potential members	14,629

Source: Farmers Home Administration. "Summary of Community Programs Loan Activity in Oklahoma," (mimeo), Stillwater (1973).

Development of Rural Water Districts in Oklahoma

A rural water district in Oklahoma is a non-profit public body organized to develop water systems for rural areas or towns of not more than 5,500 in population. Its primary function is to finance, construct, operate and maintain a rural water supply system. The system is owned and operated by the membership comprising persons living within the district who purchase a benefit unit.

A rural community desiring a centrally organized water distribution system first selects a committee to determine the number of potential members of the district and the feasibility of the water project. On the advice of the FHA, the committee hires an engineer who prepares a preliminary engineering report showing the estimated cost of the system, a tentative design of the distribution system and an estimated water rate schedule. If the costs are within reasonable limits that would not put financial strain on the members of the district, the preliminary report is submitted to the FHA.

The FHA then conducts an economic study of the community to determine the number of people which can be served by the district, the plan of operation of the water system and the proposed budget for the system. If it appears that the system is sound from the engineering and economic standpoint, the FHA authorizes the applicants to proceed with the development of the district.

The committee then employs an attorney and circulates a petition among land owners in the community to organize a water district. The petition is filed with the Board of County Commissioners who hold a hearing and incorporate the district as a legally constituted public body. The landowners in the district then elect directors and adopt by-laws. The directors thereafter have the responsibility for requesting the engineer to prepare the final plans and specifications of the water system; they advertise for construction bids; seek applications from prospective water users for membership in the district; and, apply for loans from the FHA to finance the water system.

If the funds are available for the project and the construction bid is within the funds available, the FHA closes the loan and deposits the funds in the construction account of the district. The contractor may then proceed with the construction of the water system. As a community project, the success of the district depends on how well the people in the community cooperate and how well the committee does its job.

A person who owns land in the community or who lives within the boundaries of a rural water district is not obligated in any way except when the person applies for water service and has been accepted as a water user. Persons who fail to seek membership initially can later purchase membership provided the system is not overloaded. However, they may be required to pay an additional fee.

The land and/or personal property in the district cannot be taxed to pay the cost of a water system. To retire its indebtedness and pay operating and maintenance costs, a rural water district uses the revenue from the sale of water district memberships and from the sale of water. Water sold by the district is metered and a meter serves only one business establishment or one household. Free water service is not provided.

A member can purchase more than one benefit unit on his property and each carries with it an obligation to pay a minimum monthly bill. Each member is expected to pay his monthly bills promptly and a late charge may be made if a bill is not paid by the prescribed time or the water service may be disconnected as provided for in the by-laws. A benefit unit can be transferred if the new customer receives approval of the board of directors of the district.

The rural water district has no lien on the land of the members for their share of the cost of the water system and the members are not personally liable for the debts of the district. The FHA has a mortgage only on the property owned by the district.

The water lines are usually laid on privately owned lands where they will not be disturbed and the land owners along the lines are usually requested to grant rights-of-way since the water lines contribute benefits to the lands and to the people in the community. Where it is not possible to secure easements from non-members, the water lines can be laid in the dedicated streets in towns and along section lines in rural areas. Payment for easement of private property to lay water lines is rarely done except some payment may be made for a property easement to build water towers or to develop wells.

A water meter is normally located about five feet inside the customer's property and each member has the responsibility to connect the water line with a line to his house. Usually meters are located at the property line adjacent to the point of use and this point is determined by the directors and the engineer.

The rural water systems are not designed for fire protection services but fire plugs may be installed on the water lines if the district desires. The water supplied to members is expected to be good quality water which meets the quality criteria set by the State Department of Health.

The FHA loans are made to the districts at five percent simple interest to be repaid in a period not to exceed 40 years. Grants may be made to help finance up to about 50 percent of the development cost when such grants are needed to reduce to a reasonable level the charges that the water users will have to pay.

The members generally read their own meters although a few districts employ a meter reader. The books of the district are audited annually and the water district facilities are to be maintained in such a manner as to adequately protect the government's security. All rural water districts are required to comply with civil right agreements.

The Problem

If rural is defined to encompass all persons living outside Standard Metropolitan Statistical Areas, then 56 percent of the population of Oklahoma was rural in 1960 (2, p. 1). If it is defined as open country and towns of 2,500 population or less, then 37 percent of the state population was classified rural in 1960 and 32 percent in 1970. Whichever definition is used, the rural population represents a significant proportion of the total Oklahoma population. Economists frequently regard rural development not only as providing jobs and increased incomes to rural people, but also making available a quality of rural living through increased and improved community services (2, p. 1). Ideally, economic growth should measure the well-being of people, including the quality of housing, community services, roads, clean air and water, and access to employment opportunities and services as well as income.

Schreiner (3, p. 2) notes that while rural America has long been noted for its cohesive societal, fraternal, occupational, and communal groups organized to provide community services, the pace of traditional methods to deliver community services has not been adequate to meet increased public demand. The community based water program sponsored by the FHA for rural areas in Oklahoma is a part of an effort to improve the quality of living and enhance economic opportunity in these rural areas. The rural water program has been very popular with the people and the public demand for water services has been greater than was anticipated for many districts. There is a high demand for membership in the existing districts and other communities are seeking FHA loans to establish their own water systems.

The impact of this rapid growth in Oklahoma has been enumerated by Leonard L. Downing (4, p. 199):

> ". . . This rapid growth has caused several problems:
>
> (1) We failed to provide for sufficient growth and most systems are requesting additional funds to serve more people.
>
> (2) Due to lack of planning and development of sources of supply, we let too many small districts construct a system.
>
> (3) We failed to make the Board of Directors aware of the responsibilities of operating a public water system."

The rural water system program is relatively new in Oklahoma and the problems enumerated above are not unusual in comparable situations where there are no precedents to follow. The Farmer's Home Administration is actively working to solve these problems and it is hoped that the results of this study will make some contributions to that effort. Quantitative data are needed to analyze the effects on the social and economic conditions in the areas served by the rural water districts, as well as to evaluate the effectiveness with which the intended management functions are being performed. When this study was initiated no specific research information was available on economies of size, i.e., on the possibilities of combining several contiguous districts into larger districts.

Objectives of the Study

The overall objective of this study was to determine the costs of providing different amounts of water to rural communities and to analyze the effects of the rural water districts on communities in Oklahoma.

Specifically, the objectives were:

(1) To estimate economies of size for rural water districts in Oklahoma.

(2) To analyze the social and economic impacts of the rural water districts.

(3) To identify and discuss the management functions associated with the development, operation and maintenance of rural water districts.

Selection of the Study Area

Nine Oklahoma counties were selected as the study area to reflect different characteristics in climate, topography and rural population. The counties selected were Cherokee, Cotton, Creek, Dewey, Kingfisher, Muskogee, Okmulgee, Wagoner, and Woodward (Figure 1). Counties in the western part of the state generally have flat rolling plains, low annual rainfall and sparsely populated rural areas. Those in the eastern part of the state have abundant rainfall, hilly terrain and are generally densely populated. The number of rural water districts in operation as of December 1, 1972, in the entire state of Oklahoma is indicated in Figure 1.

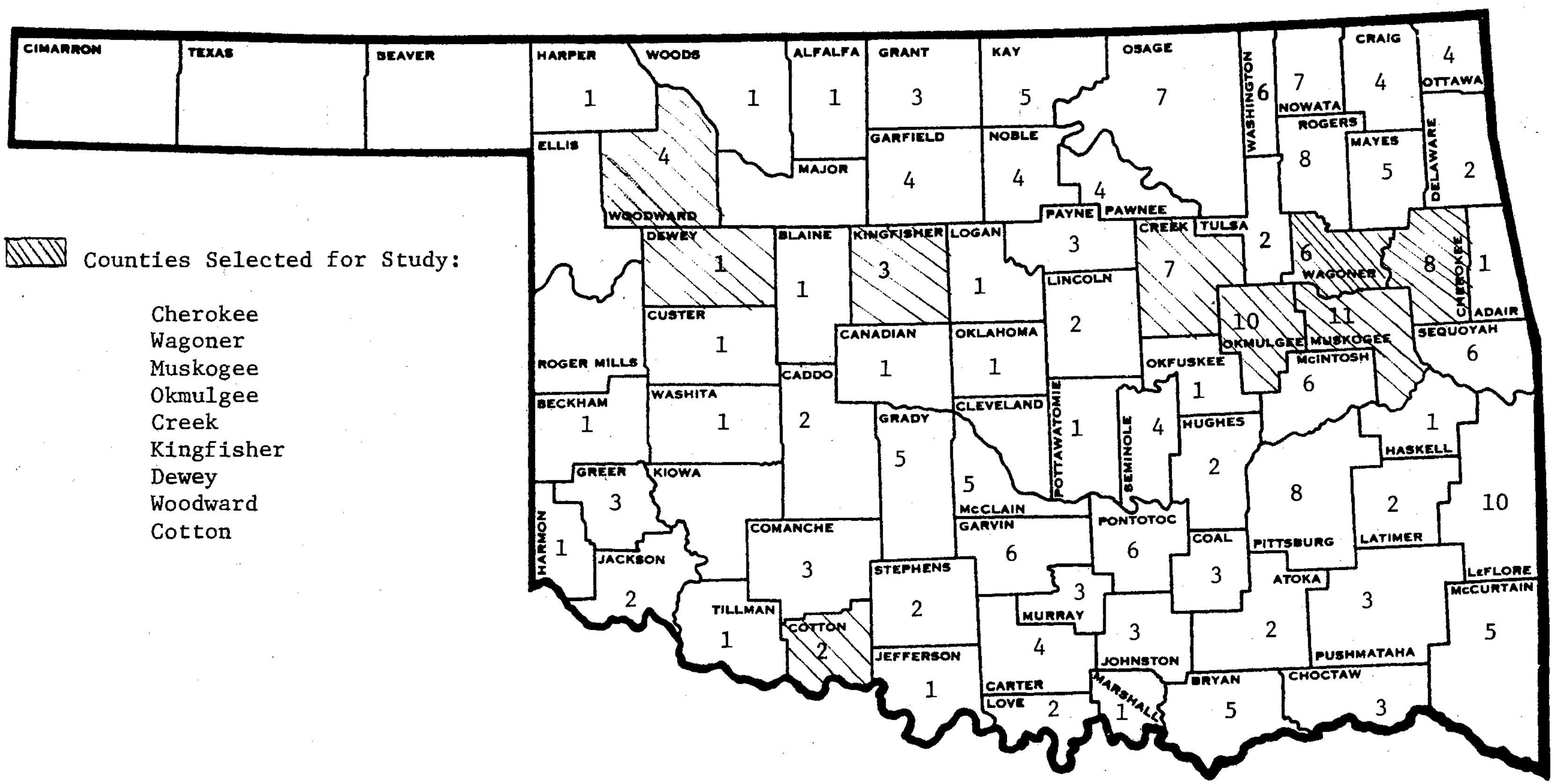

Figure 1. Counties in Oklahoma Showing Number of Rural Water Districts in Operation as of December 1, 1972

One rural water district was selected from each of six counties mentioned above, while five were selected from Muskogee County and two each from Okmulgee and Wagoner Counties. The sample selected thus included districts which differ with respect to time of establishment, distance to large urban areas and availability of other community services such as recreation. The larger number of districts selected in Muskogee County provide sufficient data for a quantitative impact analysis of that county.

Size and population, by rural and urban, for the nine survey counties are indicated in Table II. The census data show that four of the nine counties lost population from 1960 to 1970. The population figures for subdivisions of counties corresponding to rural water district boundaries were not available. This made it impossible to measure within county migrations that may have been induced by the development of rural water districts.

Organization of the Thesis

The remainder of this study is divided into five main chapters. Chapter II discusses the methodology used in this study and reviews previous studies of related subject matter. Chapter III presents the empirical results on the statistical derivation of the economies of size curve.

The results of the social and economic impact study are reported in Chapter IV while the findings of the management study are contained in Chapter V. The summary and conclusions of this study are presented in Chapter VI.

TABLE II

SIZE AND POPULATION CHARACTERISTICS OF SELECTED OKLAHOMA COUNTIES, 1960 AND 1970

County	Land Area Square Miles in 1970	1970 Population			1960 Population		
		Total	Urban	Rural	Total	Urban	Rural
Cherokee	756	23,174	9,254	13,920	17,762	5,840	11,922
Cotton	651	6,832	2,611	4,221	8,031	2,825	5,206
Creek	936	45,532	23,616	21,916	40,495	23,264	17,231
Dewey	1,018	5,656	--	5,656	6,051	--	6,051
Kingfisher	904	12,857	4,042	8,815	10,635	3,249	7,386
Muskogee	818	59,542	37,331	22,211	61,866	38,059	23,807
Okmulgee	700	35,358	21,610	13,748	36,945	22,502	14,443
Wagoner	563	22,163	7,287	14,876	15,673	4,469	11,204
Woodward	1,251	15,537	8,710	6,827	13,902	7,747	6,155

Source: U. S. Department of Commerce, Bureau of the Census. U. S. Census of Population (1970) Table 9.

CHAPTER II

METHODOLOGY AND REVIEW OF LITERATURE

Concepts of Economies of Size

The provision of a public service has a number of dimensions; the major ones are production costs and distribution costs. Unlike private firms that have a strong profit motive, local governmental agencies do not always use the optimality concept of marginal cost in decisions to supply a public service (5, p. 319). The average unit cost of a public service is influenced by the quantity and quality of the service, the service conditions, physical inputs, state of technology and the factor input prices.

The costs incurred by each rural water district in supplying water to the members depend on the prices paid for the resources used and the efficiency with which the resources are used as well as on the size and type of the water system. The cost of supplying water will vary as the quantity and quality of water changes per unit of time. It will also vary with a change in the density of customers per mile of pipeline and with the topography and soil characteristics of the area through which the pipelines have to be laid.

Economies of size result when total costs per unit of output decrease as additional units of output are produced (and/or distributed in the case of water). Real variations in the size-efficiency relationships in costs may occur because of differences in size, type of water systems, topography and soil characteristics of the districts and in prices of inputs required.

Short-run economies result from fuller utilization of a fixed plant, such that the rural water districts could have such economies by producing and distributing more water without changing the size of their treatment plants, storage tanks and pipelines. Long-run economies result from the efficiencies obtained by changing plant size, presumably involving a longer time period (6, p. 3). The long-run average cost curve assumes all resources are variable. Whether or not economies of size occur in rural water district planning has important implications for efficiency, organization and community size.

Methods of Analyzing Economies of Size

Several analytical procedures have been employed in analyzing economies of size and the procedure adopted depends on the purpose for and situation in which the study is conducted. Madden (6, pp. 24-34) and Eidman (7) provide a comprehensive discussion on many of the procedures that are frequently used in estimating economies of size.

The method presented by Stigler (8), called the survivorship technique, is based on the idea that competition among firms will sift out the more efficient sizes. Size of firm is measured in terms of the firm's capacity as a percentage of industry capacity. Firms are grouped into sizes and the size classes that exhibit a declining proportion of the industry's capacity through time are deemed to be inefficient. This approach does not adequately measure size because no provision is made for changing capacity in the industry and it is possible for a firm to shift from a small size class to a larger and more profitable class, but not necessarily a more efficient operation. Furthermore, declining relative importance of a given size of firm might result from many factors other than the inefficiency of that size of operation. Location, access to resources and markets, quality of management and degree of utilization of plant capacity could vary among the observed plants.

Another method used in estimating economies of size is the synthetic-firm approach. This method is an appropriate technique when it is intended to determine: (1) the average cost per unit of output or profits that firms of various sizes could potentially achieve under assumed technology, or (2) the differences in average cost per unit of output attributable only to differences in size of firm. In the synthetic firm approach, budgets are developed for hypothetical firms using the best available estimates of the technical coefficients and charging market prices or opportunity costs for all resources. However, this method ignores the economies or diseconomies in resource use as scale is increased. The engineering cost data often allocate joint costs arbitrarily between processes and may not distinguish between fixed and variable cost factors in a manner suitable for economic analysis. It also makes factor markets difficult to evaluate (7, p. 20).

A third method to measure economies of size is statistical regression procedure. Johnston (9, pp. 26-43) provides a detailed discussion on the procedure and problems of statistical estimation and lists four main conditions which should be satisfied in the process: (1) the basic time period for each pair of observations should be one in which the observed output was achieved by a uniform rate of production within the period; (2) the observations on cost and output should be properly paired such that the cost figure is directly associated with the output figure; (3) observations on output should be widespread so that cost behavior can be observed at widely differing rates of output; and (4) the data should be free from the influence of factors extraneous to the cost-output relationship. To examine the long-run cost-output relationship, a large number of observations on firms with widely different capacity limits should be obtained from cross section data.

Using regression analysis to estimate average cost curves requires that the data possess certain statistical properties: (1) the disturbance term should be a random normal variable with zero mean and have a constant variance regardless of the level of output; (2) for time series data the disturbances should be serially independent, i.e., the error term in cost occurring in a given time period is independent of the discrepancies that occurred in previous time periods; and, (3) the disturbance should be distributed independently of the explanatory variables.

The regression analysis method has also not been without its critics (9, pp. 169-194). The most common of the criticisms directed at the methods employed and the conclusions reached in statistical cost studies is that regression fallacy results because firms of a smaller scale are more likely to be operating at a smaller proportion of full capacity than are firms of larger capacity. Thus, cost curves do not take into account the proportion of capacity utilized, which tends to understate economies resulting from increasing the scale of plants. However, as Walters (10, pp. 210-5) has explained, if results of statistical cost analysis are interpreted as estimates of the expected cost function then the method is appropriate. The cost curve that is derived is not a technological frontier but an indication of what the expected costs could be if operations are organized as efficiently as possible under the existing conditions.

The methods that have been described for estimating economies of size have been used extensively in agricultural production and manufacturing firms. The regression procedure is most commonly used in estimating cost functions for public services and this study utilizes the procedure by employing the factors which affect the service condition as explanatory variables.

To determine the variations in the size-efficiency relationships in costs, cost functions were derived for the rural water districts using number of customers, volume of water distributed, density of customers, topography and soil characteristics as explanatory variables. The cost data used were obtained from the accounting records of the rural water districts, all of which employed a uniform accounting procedure specified by the Farmers' Home Administration. The period covered was from 1967 to 1972, except where the relevant data were not available. The summary of the data used is presented in Table III.

Lawrence G. Hines in a study (5, p. 330) of the long-run water delivery costs for selected Wisconsin communities analyzed several individual water plants using data from 1945 to 1957. Noting that during the period virtually no technological changes had taken place, he found that costs varied because of service conditions, such as the size and density of the community to be supplied, as well as the terrain. In order to neutralize terrain as a factor in the final cost of water delivery, power and pumping expenditures were left out of operating costs before fitting separate cost functions for the different types of water

TABLE III

SUMMARY OF DATA USED IN THE COST ANALYSIS FOR SELECTED RURAL WATER DISTRICTS IN OKLAHOMA

Rural Water District	Year	Number of Members	Volume of Water Produced and Distributed ('000 gal.)	Investment per Capita ($)	Total Variable Costs ($)	Total Fixed Costs ($)
Cherokee #2						
	1970	97	5,380	1,885.82	4,961.30	10,769.60
	1971	100	5,172	1,821.55	7,763.21	7,386.60
	1972	106	6,452	1,802.47	9,670.31	4,900.00
Cotton #2	1970	85	6,664	2,897.51	4,160.00	14,718.20
	1971	101	9,393	2,438.50	7,730.00	14,448.25
	1972	117	12,172	1,974.16	14,920.00	21,518.30
Creek #2	1969	1,004	85,336	1,013.39	46,220.00	52,817.50
	1970	1,104	93,836	940.85	49,970.00	52,817.50
	1971	1,286	109,305	823.65	63,120.00	52,817.50
	1972	1,400	118,994	755.44	77,020.00	53,417.50
Okarche, Inc.						
	1970	54	8,423	1,827.01	2,569.07	7,469.90
	1971	59	9,825	2,088.43	2,819.30	7,936.30
	1972	60	10,919	2,089.55	9,476.61	6,054.00
Muskogee #1	1967	173	10,130	1,147.47	2,108.81	11,201.80
	1968	193	11,301	1,007.57	5,607.04	11,168.80
	1969	220	12,883	860.89	12,047.91	11,201.80
	1970	233	13,644	747.46	10,451.37	11,201.80
	1971	244	14,288	725.83	7,750.47	11,030.30
	1972	260	15,225	696.63	8,000.00	10,926.80
Muskogee #2						
	1967	50	1,329	1,560.97	1,125.72	6,133.85
	1968	60	2,080	1,350.63	1,290.32	6,250.85
	1969	65	3,130	1,238.22	3,894.14	6,259.77
	1970	72	5,209	1,104.48	5,381.19	6,093.85
	1971	77	6,215	878.79	4,704.00	5,779.85
	1972	107	11,695	654.28	9,739.93	7,169.85
Muskogee #4						
	1969	65	5,141	1,028.55	2,487.49	3,840.00
	1970	68	5,379	963.01	3,823.68	3,830.00
	1971	72	5,695	885.10	4,969.16	3,840.00
	1972	77	6,090	827.63	11,569.92	3,844.93
Muskogee #5	1969	264	31,416	1,266.01	9,102.93	19,108.95
	1970	275	32,725	1,190.57	14,841.30	23,291.00
	1971	298	29,199	1,085.67	20,782.52	22,806.75
	1972	312	29,841	1,027.52	21,951.00	18,807.75
Muskogee #6	1970	156	2,506	1,731.44	6,241.00	13,111.75
	1971	180	2,891	1,604.36	10,641.50	15,557.75
	1972	192	3,084	1,401.40	7,163.00	15,582.75
Okmulgee #6	1970	582	32,825	1,168.46	18,000.00	37,817.00
	1971	661	37,280	1,091.32	26,800.00	37,892.00
	1972	722	40,721	1,050.75	36,358.88	41,301.07
Wagoner #2	1967	100	2,213	1,287.50	3,789.00	4,683.00
	1968	109	4,742	994.11	4,400.00	6,013.00
	1969	124	5,997	944.30	4,897.00	6,161.00
	1970	149	7,646	894.47	6,996.00	6,043.00
	1971	162	8,033	851.25	7,740.76	6,086.20
	1972	174	15,891	804.32	26,535.00	7,215.00
Woodward #1 [Including town of Freedom and Alabaster State Park]	1970	378	27,054	629.00	3,400.00	6,247.00
	1971	378	28,368	628.91	2,616.00	6,875.00
	1972	391	29,940	608.09	3,534.84	9,211.00

systems. Capacity was introduced as one independent variable and size, with adjusted plant investment as its proxy, as a second. The study found scale economies in surface water production systems where power and pumping expenses were eliminated in measuring plant size.

Richard A. Andrews (11, pp. 905-912) studied the economies in water utilities associated with (1) size of the utility and (2) size of the community using regression analysis of the annual water costs and production. The regression analysis relating cost and quantity of water produced indicated mddest economies of size. However, as the number of customers increased necessitating an increase in the mileage of water mains to reach the added customers, the economies obtained elsewhere in the system through increases in quantity of water produced were offset. The regressions indicated that if number of services could be held constant and water use at each service to increase then substantial economies would be achieved.

Andrews did not find economies associated with size of communities as great as those found with regard to economies associated within the utility. As the population increased, there was a tendency for the larger community to use more water per person per day. This was apparently because the larger communities produced more public services that necessitated water and also serviced a larger commercial base than did smaller communities.

Social and Economic Impacts of Rural Water Districts

Compared with major urban areas, rural areas have been deficient in the provision of public services. However, since 1966 the number of rural areas in Oklahoma establishing centrally organized water systems with the assistance of the FHA has been increasing. A large number of applications to establish rural water districts is being received by the FHA each year and it is possible that this essential public service has been having some desirable social and economic impacts on the communities.

These impacts can be classified as primary (direct) and secondary (indirect and induced). One primary social impact is the effect on population of communities served by the rural water districts. Location theory is often used to explain the growth or decline of small towns and many studies have shown that towns near large cities are more likely to grow than others (12, p. 397). The assumption is that places near large centers are functioning as commuter towns and possibly that industry or trade is expanding there because of locational advantages. The small town then becomes more like a suburb, providing both a market for the products of the larger town and a place of residence for many who work there. One factor which may be of important consideration in the decision to locate in a rural community is the availability of adequate water service. Adequate water supply is not only vital in satisfying the domestic needs of the individuals but is of primary importance in promoting a clean and sanitary environment.

Another primary social impact is the effect on the quality of living in the rural communities. Quality of life has been defined in many ways; e.g., Lowdon Wingo (13, p. 5) defined it as an internal physiological mechanism that produces a sense of gratification. While this may be a satisfying definition in the ethical sense, not everyone would agree that quality of life is a good in the economic sense. However, people do seek a higher quality of life and it is a scarce "good" in an economic setting.

So long as conditions exist such that people are willing to surrender other kinds of satisfaction for a higher quality of life, then it can be regarded as an economic good. The concept of quality of life encompasses the availability of the basic necessities for a decent living. The availability of water service in rural communities aids in improving the quality of life by facilitating the use of plumbing fixtures in homes, water coolers, humidifiers, clothes washing machines, hot water heaters and dishwashers for people who can afford to purchase these items.

The primary economic impact of rural water services is the effect on wages, salaries and profits resulting from employment in business establishments that have located in the communities because of the availability of water service and from the sale of plumbing fixtures and water-using appliances. Another aspect of the economic effect is the addition to livestock holdings as a result of the availability of good quality water supply.

Secondary economic impacts include additional property and sales taxes to the local governments and increases in demand for local government services resulting from a relocation of population and some increase in incomes. Another economic impact is the level of local governmental expenditures which may show an increase with increased demand for such services and facilities as schools, teachers, sewage, utilities, streets and police protection (14, pp. 69-80).

Statistical analyses using a dummy-variable approach and an economic base multiplier, were used to estimate some of these effects. The data used were developed from the questionnaire survey of the rural water districts and from published secondary data. Muskogee county was the primary focal point for this analysis because of the large number of rural water districts there.

The social and economic data obtained from the consumer questionnaire survey included:

(1) Population of the communities.

(2) Source of income of customers.

(3) Location of place of employment.

(4) Availability of jobs in the communities.

(5) Location of business in the communities.

(6) Effect on property values.

(7) Effect on water-using appliances.

(8) Housing and water facilities in homes.

(9) Uses made of the water from the water districts.

(10) Previous source(s) of water before joining the district.

(11) Reason(s) for seeking membership in the district.

(12) Rating of the performance of the district.

Secondary data were obtained on housing trends, taxes, incomes and population; unfortunately most of these data are available only for counties, and not smaller areas encompassed by rural water districts.

In a study of the impact of community water systems in small towns, Wills and Osburn (15) concluded that there were: (1) increases in the number of water using appliances; (2) increases in property values; (3) improved fire protection; and, (4) improved sanitary conditions in the communities served. Their study was a pilot project to identify and ascertain costs and benefits of FHA financed water systems. The scope of the study was small as it involved three small towns in southern Illinois.

Smythe (16, pp. 1-6) evaluated the impact of a rural water district on land values, home improvements, livestock and water hauling in Wilson County, Kansas. Land in the district sold for an average of $43.50 per acre more than land sold in an area not served by a rural water system. Some saving was also reported on water hauling and there was a marked increase in the availability of water using appliances.

While the availability of adequate good quality water supply may contribute to increasing the value of land, it is not adequate to attribute the increase in price to the water supply alone. There are other factors which could cause the increase in land value, such as the state of the economy, general rise in level of prices, number of buyers, quality and location of the land.

There is no doubt that the rural water districts have had an impact on the social and economic development of rural communities. The key issue is how to adequately measure the effects and quantify such factors as quality of life, improvement in health conditions, joy of country living and beautification of lawns.

Management Functions of Rural Water Districts

Supplying water to a community is a social service which requires managerial skills in both technical and administrative positions to ensure adequate water service, and good financial standing. The quality of service is a first consideration although the cost of the service must, nevertheless, be met since the districts are expected to be self-supporting.

For a market-oriented business enterprise the basic management information system model has four components (17, p. 21):

<u>External Environment</u>

(a) customer
(b) competition
(c) economic variable
(d) demographic variable
(e) cultural variable
(f) legal environment

<u>Internal Environment</u>

(a) accounting
(b) finance
(c) commercial
(d) governmental information sources

<u>Personnel Section</u>

(a) sales
(b) information

<u>Output</u>

(a) customer reports
(b) economic analysis
(c) budget
(d) performance
(e) sales

Management of a market-oriented firm may utilize this model in planning, implementation, evaluation and research decisions. The rural water district is a non-profit public body organized by members in a community to provide a water service. The study of its management functions therefore concerns an identification of the functions which should be performed if the social service is to be adequately provided. The degree to which a water supply system fulfills its functions to its members and the community depends a good deal on the efficiency, effectiveness and awareness of its management. Factor analysis technique was used to identify the variables of management and to compare their relative importance through the loadings in the factor matrix.

There are many duties which must be performed by the management of a water district and these can be divided into administrative duties and operation and maintenance duties (1). Under administrative duties are: (1) accounting of funds, (2) budget estimating, (3) water-rates calculations, (4) billing, (5) collection of water fees, (6) paying the money into the revenue accounts of the water district, (7) record keeping of the lay-out of the district, its business transactions, the personnel, the equipment, supplies and inventories of the district, (8) purchasing and (9) customer relations.

Operation and maintenance duties include: (1) maintenance of source of water, (2) maintenance of pumps, engines and other equipments of the district, (3) adequate water treatment, where applicable, (4) maintenance of the water distribution system, (5) maintenance of service connections to the water system, (6) maintenance and repairs of meters, (7) operation of water service in emergencies, and (8) detection and elimination of cross-connections, leaks, back-siphonage and presence of sediments or sand in water.

This is by no means an exhaustive list but an indication that water services, like other social services, require considerable management input if they are to adequately perform the functions for which they were contracted. All the duties need not be concentrated in one person but each manager should be aware of his role and the need to perform his function efficiently.

The preponderance of technical and engineering problems involved in the development, operation and maintenance of a water system requires that a qualified engineer be available for the planning, construction and development of the rural water district. In some cases, inadequacy of the water system may be encountered within a few years after the start because of poor planning, underestimated growth in demand, problems with pumps, storage facilities and/or distribution lines which are too small to properly and adequately serve new areas which should have been taken into consideration during the original plan.

In a study of the problems and characteristics of rural water districts in Missouri, McNabb and Blase (18, pp. 1-12) found that over one fourth of the districts experienced more than ten percent failure to hook-up among people who originally contracted for water. About half of the districts had more than ten percent of the original users drop out at the end of six months. The reasons given were that many people only wanted a water line through their property either to increase its value or for insurance against failure of their individual water systems. On the average, seven hours of clerical time was required for each 100 users per month. In concluding, McNabb and Blase suggested that each board of directors hire a competent engineer during the planning and development stages of the district and provision be made for inspection during the construction period.

John H. Peterson, Jr. (19) studied the influence of community organization on the organization and management of community water systems in selected rural communities of Mississippi. He found that community organization was significantly related to effectiveness in water system organization. The management problems observed resulted from three major sourdes: (1) major equipment failure; (2) lack of management ability; and (3) an inflated initial membership.

Peterson found that where the water system served a single community, the process of organizing the water system tended to strengthen local leadership, and the water system was operated informally. Social pressure was more often used to encourage payment of water bills while maintenance and secretarial work were often undertaken as a volunteer service. Common participation was rare in multi-community systems and the formal pattern of operation with paid maintenance and secretarial services were adopted.

In this study, factor analysis of the operation of Oklahoma rural water districts was used to measure the relative importance of the management functions. Recommendations based on actual management practices should enable future rural water districts to serve the maximum number of people in an efficient manner.

Data were obtained on the factors listed below to determine the managerial capacity available to the rural water districts and to determine the role of management in the efficient operation of a rural water district.

(1) Meter reading, billing of customers.

(2) Maintenance of the system.

(3) Problems of the water system.

(4) Financial status with respect to loan repayment.

(5) Adequacy of the water system to meet its obligation to users.

(6) New ideas on the development, operation and maintenance of a rural water system.

(7) Weights on the variables important to management.

Personal interviews were held with the directors and bookkeepers of the rural water districts and also with officials of the FHA to obtain information on the development and management of rural water districts. Data from the annual business report and data on the construction, operation, and maintenance of the selected districts were obtained from records of the Farmers Home Administration in Stillwater. Copies of the two questionnaires used in the study are presented in the Appendices. The Director's Survey is in Appendix A. The Water User's Survey is in Appendix B.

CHAPTER III

ECONOMIES OF SIZE FOR RURAL WATER DISTRICTS IN OKLAHOMA

As was indicated in the discussion of the theory of economies of size, the long-run least cost curve that is derived from the cost-output relationship is useful for planning purposes. The curve indicates the levels of cost that may be expected from the operations of the rural water districts of various sizes when the operations are organized as efficiently as possible under the existing technological conditions and prices.

Components of Costs of Rural Water Systems

The main components of the costs of rural water systems are construction costs, operation, and maintenance costs. The operation and maintenance costs are primarily expenses on: (1) wages, salaries; (2) office expenses (telephone, rent, supplies); (3) taxes, insurance, fidelity bonds; (4) fees (accounting, legal); (5) utilities; (6) repair to facilities and equipment; (7) fuel, gas, oil; (8) miscellaneous material and supplies; (9) director travel and expense; (10) equipment hire; and, (11) water purchase. The construction costs are the cash outlays used in building the source of water supply and the distribution systems.

The cost of producing and distributing water from the rural water system is dependent on the density of the customers being served; the terrain (physical characteristics of the soil) in the area; the amount of water produced and distributed; treatment of the water, where applicable; and, the long term debt. Low density of customers per mile of pipeline increases the per capita costs. Hilly and/or rocky terrain also leads to increased construction costs. The input cost data were adjusted for inflationary effects by using whole price indexes with 1967 = 100, which thus converted the costs to the same price level.

The Choice of Explanatory Variables

The cost functions that were estimated by using regression procedure included number of customers, amount of water produced and distributed annually, density and terrain factor as the explanatory variables. A knowledge of the rural water districts shows that these variables constitute the main items of the total costs of the rural water districts. The adjusted investment cost per capita was used as a proxy variable for the density of customers per mile of pipeline and the terrain of the districts because:

(1) The distance between homes in the rural communities is large and many miles of pipeline are usually laid from the source of supply before the first customer in the district ties-in to the distribution system. This in turn greatly reduces the density of customers per mile of pipeline to very small numbers which do not adequately represent the density in the main supply area.

(2) No quantitative value can be attributed to the terrain in the communities other than the cost which the terrain causes in the supply of water to customers. Whatever the topography of the area and the physical characteristics of the soils, the effects will be reflected in the investment costs of the water systems.

(3) The investment costs per customer will also reflect the situations where the density of customers varies while the terrain remains constant and where the density remains constant but the terrain changes. Under these circumstances, the adjusted investment cost per capita was used as a proxy variable for the density of customers and terrain of the districts.

The Model Postulated and Classification of Costs

The conceptual model used was a cost function of the type

$$C = f\ (M, X, D)$$

where:

C = total costs;

M = number of customers;

X = volume of water produced and distributed annually (in thousand gallons); and

D = adjusted investment cost per customer as a proxy for density of customers and terrain of the districts.

A number of alternative mathematical models were applied to the set of data to estimate the cost-size relationship of the rural water districts by means of regression analysis procedure. Data were obtained from 12 rural water districts (Table III), three of which owned and operated wells while nine districts purchased treated water from other cities. The three districts having their own wells are Cherokee #2, Wagoner #2 and Woodward #1. Separate cost functions were derived for the rural water districts based on their source of water supply, i.e. from own wells or purchased water.

The annual cost data obtained from the accounting records of the water districts were classified into fixed and variable categories. The fixed costs included taxes, insurance, fidelity bonds, legal and accounting fees, amortized investment outlay and interest charges on investment cost. The investment cost included the loans, grants and cash contributions used in establishing the water system. The method of charging interest on investment cost thus takes account of the opportunity cost of all the capital invested. The variable costs consisted of the operation and maintenance expenses.

Total costs were obtained by summing the fixed and variable costs classified as follows:

Fixed Costs

(1) Taxes, insurance, fidelity bonds (on Treasurer)

(2) Legal and accounting fees

(3) Depreciation

(4) Interest on investment cost

Variable Costs

(1) Wages, salaries

(2) Office expenses

(3) Repair to facilities and equipment

(4) Utilities

(5) Water purchase

(6) Equipment and machinery hire

(7) Chemicals

(8) Fuel, oil and gas

(9) Miscellaneous materials and supplies

The statistical models postulated for deriving the average cost curves were:

$$Y = \alpha_o + \alpha_1 M + \alpha_2 M^2 + \varepsilon \quad (1)$$

$$Y = \alpha_o + \alpha_1 M + \alpha_2 M^2 + \alpha_3 MX + \alpha_4 X + \alpha_5 X^2 + \varepsilon \quad (2)$$

$$Y = \alpha_o + \alpha_1 D + \alpha_2 D^2 + \alpha_3 DX + \alpha_4 X + \alpha_5 X^2 + \varepsilon \quad (3)$$

$$Y = \alpha_o + \alpha_1 M + \alpha_2 M^2 + \alpha_3 MX + \alpha_4 X + \alpha_5 X^2 + \alpha_6 XD + \alpha_7 D + \alpha_8 D^2 + \varepsilon \quad (4)$$

$$Y = \alpha M^b \quad (5)$$

$$Y = \alpha M^b X^c \quad (6)$$

$$Y = \alpha X^b D^c \quad (7)$$

$$Y = \alpha M^b X^c D^g \quad (8)$$

where Y = average annual total cost per customer,

X = volume of water produced and distributed annually,

M = number of customers,

D = density and terrain factor,

α, b, c, g are parameters of estimate, and

ε is a disturbance term.

The same set of models were used to derive cost functions using (Z), the average total cost per thousand gallons of water produced and distributed annually as the dependent variable. Equations (1) and (5) above were modified to:

$$Z = \alpha_o + \alpha_1 X + \alpha_2 X^2 + \varepsilon \quad (9)$$

$$Z = \alpha X^b \quad (10)$$

The Equations Obtained by Regression Method

For rural water districts that purchase treated water, the number of observations was 36. The equations obtained were:

$$Y = 157.4327 - \underset{(0.0702)^{*}}{0.2043M} + \underset{(0.00005357)^{*}}{0.0001164M^2} \qquad R^2 = .31 \qquad (11)$$

$$Y = 115.1534 - \underset{(0.002898)}{0.004053X} + \underset{(0.00000001)}{0.00000002X^2} + \underset{(0.00000218)}{0.00000278XD} - \underset{(0.06907)}{0.0004207D}$$

$$+ \underset{(0.0000204)}{0.00001286D^2} \qquad R^2 = .55 \qquad (12)$$

$$Y = 163.8544 + \underset{(0.001683)^{***}}{0.005039X} + \underset{(0.00000016)}{0.00000006X^2} - \underset{(0.1721)^{***}}{0.6670M} + \underset{(0.000938)}{0.001198M^2}$$

$$- \underset{(0.000024)}{0.000017XM} \qquad R^2 = .47 \qquad (13)$$

$$Y = 125.7001 + \underset{(0.0064)}{0.0033X} - \underset{(0.00000018)}{0.00000012X^2} - \underset{(0.4279)^{*}}{0.7054M} + \underset{(0.001)}{0.00003786M^2}$$

$$+ \underset{(0.0786)}{0.0170D} + \underset{(0.00002063)}{0.00000235D^2} + \underset{(0.0000047)}{0.00000092XD} + \underset{(0.00002829)}{0.00001284XM}$$

$$+ \underset{(0.0003164)}{0.0002165MD} \qquad R^2 = .71 \qquad (14)$$

The values in parentheses are standard errors of estimate.

* means that coefficient is significantly different from zero at ten percent probability level.

** means that coefficient is significantly different from zero at five percent probability level.

*** means that coefficient is significantly different from zero at one percent probability level.

R^2 is coefficient of multiple determination which indicates the proportion of the variation in average cost that is explained by the fitted regression equation.

Equation (11) was selected as the equation to be used in deriving the economies of size curve because of the correct signing and the statistical significance of the coefficients. Theoretical cost curves are usually drawn showing the output of the product as the measure of the size of the producing unit. However, to measure the size of a rural water district in terms of volume of water produced and distributed raises an obvious question. The rural water districts were set up primarily to furnish water to a given number of customers, with some provision made for possible changes in that number. Secondly, the amount of water produced and distributed by the districts depends mainly on the intensity of use of the water by the customers and their families. Lastly, the water produced is distributed to the customers in their various locations and the cost of this distribution incorporates the effects of the density of the customers per mile of pipeline and the terrain of the district. Consequently, the number of customers served by the rural water districts was used as a measure of size, especially as size of a community is used to refer to number of people in that community.

To derive the economy of size curve, different values were substituted for (M) in equation (11):

$$Y = 157.4327 - 0.2043M + 0.0001164M^2 \qquad (11)$$

When M is:	Average Annual Cost Per Customer is:
50	$147.5
100	138.2
200	121.2
300	106.6
500	84.4
600	76.8
800	68.5
900	67.8
1000	69.5
1050	71.2
1100	73.5
1500	112.9
2000	214.4

This cost-size relationship is illuatrated graphically in Figure 2. The relationship shows that the average total cost per customer first decreases as number of customers increases until a minimum point is attained when the number of customers is 900. Thereafter, the costs begin to increase as number of customers increases. This relationship therefore indicates that economies of size exist for rural water districts in Oklahoma and it implies that some saving in costs could be

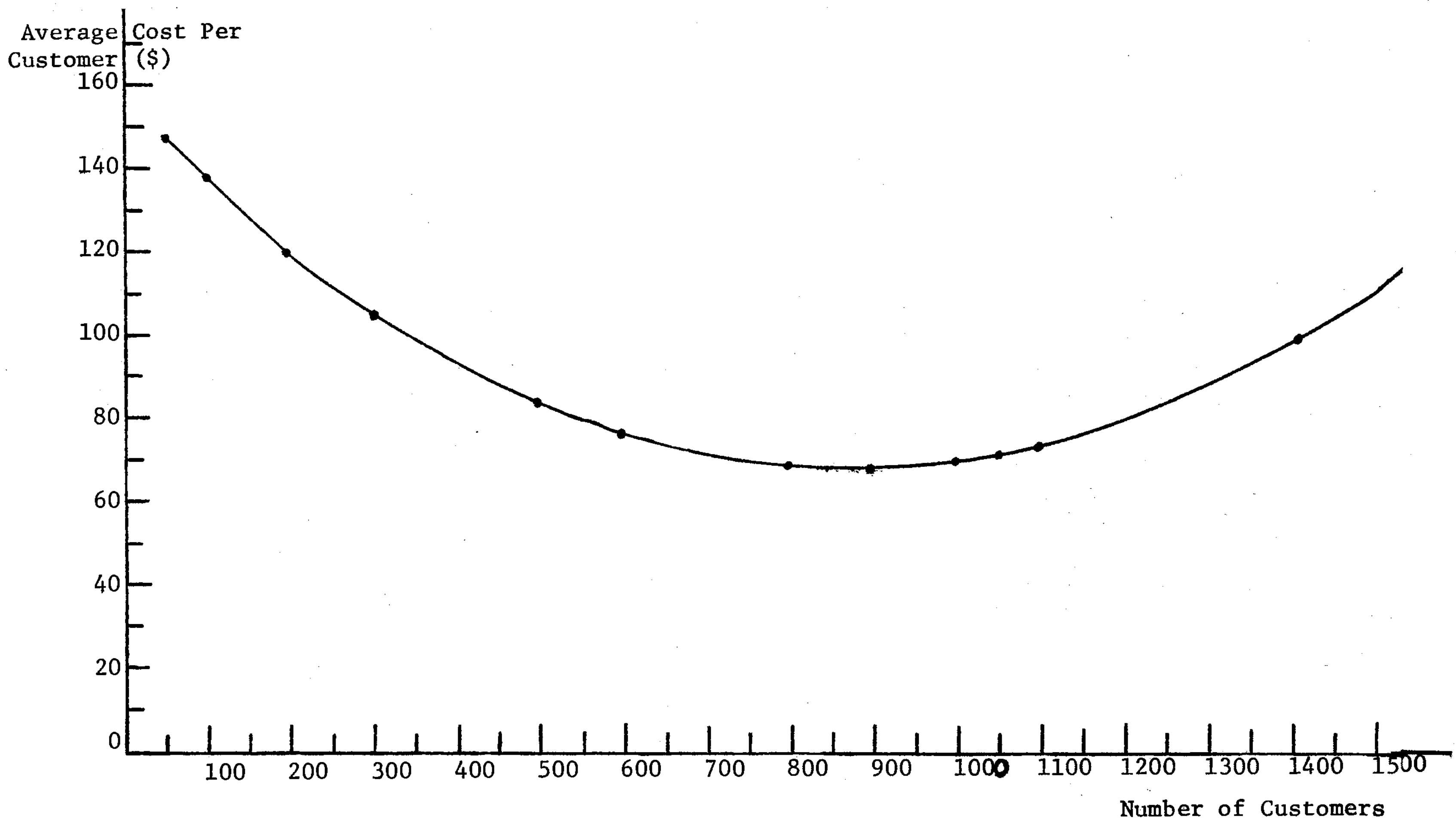

Figure 2. Average Total Cost Curve for Rural Water Districts to Illustrate Economies of Size

achieved by organizing rural water districts of size between 800 and 1000 customers. The minimum average total cost per customer of $67.80 could be realized in water districts of 900 customers. The increase in average cost after this minimum point is due to increased management and equipment costs necessary to serve the additional customers.

Equation (13) introduces the amount of water produced and distributed explicitly into the equation. The economies of size curve was estimated from this equation by holding the volume of water constant at different levels. The equation was:

$$Y = 163.8544 + 0.005039X + 0.00000006X^2 - 0.6670M + 0.001198M^2 - 0.000017XM$$

The curve reveals that economies of size exist for the rural water districts. The lowest points on the curves for X = five million and X = ten million gallons of water are attained when the number of customers is 300. Both curves show a decline in average costs as the number of customers is increased until the minimum point is reached. Thereafter, the costs begin to increase as number of customers is increased (Figure 3). When the amount of water produced and distributed annually is held fixed at X = 50 million gallons of water, a decline in average cost curve is also indicated but the minimum point on the curve occurs when the number of customers is 600. When the volume of water produced and distributed is held constant at X = 100 million gallons of water, the average cost per customer shows a declining trend with a minimum point at M = 1,000.

The conclusions drawn from Table IV are: (1) the average cost curves indicate economies of size; (2) the lowest point on each curve differs for different amounts of water produced and distributed; (3) the

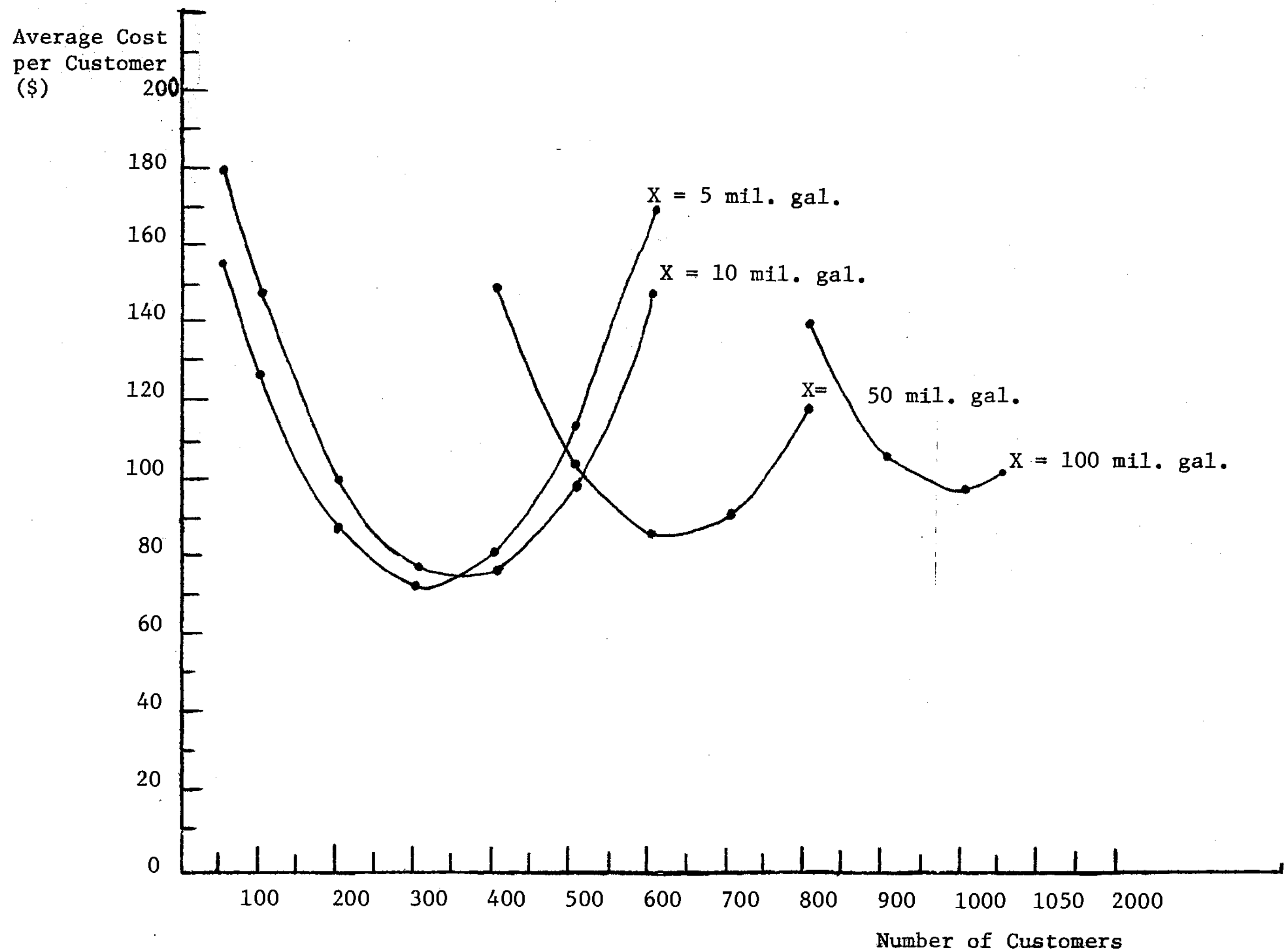

Figure 3. Average Cost Curves for Rural Water Districts at Different Levels of Volume of Water Produced and Distributed Annually

TABLE IV

DERIVATION OF AVERAGE COST CURVES FOR RURAL WATER DISTRICTS USING EQUATION (13)

M	X = 5 mil. gal.	X = 10 mil. gal.	X = 50 mil. gal.	X = 100 mil. gal.
50	$155.90	$181.40	$493.00	$1152.50
100	127.30	148.50	426.10	1043.10
200	88.10	100.80	310.40	842.40
300	72.80	77.00	218.60	665.60
400	81.40	77.10	150.70	512.70
500	114.10	99.30	104.90	381.90
600	170.60	149.30	86.90	211.90
800	355.70	317.40	119.00	141.00
1000	636.60	581.30	246.90	98.90
1050	721.70	662.20	293.80	103.30

minimum average cost per member varies between \$72.80 at X = 5 mil. gal. and \$98.90 at X = 100 mil. gal.; (4) after the minimum point on each curve, the rate of increase in the average cost curve decreases for higher levels of X. The implication of these results are: that rural water districts producing and distributing five million and ten million gallons a year could expect the minimum average cost per customer to occur when the size of the district is 300 customers; a district producing and distributing 50 million gallons of water could expect a minimum average cost per member of \$86.90 when the number of members served is 600; and the minimum annual average total cost is \$98.90 when districts produce and distribute 100 million gallons to serve 1000 customers.

The results of the log regressions also showed that economies of size exist for the rural water districts. The coefficients of the log functions are the elasticities and they indicate the percentage change in average costs that is associated with one percent change in the explanatory variables. One percent increase in the explanatory variable which is associated with less than one percent increase in costs indicates economies of size. For example, the coefficient of log M in equation (15) means that, on the average, an increase in the number of customers, (M), by one percent, is associated with a decrease in average costs per member, (Y), of 0.2109 percent. The log functions estimated were:

$$\text{Log } Y = \log 5.8308 - \underset{(0.0458)^{*}}{0.2109} \log M \qquad R^2 = .38 \tag{15}$$

$$\text{Log } Y = \log 1.2905 - \underset{(0.040)}{0.044} \log X + \underset{(0.1219)^{***}}{0.5554} \log D \qquad R^2 = .48 \tag{16}$$

$$\text{Log } Y = \log 1.4476 - \underset{(0.0676)^{***}}{0.3006} \log M + \underset{(0.0578)^{**}}{0.1693} \log X + \underset{(0.0992)^{***}}{0.4685} \log D \qquad R^2 = .68 \tag{17}$$

$$\text{Log } Y = \log 5.1650 - \underset{(0.0850)^{***}}{0.3634} \log M + \underset{(0.0740)^{*}}{0.1549} \log X \qquad R^2 = .46 \qquad (18)$$

Equation (16) indicates that, on the average, an increase in the volume of water produced and distributed, (X), by one percent, holding the adjusted investment cost per capita, (D), constant at the mean, is associated with a decrease in average costs, (Y), of 0.044 percent. Similarly, an increase of one percent in the adjusted investment cost (D), is on the average associated with an increase of 0.5554 percent in average costs, (Y), holding volume of water produced and distributed constant. The elasticities shown in equations (15) to (18) indicate that there are economies of size for the rural water districts studied. Regression equations estimating the average fixed and the average variable cost functions are listed in Appendix C.

Regression Equations Obtained Using Average Cost Per Thousand Gallons of Water as the Dependent Variable

For rural water districts that purchase treated water, the following set of average cost functions were estimated using average cost per thousand gallons of water produced and distributed as the dependent variable:

$$Z = 3.3731 - \underset{(0.00003242)^{**}}{0.00009617X} \qquad R^2 = .27 \qquad (19)$$

$$Z = -2.7855 + \underset{(0.0001279)}{0.00009466X} + \underset{(0.003049)^{**}}{0.00787D} - \underset{(0.0000009)^{**}}{0.00000207D^2} - \underset{(0.0000001)^{*}}{0.00000015XD} \qquad R^2 = .41 \qquad (20)$$

$$Z = 2.4206 - \underset{(0.00004)^{***}}{0.00035X} + \underset{(0.00000000)^{***}}{0.00000002X^2} + \underset{(0.00454)^{***}}{0.02240M} + \underset{(0.00002476)^{***}}{0.0000663M^2} - \underset{(0.00000064)^{***}}{0.00000239XM} \qquad R^2 = .75 \qquad (21)$$

$$Z = -2.1110 + \underset{(0.0001596)}{0.0001434X} + \underset{(0.00000000)^{***}}{0.00000002X^2} + \underset{(0.001962)^{***}}{0.00531D} - \underset{(0.0000005)^{*}}{0.0000008D^2}$$

$$+ \underset{(0.01068)}{0.00546M} + \underset{(0.00002609)^{***}}{0.00006527M^2} - \underset{(0.00000012)^{***}}{0.0000004XD} - \underset{(0.00000071)^{***}}{0.00000236XM}$$

$$+ \underset{(0.0000079)}{0.00000863MD} \qquad R^2 = .88 \qquad (22)$$

$$\text{Log } Z = \log 3.9928 - \underset{(0.0654)^{*}}{0.3667 \log X} \qquad R^2 = .48 \qquad (23)$$

$$\text{Log } Z = \log 2.5769 - \underset{(0.0715)^{***}}{0.3440 \log X} + \underset{(0.2155)}{0.1731 \log D} \qquad R^2 = .49 \qquad (24)$$

$$\text{Log } Z = \log 2.2074 - \underset{(0.074)^{***}}{0.8456 \log X} + \underset{(0.1270)^{**}}{0.3773 \log D} + \underset{(0.0865)^{***}}{0.7068 \log M} \qquad (25)$$

$$R^2 = .83$$

$$\text{Log } Z = \log 5.2013 - \underset{(0.0822)^{***}}{0.8572 \log X} + \underset{(0.0943)^{***}}{0.6563 \log M} \qquad R^2 = .79 \qquad (26)$$

All the coefficients of equation (25) are significant at five percent probability level and 83 percent of the variation in the average costs is accounted for by the equation. The coefficients (elasticities) indicate that there are economies of size. The interpretation of the equations is similar to the ones given earlier.

Regression Equations Estimated for Rural Water Districts That Operate Own Wells

The statistical models postulated for deriving the cost functions for rural water districts that operate their own wells are the same as those used for districts that purchase treated water. The purpose of deriving separate functions was to show if both sources of water supply were subject to economies of size. The following equations, with average cost per customer as the dependent variable, were estimated:

Number of observations = 12

$$Y = 96.6625 + \underset{(0.7646)}{0.2546M} - \underset{(0.00154)}{0.001156M^2} \qquad R^2 = .66 \tag{27}$$

$$Y = 163.6820 - \underset{(0.003527)}{0.002930X} - \underset{(0.00000012)}{0.00000015X^2} + \underset{(0.00000036)*}{0.00000055XD}$$

$$- \underset{(0.00153)***}{0.0102D} + \underset{(0.00000017)}{0.00000015D^2} \qquad R^2 = .97 \tag{28}$$

$$Y = 241.0126 + \underset{(0.0167)**}{0.0125X} + \underset{(0.00000111)}{0.000000X^2} - \underset{(1.3158)**}{2.7602M} + \underset{(0.0102)}{0.0102M^2}$$

$$- \underset{(0.0002)}{0.000189XM} \qquad R^2 = .95 \tag{29}$$

$$\text{Log } Y = \log 10.1376 - \underset{(0.1853)*}{1.1488 \log M} \qquad R^2 = .79 \tag{30}$$

$$\text{Log } Y = \log 10.0111 - \underset{(0.2129)*}{0.6096 \log X} - \underset{(0.1888)}{0.0196 \log D} \qquad R^2 = .52 \tag{31}$$

$$\text{Log } Y = \log 7.3920 - \underset{(0.3079)**}{2.6230 \log M} + \underset{(0.1967)**}{0.9527 \log X} + \underset{(0.0672)**}{0.1788 \log D} \qquad R^2 = .95 \tag{32}$$

$$\text{Log } Y = \log 8.4990 - \underset{(0.3737)**}{2.3395 \log M} + \underset{(0.2492)**}{0.8461 \log X} \qquad R^2 = .91 \tag{33}$$

The number of observations on which the regression equations (27) to (33) were based was 12. This number was not large enough to estimate good fitting quadratic equations. A good fitting regression equation would be one with significant coefficients at the desired probability level; correct signs on the coefficients; large coefficient of multiple determination; and, one that is supported by economic theory. Consequently, the log equations, which can utilize small degrees of freedom, provided the best equations.

Equations (30) to (33) were the log functions estimated. The negative signs on the coefficients (elasticities) of (M) indicate that a percent increase in number of customers would result in a percent decrease in average costs per customer of the magnitude of the coefficient, holding other variables constant.

Using equation (32) as an example, a one percent increase in adjusted investment cost per capita would, on the average, result in 0.1788 percent increase in average cost per customer, holding volume of water produced and distributed annually and number of customers constant. A one percent increase in volume of water produced and distributed annually would, on the average, increase average costs per customer by 0.9527 percent, holding investment cost per capita and number of customers constant. A one percent increase in number of customers would, on the average, decrease average costs per customer by 2.6230 percent holding constant the volume of water produced and distributed annually as well as the investment cost per capita. The equation fitted accounted for 95 percent of the variation in average costs per customer.

Since one percent increase in the independent variables is associated with less than one percent increase in average costs per customer, there are economies of size in the rural water districts.

Regression Equations Obtained Using Average Cost Per Thousand Gallons of Water Produced and Distributed as the Dependent Variable

The statistical models used were similar to those used to estimate the regression equations for rural water districts that purchase water. In this case of districts that operate their own wells, the number of observations was 12. The following equations were obtained:

$$Z = 3.4906 - \underset{(0.00010)^{*}}{0.0002334X} \qquad R^2 = .80 \tag{34}$$

$$Z = 4.8330 - \underset{(0.000088)^{***}}{0.0004786X} + \underset{(0.00000000)^{***}}{0.00000001X^2} - \underset{(0.00003816)^{**}}{0.00009366D}$$

$$+ \underset{(0.00000000)^{**}}{0.00000001D^2} - \underset{(0.00000001)}{0.00000001XD} \qquad R^2 = .96 \qquad (35)$$

$$Z = 7.1773 + \underset{(0.0001770)^{**}}{0.0004339X} + \underset{(0.00000002)^{***}}{0.0000001X^2} - \underset{(0.0218)^{***}}{0.0892M} + \underset{(0.0001689)^{***}}{0.0007736M^2}$$

$$- \underset{(0.00000338)^{***}}{0.00001666XM} \qquad R^2 = .97 \qquad (36)$$

$$\text{Log } Z = \log 9.3014 - \underset{(0.1264)^{**}}{0.9935} \log X \qquad R^2 = .86 \qquad (37)$$

$$\text{Log } Z = \log 9.0730 - \underset{(0.1414)^{***}}{1.0108} \log X + \underset{(0.1253)}{0.0436} \log D \qquad R^2 = .86 \qquad (38)$$

$$\log Z = \log 7.4555 - \underset{(0.195)}{0.046} \log X + \underset{(0.0666)^{**}}{0.1661} \log D - \underset{(0.3050)^{***}}{1.6199} \log M \qquad R^2 = .97 \qquad (39)$$

$$\text{Log } Z = \log 8.4842 - \underset{(0.2398)}{0.1450} \log X - \underset{(0.3597)^{**}}{1.3565} \log M \qquad R^2 = .95 \qquad (40)$$

These equations when interpreted like the others also indicate that economies of size exist for the rural water districts.

These analyses of average total cost functions show that economies of size exist for the rural water districts. This thus provides policy makers with information about the future consequences of particular organizational alternatives of rural water districts in light of existing cost-size relationships.

Summary

This study has presented a decision model using the cost-output data of 12 rural water districts in Oklahoma to determine whether economies of size exist for the water districts. The statistical models, based on economic theory and a knowledge of the districts, utilized a least squares regression procedure to derive cost functions from which average cost curves were drawn. The economies of size curves show the levels of average total cost that rural water districts of various sizes may expect when operations are organized as efficiently as possible under the given conditions of technology and prices. The log regression equations were used to indicate the percent change in cost associated with a percentage change in the independent variables. The coefficients of the variables in these equations are also called elasticities and they can be used to measure economies of size. A one percent change in the independent variable associated with less than one percent change in costs indicate economies associated with size.

CHAPTER IV

SOCIAL AND ECONOMIC IMPACTS OF RURAL WATER DISTRICTS IN OKLAHOMA

The provision of good quality water supply in rural communities is a part of an effort to improve the economic opportunity and quality of living in the communities. This study of the social and economic impacts of the rural water districts was designed to further aid policy makers in determining the effects which the provision of this essential service has had on rural communities. When compared to urbanized areas many rural communities have lacked adequate social services. Water supply especially, has tended to remain the responsibility of the individual. The dependence on wells, hauled water or rain water had not adequately met the needs of the people in terms of cost, quantity and quality of water, and sanitation. The availability of an adequate good quality water supply is important to the development of a community especially as stable communities cannot exist where water is scarce or unfit to drink and where raw sewage flows in the open.

Characteristics of the Rural Water Districts

Data on five rural water districts in Muskogee County were obtained to analyze the social and economic impacts which the water districts may have had on the communities. If urban population is defined as persons living in places of 2,500 or more incorporated as cities, towns, or villages, only the city of Muskogee would be classified as urban with the remaining population rural.

The population of Muskogee has shown a declining trend from 1950 to 1970. Several factors are associated with the decline in population. The primary cause is the effect of the relative distance of Muskogee to other larger size urban centers of a higher order in functional hierarchy. For instance, Tulsa has a large, viable and diverse economic base with greater centralization of economic activity and resulting job opportunities which are not in Muskogee. Hence young people entering the labor force have migrated to the larger urban centers to seek employment, leaving behind an older population. This movement of people to take advantage of job opportunities in larger centers often results in permanent transfer of residence to the larger centers.

This is in contrast with what happens in small urban centers near enough to a larger one that is providing both job and shopping opportunities. Residence in the smaller centers are often maintained while employment and shopping are engaged in on a commuting basis to the large center. The growth in population of small communities in Wagoner and Creek Counties which are near to the Tulsa metropolitan area is an example of the growing importance of commuting and the desire to live in a rural atmosphere. The 1950-1970 trends in population for Muskogee, Creek, and Wagoner Counties are presented in Table V.

Only Muskogee showed population losses in both the 1950-1960 and 1960-1970 census periods. The rural population of Creek and Wagoner counties gained 27 percent and 33 percent respectively in the 1960-1970 period while the rural population in Muskogee declined by 6.7 percent.

TABLE V

TRENDS IN POPULATION OF MUSKOGEE, CREEK AND WAGONER COUNTIES, OKLAHOMA 1950-1970

County	Population	1950	1960	1970	Percentage Change 1950-1960	Percentage Change 1960-1970
Muskogee	Total	65,573	61,866	59,542	- 5.6	- 3.7
	Urban	37,289	38,059	37,331	2.1	- 1.9
	Rural	28,284	23,807	22,211	-15.8	- 6.7
Creek	Total	43,143	40,495	45,532	- 6.1	12.4
	Urban	23,638	23,264	23,616	- 1.6	1.5
	Rural	19,505	17,231	21,916	-11.7	27.2
Wagoner	Total	16,741	15,673	22,163	- 6.4	41.4
	Urban	4,395	4,469	7,287	1.7	63.1
	Rural	12,346	11,204	14,876	- 9.2	32.8

Source: Bureau of Census, U. S. Department of Commerce, 1950, 1960 and 1970 Census Reports

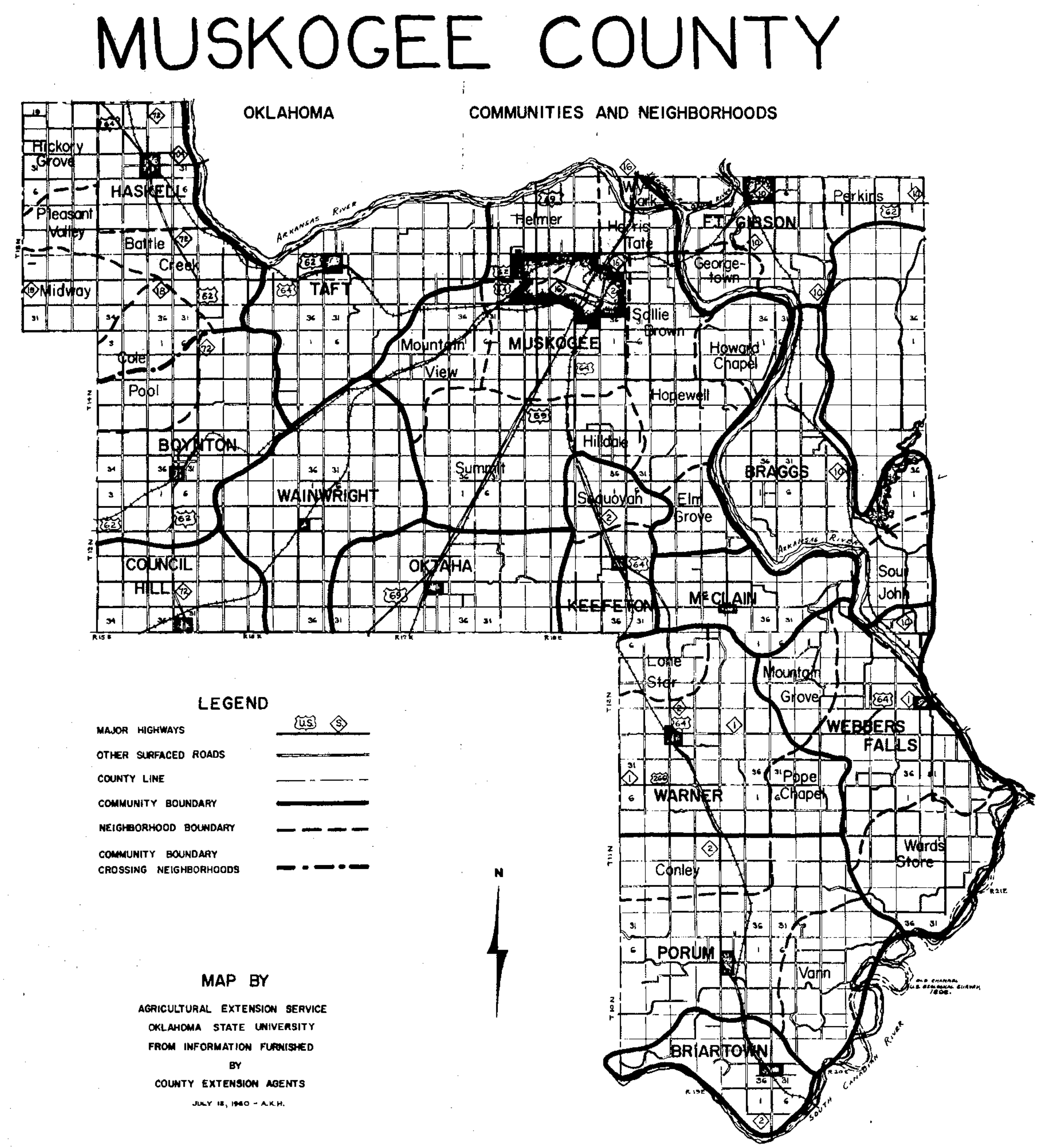

Figure 4. Communities in Muskogee County

The declining trend in the population of Muskogee does not permit an impact analysis of the role which rural water districts play in the decision of people to locate in rural communities. Although it appears that economic factors such as employment and income opportunities are considerations in deciding to locate in an area, provision of public services in a rural area does attract people to move to that area. Unfortunately, lack of detailed population data by small tracts did not allow for such an analysis.

Between 1964 and 1970, eleven different communities had established rural water districts in Muskogee County, (Table VI and Figure 4). The five rural water districts in the sample were those in Oktaha, Gooseneck Bend, Glendale, Keefton and Wainwright.

Impact of Rural Water Districts on Quality of Living

Quality of living is fundamentally a normative construct which is used to refer to the extent to which the social and physical environments are conducive to one's state of happiness and comfort. Factors which are relevant and important to the quality of living of individuals in a rural community include: the availability of social services; real personal income; good quality housing; and, a healthy environment.

Rural water districts provide members in the rural community with an adequate quantity of good quality water for personal and domestic uses. This has enabled many members with enough income to improve the quality of their housing through the addition of standard plumbing fixtures. It has also facilitated the use of additional household appliances such as dishwashers and clothes washers. Many homes have now been

TABLE VI

RURAL WATER DISTRICTS IN MUSKOGEE COUNTY
(AS OF DECEMBER 1, 1972)

Rural Water District	Community	Date FHA Loan Was Closed	Amount of Loan ($)	Amount of Grant ($)	Number of Users at the Start
Rural Water District #1	Oktaha	11/15/65	198,000	--	233
Rural Water District #2	Gooseneck Bend	1/26/66	76,000	--	84
Rural Water District #3	Council Hill	1/13/67	199,000	--	141
Rural Water District #4	Glendale	6/26/67	68,000	--	69
Rural Water District #5	Keefton	11/20/67	325,000	--	275
Rural Water District #6	Wainwright	4/18/69	260,000	--	156
Rural Water District #7	Perkins	2/11/69	83,000	--	57
Boynton Public Works Authority	Boynton	11/21/66	125,000	115,000	190
East Central Oklahoma Water Authority	Webber Falls	10/23/64	220,000	--	497
Porum Public Works Authority	Porum	7/22/70	215,000	--	323
Warner Utilities Authority	Warner	9/ 4/70	200,000	--	320

Source: State Office, Farmers Home Administration, U.S.D.A., Stillwater equipped with flush toilets, bathtubs, showers and humidifiers. The building of sewer systems has also been facilitated in the rural communities. The ownership and use of these facilities contribute to the quality of living of the individuals and are dependent upon the level of real personal income. The availability of dependable good quality water from the rural water districts encourages ownership and facilitates the use of these household conveniences.

To determine whether rural water districts have had a significant effect in the availability and use of these household facilities in the five communities in Muskogee county, a statistical analysis using the dummy variable approach was used. Two time periods were considered: (1) the period from 1960-1965 before there were rural water districts in the communities; and, (2) the period 1966-1972 during which the five rural water districts have been functioning. The dummy-variable approach was used to take account of the fact that the two time periods may have separate deterministic effects on the availability and use of household facilities in addition to the effects caused by variations in real personal income.

The statistical model used was of the form

$$Q = \alpha_0 + \alpha_1 Y + \alpha_2 Z + \alpha_3 P_1 + \cdot \cdot \cdot + \alpha_9 P_9 + \varepsilon \qquad (50)$$

where Q = number of facilities owned; categorized as plumbing fixtures, dishwashers, clothes washers, flush toilets, bathtubs, showers, humidifiers, water-coolers and sewer systems,

Y = per capita personal income,

Z is a dummy variable which has the value $Z = 0$ when observation is for the 1960-1965 period and $Z = 1$ when observation is for the 1966-1972 period,

P_1 to P_9 = price per unit of each facility owned, and

α_o, α_1 ... α_9 are parameters of estimate and ε is an error term.

The model postulated has three properties: the expected value of Q when $Z = 0$ can be expressed as

$$E(Q|Z = 0) = \alpha_o + \alpha_1 Y + \alpha_3 P_1 + . . . + \alpha_9 P_9 \quad (51)$$

and the expected value of Q when $Z = 1$ can also be expressed as

$$E(Q|Z = 1) = \alpha_o + \alpha_1 Y + \alpha_2 + \alpha_3 P_1 + . . . \alpha_9 P_9 \quad (52)$$

such that α_o = 1960-1965 intercept and $\alpha_o + \alpha_2$ = 1966-1972 intercept. The difference between 1960-1965 and 1966-1972 intercepts is thus α_2. The test on α_o is equivalent to testing whether the 1960-1965 intercept is significantly different from zero while testing α_2 is equivalent to testing whether there is any significant difference between the 1960-1965 and 1966-1972 intercepts. Because the rural water districts were in operation during the 1966-1972 period only, this test on α_2 is essentially a test on determining whether the rural water districts have made a difference in the availability and use of household facilities.

The $\hat{\alpha}_2$ estimated was 55.0514 and was significant at the five percent probability level. The dummy-variable approach used indicates that the establishment of rural water districts has made a significant difference in the availability and use of household facilities compared with the period when there were no rural water districts in the communities studied. Thus, evidence exists that rural water districts have contributed to the increasing conveniences and thus an improvement in the quality of living in the rural communities.

Given the income of the members and the level of prices of the household facilities, the availability and use of these facilities including the disposal of sewage through public sewer systems are directly related to the availability of dependable good quality water supply such as provided by the rural water districts.

In the questionnaire survey of members of the five rural water districts in Muskogee County, the respondents indicated that they obtained their water supply from two main sources before the rural water district provided water: (1) wells and (2) hauled water. Various reasons were then given for seeking membership in the rural water districts. These included: (1) convenience, in that the water was available directly to the homes; (2) lower cost of water compared with the cost of obtaining the same quantity and quality of water from previous sources; (3) better quality of water from the rural water districts; (4) dependability and adequacy of the supply of water; and, (5) to help other members in the community obtain good quality water. This "help" was possible through the lower cost of water service resulting from an increased number of memberships. The respondents answered that their past reliance on wells or on hauled water did not provide them with an adequate supply of water, either for meeting all of their domestic requirements or for use in large livestock enterprises. Under the two sources, the amount of water that was used by a family was kept to a minimum to keep costs within the budget of the family and also to minimize the inconvenience of frequent large scale water hauling. In addition to the use of the water from rural water districts for household purposes, respondents indicated that they also used the water to wash their cars, and to water lawns and gardens. A summary of the questionnaire responses is presented in Table VII.

Economic Impact of Rural Water Districts

The primary or direct impact of the rural water districts in Muskogee County is the payroll of the business establishments which have

TABLE VII

MEMBERSHIP RESPONSES TO QUESTIONNAIRE SURVEY OF RURAL WATER DISTRICTS IN MUSKOGEE COUNTY, 1972

	RURAL WATER DISTRICT				
Factors	No. 1	No. 2	No. 4	No. 5	No. 6
First Year of Operation	1967	1966	1968	1967	1970
Members at Start	173	49	50	214	114
Members in 1972	260	122	77	312	192
Previous Sources of Water					
Well	208	105	72	265	156
Hauled Water	150	60	41	102	39
Reason for Joining RWD					
Convenience	70	43	29	165	140
Lower Cost of Water	130	51	40	220	153
Larger Quantity of Water	94	60	52	140	150
Dependability of Supply	140	68	65	242	146
To Help Others	0	36	40	68	30
Additional Uses Made of the Water					
Showers and Bathtubs	233	102	68	275	156
Flush Toilets	230	100	66	280	150
Water-Using Appliances	200	98	62	206	145
Car Washing	256	105	60	175	100
Garden Watering	120	73	30	156	52
Lawn Watering	70	85	50	185	68
Livestock Watering	130	60	28	106	86
Cost of Membership	$110	$100	$100	$110	$110
Average Monthly Water Bill	$ 11.23	$ 10.56	$ 10.48	$ 11.25	$ 11.87
Average Cost of Drilling Well	$700	$800	$650	$815	$720
Average Monthly Well Maintenance and Operation Costs	$ 16.10	$ 15.42	$ 12.75	$ 15.30	$ 13.48

located in the rural communities as a result of the availability of an adequate supply of good quality water from the rural water districts. The secondary or indirect impact involves the multiplier effects which the re-spending of the payroll have on the business volume, employment and incomes in the economy of the local communities.

The economic impact of the rural water districts in the five Muskogee communities was estimated through the use of economic base theory. The method required that the economic activity be partitioned into basic and non-basic sectors. Using income as a measure of economic activity, the basic income was defined as that derived from sources outside the communities whether or not in return for productive activity. This meant that public assistance income was classified as basic income. Nonbasic income was defined as that derived from the local consumption sector in the communities which was dependent on the respending of the basic income. The income multipliers of the communities were then calculated as the ratio of the change in basic income over the study period 1960 to 1972. The total impact of the establishment of water districts on personal income in the economy of the communities was then determined by applying the multiplier to the payroll from the business establishments.

The sources of basic income in the five study communities were agriculture, mining, manufacturing, construction, wholesale and retail trade, services, property income and transfer payments. Some part of the wage and salary income was earned by residents who commuted to jobs outside of their communities. Because this source of income was located outside the study communities the wages were treated as basic income. The business establishments that located in the study communities because of the availability of water from the rural water districts were auto repair garages, service stations, general stores, grocery stores and trailer courts, all of which could be classified as belonging to the wholesale and retail trade sectors of the economy. Others were restaurants and launderettes which were classified with the services sector of the economy. The data used in the analysis were derived from publications of: (1) the Bureau of Business Research, College of Business Administration, University of Oklahoma, (2) Oklahoma Employment Security Commission, (3) Oklahoma Tax Commission, (4) Oklahoma State University Research Foundation, (5) Oklahoma State University Extension Service, and (6) U. S. Bureau of the Census, Census of Retail Trade, wholesale trade and selected services.

The income multiplier analysis is presented in Table VIII. The five communities studied were small, i.e., none had more than 500 people. The economy was dominated by agriculture and annual per capita incomes in 1970 were less than $2,000. The total effect on income for a particular community is equal to the income multiplier times the local payroll of new business establishments. The contribution of the businesses to the annual personal income in the communities ranged from $22,000 in RWD No. 2 to $47,000 in RWD No. 4 (Table VIII). The interpretation of the impact on personal income, e.g., in RWD No. 1, is that the new business establishments generated an increase in annual personal income of $39,000.

The variation in the income multipliers between the communities may have been due to the differences in size of the communities and the availability of services needed by residents. The larger the community, the greater the variety of goods and services provided, such that leakages from the local income stream tend to be minimized. These leakages

TABLE VIII

SUMMARY OF INCOME MULTIPLIER ANALYSIS FOR FIVE RURAL WATER DISTRICT COMMUNITIES IN MUSKOGEE COUNTY

	RWD No. 1	RWD No. 2	RWD No. 4	RWD No. 5	RWD No. 6
Basic Income ($1,000)					
(1) 1972	$2,014	$ 968	$ 620	$1,085	$1,487
(2) 1965	963	366	214	610	586
(3) Increase	$1,051	$ 602	$ 406	$ 475	$ 901
Total Income ($1,000)					
(4) 1972	$2,920	$1,365	$ 955	$1,411	$1,784
(5) 1965	1,329	505	323	781	721
(6) Increase	$1,591	$ 860	$ 632	$ 630	$1,063
Multipliers					
(7) Ratio of (4) to (1)	1.45	1.41	1.54	1.30	1.20
(8) Ratio of (5) to (2)	1.38	1.38	1.51	1.28	1.23
(9) Ratio of (6) to (3)	1.51	1.43	1.56	1.33	1.18
Impact of RWD ($1,000)					
(10) Local payroll of business firms	$ 26	$ 15	$ 30	$ 17	$ 24
(11) Impact on total income ((10) x (9))	$ 39	$ 21.5	$ 47	$ 23	$ 28

are used to refer to the spending of income earned in the community in another community for goods and services which are available there.

The employment multipliers for the communities were not as sensitive as income multipliers in measuring the economic base of the small rural economy. An analysis of the basic income growth showed that property income and transfer payments constituted a large proportion of the income. Also, although the agricultural employment declined, income derived from agriculture increased. None of the business establishments employed as many as 20 employees. Thus, the employment multiplier computed as the ratio of the change in total employment to the change in basic employment would not be very significant in measuring the economic base.

The explanation of the small employment effect can be traced to the characteristics of the business establishments and the communities. The businesses did not require highly skilled labor for their services and the existing labor force was able to fill the jobs created; hence population growth by immigration was not induced. Because of the smallness of the communities, it was possible for the businesses to absorb considerable increases in sales without hiring additional workers at a commensurate rate if the work force was underutilized in the first case.

Impact on Property Values

Two types of change have occurred in the communities with rural water districts: (1) there have been new additions in the stock of property in the form of new houses and expansion of existing homes; and, (2) appreciation in the values of existing properties.

New additions to property, while generally improving community and personal living conditions, did not represent total net gains to the communities because some inputs for the additions were purchased outside the communities. The net community benefits from new additions of property primarily were employment and income for construction workers and people providing construction supplies and business profits obtained on the sale of building materials. Local governments also obtained benefits through the new sources of tax revenue. The data estimates of these tax revenues were available only at the county level and could not be disaggregated on the basis of the five RWD communities studied. The number of new homes that were built along the areas served by the water distribution lines is shown in Table IX.

TABLE IX

NUMBER OF NEW HOMES RELOCATED IN FIVE RURAL COMMUNITIES IN MUSKOGEE COUNTY

Rural Water Districts	Number of New Homes Built							
	1966	1967	1968	1969	1970	1971	1972	1973
Muskogee #1	--	--	--	--	--	10	24	4
Muskogee #2	1	1	10	5	7	20	30	7
Muskogee #4	--	--	15	3	4	5	30	27
Muskogee #5	--	--	20	19	8	20	12	28
Muskogee #6	--	--	--	--	--	--	20	33

Source: Survey Data of Rural Water Districts in Muskogee County, 1972

There is evidence of an increase in the value of real estate in the rural water districts. Land serviced by rural water lines was selling for between $200 and $300 per lot more than land in other areas of the communities not served by the water lines. The availability of water is, however, only one factor, among other factors, contributing to the increase in value of land in these rural communities. Other factors are: location, quality of the land, number of buyers and state of the economy.

Appreciation in the values of existing properties represented a net gain to home owners because it involved no additional use of resources or expenditures. By shifting property resources to more intensive uses, such as agricultural land to residential or industrial use, or increasing demand of property for the same use such as appreciation in the value of existing houses generally increased the values of existing properties without requiring new additions to the stock of property. Real estate values tended to remain high in the communities studied.

Summary

Recent years have witnessed great public interest in the nature and consequences of migration of rural people to the cities and towns where adequate income and employment may not be attained by the migrants. The loss of population by rural areas affects their ability to provide essential social services. Total demand for real estate diminishes and public infrastructure becomes underutilized.

The analysis of the data on the population of Muskogee County showed a declining trend from 1960 even though there were eleven rural water districts in the rural communities. When compared with other communities near large urban centers which have grown in population, it was evident that the economic considerations of income and employment were of greater importance in affecting growth of population in a given community.

However, the rural water districts are contributing to the social and economic development of the rural communities. The quality of living is being enhanced and local initiative has been developed to strive for improvement in the social and physical environment in rural areas.

Results of the regression analysis, using the dummy-variable approach, that was applied to the data from five Muskogee RWD communities, showed that the rural water districts have had a significant effect in improving the quality of living of the members.

The rural water systems have been providing an adequate quantity of good quality water to the customers who have been able to expand their livestock enterprises, add plumbing fixtures to their homes and acquire water-using appliances.

The economic impact of the rural water districts was analyzed by constructing income multipliers. The fundamental unit of analysis was personal income which was used as the indicator for the basic economic activity in small rural communities. The analysis showed that modest improvements have been made in the personal income in the local consumption sector while the effect on employment was small. There has also been some impact on property values in the communities served by the rural water districts. New additions have been made to the stock of property and existing properties have appreciated in value.

There has been some relocation of new homes along the areas served rural water distribution lines. This would in turn have effect on local government expenditures if new streets and extension of other services were needed by the residents who have relocated.

CHAPTER V

MANAGEMENT FUNCTIONS OF RURAL WATER DISTRICTS IN OKLAHOMA

Good management is a vital factor in the successful development and operation of a rural water district. Management can be divided into two functions: administrative, and operation and maintenance. The administrative function includes the following processes: (1) planning; (2) organizing; (3) personnel services; (4) supply planning; (5) record keeping; (6) directing; and (7) controlling. The operation and maintenance function broadly describes the conveyance and delivery of safe water from the source to the consumers. These two functions are interdependent and are usually coordinated to achieve integrated management.

The rural water districts in Oklahoma are non-profit public bodies organized to provide water service for rural communities. As such they are different from market-oriented firms whose primary motive is to maximize net returns or to minimize costs. Thus, the study of the management of rural water districts is restricted to the identification and analyses of the factors which lead to the successful development and operation of a rural water district.

The Management Analysis Model Used

The factor analysis method was used to estimate the relative importance of the management functions of rural water districts. Each response variate is represented as a linear function of a small number of unobservable common factor variates and a single latent specific variate. It is assumed that the observations are from a multinormal population of full rank (20, pp. 259-276).

The mathematical form for the factor structure used was:

$$W = \Lambda\chi + \varepsilon \qquad (60)$$

$$W = (\phi,\ \varepsilon)$$

$$\chi = (\phi,\ I)$$

$$\varepsilon = (\phi,\ \Psi)$$

where W = observed random variable with nonsingular, multinormal distribution;

χ = common factor variate;

Λ = parameter reflecting the importance of a factor or the loading of a response on the common factor; and,

ε = specific-factor variate.

In matrix form,

$$W' = [W_1,\ \ldots,\ W_p] \qquad (61)$$

$$\chi' = [\chi_1,\ \ldots,\ \chi_m] \qquad (62)$$

$$\varepsilon' = [e_1,\ \ldots,\ ep] \qquad (63)$$

and
$$\Lambda = \begin{bmatrix} \lambda_{11} & \cdots & \lambda_{1m} \\ \cdot & \cdot & \cdot \\ \lambda_{p1} & \cdots & \lambda_{pm} \end{bmatrix} \qquad (64)$$

Equations (61) to (64) can be expressed as:

$$\begin{bmatrix} W_1 \\ W_2 \\ \cdot \\ \cdot \\ \cdot \\ W_p \end{bmatrix} = \begin{bmatrix} \lambda_{11} & \lambda_{12} & \cdots & \lambda_{1m} \\ \lambda_{21} & \lambda_{22} & & \lambda_{2m} \\ \cdot & \cdot & \cdot & \cdot \\ \lambda_{p1} & \lambda_{p2} & & \lambda_{pm} \end{bmatrix} \begin{bmatrix} \chi_1 \\ \chi_2 \\ \cdot \\ \cdot \\ \cdot \\ \chi_m \end{bmatrix} + \begin{bmatrix} e_1 \\ e_2 \\ \cdot \\ \cdot \\ \cdot \\ e_p \end{bmatrix} \qquad (65)$$

where p = number of responses; and

m = number of common-factor variates in χ which are independently and normally distributed with zero means and unit variances.

Similarly, it is assumed that the elements of ε are normally and independently distributed with mean zero and variances, Var (ei) = Ψ_i. Ψ_i is called the specific variance or specificity of the i^{th} response.

$$\Psi = \begin{bmatrix} \Psi_1 & \cdots & 0 \\ \cdot & \cdot & \cdot \\ 0 & \cdots & \Psi_p \end{bmatrix} \tag{66}$$

$$\text{Cov}\ (W, X') = \Lambda \tag{67}$$

and $\Sigma = \Lambda\Lambda' + \Psi$ (68)

The diagonal elements of $\Lambda\Lambda'$ are called communalities of the responses.

The factor analysis technique was used as an aid in determining the appropriate number of factors which could be used in describing the important variables that in varying degrees affect the management of rural water districts. The data used in the analysis were derived from the responses of the members of the board of directors of 12 rural water districts in Oklahoma. During the personal interviews, the members were required to give relative weights to the variables which they considered important in the management of their rural water districts. From a list of variables, they were to attach weights between zero and ten, with the most important variables being rated ten and the least important rated zero.

The variables on which responses were obtained were:

(a) good engineering of water system;

(b) accurate projection of growth of community;

(c) supply planning and use of large-size pipelines;

(d) use of good meters;

(e) minimum leakage of water;

(f) cooperation of board members;

(g) dynamic manager;

(h) good public relations in the community;

(i) regular payment of water rates;

(j) salaried manager and bookkeeper;

(k) education of manager and bookkeeper;

(l) trained maintenance personnel

(m) well kept records.

The mean weight of each variable was then calculated for each district before applying the factor model.

Results of the Factor Analysis

The statistics obtained from the analysis of the model were: (1) mean; (2) standard deviation; (3) correlation (covariance matrix); (4) eigen values (characteristic roots); (5) cumulative percentage of the eigen values; (6) eigen vectors (characteristic vectors); (7) transformed input data; (8) factor matrix; (9) rotated factor matrix; and, (10) check on the communalities. These statistics for a ten-factor matrix solution are listed in Appendix D.

The two-factor matrix solution which accounted for 52 percent of the variance was considered adequate in explaining the results and is presented in Table X. The identification of the variables is as given above.

Interpretation of the Factor Matrix Derived

Factor one is the general average loadings for all the management variables. Good public relations in the community has the highest loading of 0.87311, followed by use of good meters with an equally high

TABLE X

2-FACTOR MATRIX SOLUTION FOR RURAL WATER DISTRICT MANAGEMENT VARIABLES

Variables	Factors	
	1	2
A	0.35597	0.15843
B	-0.11478	0.69890
C	-0.18712	0.81840
D	0.80798	0.13153
E	-0.61313	0.26802
F	0.71945	-0.03359
G	0.70173	0.25488
H	0.87311	0.18572
I	0.65562	0.42980
J	-0.05381	0.81584
K	0.59394	-0.49403
L	-0.52891	0.23462
M	-0.44320	-0.22069

loading of 0.80798. The next group of variables receiving appreciable loadings are: cooperation of board members, (0.71945); dynamic manager, (0.70173); regular payment of water rates, (0.65562); and, education of manager and bookkeeper, (0.59394).

Three variables had fairly large negative loadings: minimum leakage of water, (-0.61313); trained maintenance personnel, (-0.52891); and, well kept records, (-0.44320). The loadings on the variables indicate that factor one can be used as a measure of the relative importance of operational functions of rural water districts.

Factor two provides a comparison between the different categories of management functions. The loadings on the administrative function variables dominate the factor. Supply planning and use of large size pipelines variable has the largest loading (0.81840), followed by salaried manager and bookkeeper (0.81584). Accurate projection of growth of community also has an appreciable loading of 0.69890. The loadings on these three variables which are part of administrative functions can be contrasted with the relatively small loadings on variables classified as maintenance, minimum leakage of water (0.26802), and trained maintenance personnel (0.23462). The loadings on the variables which are part of operational function are small. Well kept records has a negative loading of -0.22069, use of good meters has a loading of 0.13153, cooperation of board members (-0.03359) and education of manager and bookkeeper (-0.49403).

Problems of Managers of Rural Water Districts

Nine districts reported that they had maintenance problems with leaks in the water lines. Two districts felt that the engineering of their water systems could have been done better. There were instances of irregular electrical power supply, dirt in water and back siphonage. One district had problems of mineral deposits in the water as well as water hardness which led to high soap consumption and difficulty in obtaining clean dishes. Leakage of water constituted the major problem of the rural water districts. Leakage surveys had to be conducted along the distribution lines to detect the leaks in several instances. Another problem facing the districts was the frequent breakage of the plastic pipelines by people digging through the same easements used by the water districts. Personnel of the telephone, electricity and natural gas companies and housing construction workers were often responsible for this breakage.

The managers indicated that the requests for new memberships received each year had been much greater than they had anticipated. To meet the increasing demand of new customers there was continuous capital addition to the transmission and distribution parts of the water system. Some systems had reached full capacity where additional customers could no longer be added on the distribution lines. In addition some pipelines were too small to allow for extensions to reach new customers. Although some looping of lines had been done in several districts to obtain adequate flow of water to customers, the cost of doing this has been very high.

Current Method of Operation of Rural Water Districts

Rural water districts in Oklahoma are community owned and operated. This requires that effective use be made of the community organization and leadership so that the water systems serve the maximum number of people satisfactorily.

The process of organizing the rural water districts in Oklahoma has tended to strengthen local leadership in the communities and common participation by the members has been strong. In the initial years of the districts, maintenance and secretarial work were undertaken as volunteer service. As some of the districts grew in size this type of informal operation was replaced by the formal pattern of operation with paid maintenance and secretarial services. In the survey conducted in 1972, all the directors and secretaries indicated that all management positions should be paid for services rendered to encourage efficiency.

Two districts reported that they employed a meter reader while in seven others, individual customers read their own meters and paid bills according to specified charges in the water rate schedule. In three districts, the manager or secretary read the meters. In all cases the revenue received from the water sales was deposited in the bank and credited to the water districts' accounts. Once a year the manager or an auditor checked the meters to ensure that the meters were functioning properly and that the readings were accurate.

Complaints of Customers of the Rural Water Districts

Few complaints were brought to the attention of board members by some customers. Some members did complain that after a breakage had occurred on the water line they often found some dirt in the water; and that too much time was taken in some cases to repair broken lines or to install new meters thereby interrupting water service to the customers on the affected lines. Also, some members complained of inadequate treatment of their water supply because of the hardness of some supplies and the bad taste during the summer months. A familiar cry was that the water rates should be reduced.

The managers of the affected rural water districts indicated that they were actively working to solve these problems and provide better service to the satisfaction of their customers.

Suggestions for Improving Management Functions

The role of a good engineer in the development and construction of rural water systems should be strongly emphasized by all the managers of the rural water districts. Because quality of construction affects overall performance of rural water systems in adequately meeting the needs of customers, utmost care should be taken not to overlook any factors of importance during the process of design. As a first requirement, the engineer must be sufficiently familiar with the rural environment to appreciate the nature of the problem with terrain, density of customers, source of water supply and demand characteristic of the potential customers.

A very important function of management is to predict expected demands under given conditions and design demands with certain probabilities of being exceeded. These require that the expected change in the number and structure of the population being served be fairly accurately predicted. In addition, due consideration should be given to the density of the customers and the size and terrain of the area to be served.

Good pipe materials, good water source points and care in laying the water distribution system are also essential for quality of construction. Rural water systems in Oklahoma serve customers in areas where the distance between homes is usually great. This factor accentuates the need for economy and also the need for use of long lived materials in the construction of the water systems. This saves the customers the cost of short term replacement of materials caused by failure or deterioration. Another important consideration is the ability of the pipes to carry the required quantities of water and still have low friction losses. Regular engineering evaluations of sources of supply, treatment facilities, adequacy of operation and protection in the distribution systems are also necessary after construction of the water systems.

Special attention needs to be given to water meters because in many respects, they are the most important appurtenance of the water system. Experience with the functioning of the water meters shows that they will record slower with continued wear or when there is some trash inside the meters. Under these circumstances the meters will be letting more water pass through than is actually recorded. It is thus desirable that the water meters be replaced at periodic intervals and be recalibrated to obtain accurate readings of the amount of water used.

Other maintenance functions on which management should pay close attention are: flushing of dead end lines at frequent intervals; and, sampling of water at various points on the distribution system at regular intervals. Flushing is necessary because water becomes stale at such extremities as the dead end of lines. Loops may be installed to provide recirculation of the water within the system and thus eliminate the stale water. Any of the two methods that is adopted will serve the purpose and the choice made by the district should be guided by cost considerations. The regular sampling of the water is to insure that the physical, bacterial and the chemical qualities of the water that reaches the consumers continuously meet the quality criteria established by the State Health Department.

Record keeping is a vital administrative function which many districts did not adequately perform. It was difficult to obtain detailed up-to-date layout maps of entire water system of a district, showing the location and depth of the water lines, the valves, service lines, the sizes of the pipelines and the location of the customers along the lines. Such maps are not only helpful when repairs are to be made but they are necessary for the orderly development and growth of the water districts. It is suggested that the FHA insure that such records be properly kept by all rural water districts.

In addition, monthly records should be kept on (1) volume of water produced, (2) volume of water distributed, (3) volume of water unaccounted for due to leakage, (4) costs of operation, (5) costs of maintenance, (6) amount of revenue received, (7) personnel, (8) nature of services performed and number of hours of work involved, and (9) equipment, supplies and inventories of the district. To ensure uniformity of the records for all the rural water districts in Oklahoma, the FHA should design these records and instruct the districts on how to fill in the required information. In addition, the districts should keep copies of the completed records with the FHA. The availability of such records would greatly assist future studies of the operations of the rural water districts.

With respects to the complaints on the breakage of water lines, cooperation is needed in notifying the manager or any board member as soon as it occurs such that repairs can be quickly made. This reduces the chance of too much dirt getting into the distribution system. It is also suggested that persons who use the same easements as the rural water districts obtain the layout map of the water distribution systems showing location and depth of the distribution systems before digging the area. Also, the managers of the water districts should be informed of the date and time when digging might be done in a piece of ground where water lines are laid to enable them to prepare for possible repair action in case of accidental breakage of the pipelines.

The time of interrupted water service is directly related to the nature of the problem to be solved, the availability of spare parts and maintenance personnel. Management personnel should be alert to minimize the inconvenience caused by prolonged interruption of water supply. Plans should be made in anticipation of any of the problems associated with the development and operation of a rural water system so that needs are met as quickly as they arise. Such preparedness adds to the efficiency and effectiveness of management.

Adequate treatment of water at the source of supply will help maintain the desired concentration level of minerals in the water to make it suitable for use. Calcium and magnesium are the chief causes of hardness of water while other minerals like iron, sulphur, manganese discolor the water. The methods of obtaining the desired concentration level are specified by the State Department of Health.

The taste and odor problem of water which occurs in some lakes during the summer months is due to a process referred to as the "turning over" of the lake. This process of summer stratification of the lakes results in a formation of vertical zones in gradations of water temperature from the top to the bottom of the lake. The stratification is induced by temperature and is dependent on the density of the water. For instance, the presence of dissolved solids in lakes could prevent temperature induced stratification.

The summer temperature may also give rise to excessive growth of algae and other higher plants in the lakes resulting in the water quality problem of taste and odor. The rural water districts affected could solve this problem in many ways including chemical and biological control of plant growth in the water, dredging and mixing of the lakes.

The water rate schedule for 12 rural water districts is presented in Table XI. The minimum rates vary from $5.50 per month to $12.00 per month. The charges are established to insure that the water revenue obtained covers the expenses for operation, debt service costs (interest charges and amortization), taxes and the cost of normal extensions and improvements. The rural water districts are non-profit bodies but they are expected to be financially self supporting.

Considering the factors which are used in determining the water rate charges, the uses made of the water by the customers and the costs of obtaining such quantity and quality of water from other sources, the water rate cannot be said to be excessive. Adequate finances ensure that the districts are self supporting and that they render satisfactory service to customers. Where a district cannot afford a full time staff, part time staff or cooperation with other nearby districts are good possibilities. Some of the management functions in which cooperation could immediately be tested are meter reading, billing of customers, collection of revenue and maintenance of the water systems. This cooperation will evidently yield some saving in costs to the rural water districts.

TABLE XI

WATER RATE SCHEDULE OF SELECTED RURAL WATER DISTRICTS IN OKLAHOMA, 1972

Rural Water District	Minimum Monthly Charge	Charge for Next 3,000 Gal.	Charge for Over 4,000 Gal.
Cherokee #2	$ 6.50 for 1st 1,000 gal.	$1.16 per 1,000 gal.	$0.45 per 1,000 gal.
Cotton #2	11.50 for 1st 1,000 gal.	1.00 per 1,000 gal.	0.50 per 1,000 gal.
Creek #2	6.00 for 1st 1,000 gal.	1.00 per 1,000 gal.	0.70 per 1,000 gal.
Dewey #1	5.50 for 1st 2,000 gal.	1.00 per 1,000 gal.	0.60 per 1,000 gal.
Okarche Inc.	12.00 for 1st 1,000 gal.	1.10 per 1,000 gal.	0.52 per 1,000 gal.
Muskogee #1	6.00 for 1st 1,500 gal.	1.50 per 1,000 gal.	0.75 per 1,000 gal.
Muskogee #2	6.50 for 1st 2,244 gal.	0.90 per 748 gal.	0.60 per 748 gal.
Muskogee #4	6.50 for 1st 2,000 gal.	1.75 per 1,000 gal.	0.87 per 1,000 gal.
Muskogee #6	6.50 for 1st 1,000 gal.	1.50 per 1,000 gal.	0.62 per 1,000 gal.
Muskogee #7	6.80 for 1st 1,500 gal.	1.75 per 1,000 gal.	0.70 per 1,000 gal.
Wagoner #6	6.00 for 1st 1,500 gal.	1.00 per 1,000 gal.	0.62 per 1,000 gal.
Woodward #1	10.00 for 1st 2,000 gal.	1.50 per 1,000 gal.	0.50 per 1,000 gal.

Summary

The role of management is very important in successfully developing, operating and maintaining a rural water system. This study has utilized the information obtained from the personal interviews of the managers and secretaries of selected rural water districts in Oklahoma to develop the essential management functions of rural water districts.

A factor analysis model was used to estimate the relative importance of the management functions of rural water districts. Using a two-factor matrix solution, the loadings of the components were used as a means of comparison between variables and groups of variables.

The management functions could be subdivided into administrative, operation and maintenance functions but they should be well coordinated to achieve a unified service. The implication for policy is that all managers of rural water districts should be sufficiently informed and instructed on the functions which they must perform to ensure the success of their water districts.

CHAPTER VI

SUMMARY AND CONCLUSIONS

Summary

Rural water districts in Oklahoma are serving a real need in the communities. The water systems have enabled communities to assure an adequate supply of water for domestic and small business uses. In addition, they have served as efficient means of collecting waste materials.

Rural water districts in Oklahoma are public bodies organized to develop water systems for rural areas or towns of not more than 5,500 population. They are quasi-municipal corporations which are not organized for profit; their primary function is to finance, construct, operate and maintain rural water systems. The State Rural Water District Act of 1972 empowers the districts to also own and operate waste disposal systems. The Farmers Home Administration makes loans and grants to the rural communities and also provides technical assistance to help in the development of the water systems.

Since 1963 when the idea for the formation of rural water districts first gained organized effort, many rural communities have developed their water systems. By 1972, the FHA had made loans and grants worth over $60 million for the construction of 245 completed rural water systems in Oklahoma. The number of applications from other communities requesting FHA financial and technical assistance to develop their water systems increases every year. The existing districts are experiencing high demand for membership from residents who initially did not contract for water and from new residents who have built homes in the rural communities after the establishment of the water systems. Small business establishments that have located in the communities after the water systems were developed have also added to the demand for water service.

This study was designed to accomplish three objectives: to (1) determine whether economies of size exist for the rural water districts; (2) discuss the social and economic effects of the rural water systems on the communities; and (3) identify the management functions necessary to efficiently develop, operate and maintain rural water systems.

Twelve rural water districts were selected from nine counties in Oklahoma to reflect the different climatic, topographic and social characteristics that are evident in the state. Questionnaires were sent to a number of customers in each district while personal interviews were held with the managers and secretaries as well as with FHA officials. Data were also obtained from the records of the water districts.

On the investigation of the economies of size, average cost functions were developed by using statistical regression procedure to analyze the cost-size relationships for rural water districts based on their source of water supply. The evidence for the existence of economies of size was shown by the decline in the long-run average cost curves as the number of customers served increased. The curves obtained by the regression procedure are also called economies of size curves. They show that reduction in costs could be achieved by increasing the number of customers served. After a minimum point, the curves begin to rise indicating that the least average cost had been achieved beyond which costs begin to increase as number of customers increases. The curves therefore, could be used for planning since they show the average total cost per customer that could be expected for different sizes of rural water districts under the given conditions of technology and prices.

Based on the regression analysis of average total cost on number of customers for districts which purchased treated water, the curve that was derived had a minimum average total cost per customer of $67.80 at the point where the number of customers was 900. The value of the average total cost per customer varied from $68.50 at the point where the number of customers was 800 to $69.50 when the number of customers was 1,000.

When the volume of water produced and distributed annually was explicitly introduced into the equation, the minimum average total cost per customer was $72.80 when the number of customers was 300 and the volume of water produced and distributed annually was five million gallons. The minimum average total cost per customer was $77 when the number of customers was 300 and the volume of water produced and distributed annually was ten million gallons. When the volume of water produced and distributed annually was 50 million gallons, the minimum average total cost per customer was $86.90 at the point where the number of customers was 600. This value was $98.90 when the number of customers was 1000 and volume of water produced and distributed annually was 100 million gallons. These values indicate that more saving in costs could be achieved if the customers increased the amount of water used.

Other shift variables which affected the cost-size relationships were the density of customers and terrain in the districts. The effects of these variables on the average total cost per customer were estimated by using adjusted investment cost per capita as a proxy variable. The regression equations derived for rural water districts which use wells for their source of water supply also indicated that economies of size exist for the rural water districts.

On the social and economic impacts, results of this study indicate that the availability of good quality water supply in rural communities in Oklahoma is actively contributing to the increase in the economic opportunity and quality of living in the communities. The availability of water has enabled the customers with the income to improve the quality of their housing by adding plumbing fixtures, showers, bathtubs and flush toilets and to use such water-using appliances as dishwashers, clothes washers, water coolers, humidifiers and water heaters. Other uses made of the water from the districts were to wash cars, water gardens, lawns and for livestock.

Small business establishments had located in the communities mainly because adequate water service was available. Common among these were: service stations; garages; stores, restaurants; launderettes, trailer courts; mobile homes; housing and building trades. The water districts had opened up a good market for plumbing fixtures and appliances. On the other hand, they had cut the business of private well drillers, pump replacement market and have replaced private water supplies.

The analysis using a dummy variable approach indicated that the rural water districts have had significant effects on the quality of living in five rural communities in Muskogee County. The availability of adequate supply of good quality water had facilitated the use of household facilities in the rural communities for customers who could purchase the facilities. The economic impact analysis showed that modest increases in personal income had resulted from the payroll of business establishments which had located in the rural communities because water service was available from the rural water districts.

The communities in Muskogee County did not show increases in population because of the rural water districts. The county in general had lost population between 1960 and 1970, probably due to the availability of more job opportunities in other urban centers outside Muskogee. However, there has been a relocation of some housing to areas served by the water distribution lines.

Two types of change in property value were observed in the rural communities: (1) new additions were made to the stock of property in the form of new houses and expansion of existing homes; and (2) existing properties appreciated in value as reflected in the increase in real estate values.

Compared with alternative sources of water supply for the rural communities in Oklahoma, the rural water systems are providing, dependable, good quality water at a lower cost to the customers.

Efficient management is required for the successful development, operation and maintenance of the rural water systems. Factors analysis technique was used to load the variables which are important to the management of rural water districts, thus allowing individual variables and groups of variables to be compared. The functions of management could be classified as administrative, operation and maintenance. The administrative function involves: (1) accounting of funds and budget estimating; (2) water rate calculations and billing of customers; (3) collection of fees; (4) record keeping of personnel, equipment, supplies and inventories; (5) purchasing; and, (6) customer relations.

Operation and maintenance include the following functions: (1) treatment of water; (2) maintenance of source of supply; (3) pump and engine maintenance; (4) maintenance of the distribution system; (5) repair and maintenance of meters; (6) detection and elimination of cross connections, leaks; and, (7) repair of breakages. If these functions are adequately performed, the rural water districts will be fulfilling the purposes for which they were organized.

Conclusions

The evidence for the existence of economies of size for the rural water districts would suggest that when new applications are received by the FHA from communities wishing to form rural water districts, efforts should be made to solicit wider participation in the proposed district by other surrounding communities. This study shows that cost advantages can be achieved by larger districts; thus communities might be better off cooperating with one another where it is technologically possible.

Costs of operation and maintenance might also be reduced if contiguous districts cooperatively perform some management functions such as maintenance of the water systems, meter reading, billing of customers and record keeping.

The FHA should have the responsibility of adequately informing and instructing managers of the management functions which they must perform as they begin the development and operation of a rural water system. Short term workshops could be organized by the FHA in cooperation with other agencies such as the Extension Service to carry out this instruction. It could be held at such time intervals as the FHA finds necessary and should include an evaluation process to determine the effectiveness of the instruction. Adequate record keeping of all the business activities of the rural water districts should be kept as this would immensely assist in future studies of the rural water districts.

The effects on the quality of the water systems by good engineering require that the engineer be sufficiently knowledgeable about the rural areas to be served and that future growth in demand be fairly accurately predicted when designing the water systems. The formal pattern of operation with paid management positions could be adopted as this would increase the efficiency of management of the rural water systems.

Limitations of This Study

The number of rural water districts analyzed was small. The study involved twelve districts and out of 245 rural water districts in Oklahoma which were in operation as of December, 1972. Though their methods of operation and financing are similar, a larger number of these districts could be studied for the results to have a wider applicability. Many districts did not have records on the amount of water produced and distributed annually.

It was difficult to obtain relevant data on the economic activities of the rural communities. Being subdivisions of larger communities, separate data on tax revenues, local government expenditures on roads, schools and other facilities in the communities could not be obtained.

Need for Future Research

There is need to empirically determine in rural communities that have gained population, the effect which the availability of water service from rural water districts has had in the decision of people to locate in these communities.

In communities where there has been a relocation of homes to the areas served by the rural water lines, there is need to determine the impact which this has on land values and on local government expenditures for roads, schools, utilities and police protection. There is also need to accurately analyze the rural communities' potential for growth or decline to assist in planning for the present and future water service needs. The correct amount of water service can be determined if there is accurate information on projected number of residences, businesses and other establishments that are likely to locate in the rural communities over time. Research on the costs and benefits of each community water system would be helpful in determining the desirability of the community water projects.

REFERENCES CITED

(1) Wagner, E. G., and J. N. Lanoix. *Water Supply for Rural Areas and Small Communities*. Geneva: World Health Organization, 1959.

(2) Tweeten, Luther. "Elements of Economic Growth in Rural Areas." *Research Application in Rural Economic Development and Planning*. Research Report P-665. Stillwater: Agricultural Experiment Station, Oklahoma State University (July, 1972), pp. 1-14.

(3) Schreiner, Dean F. "A Planning Framework for Rural Public Sector Analysis." Stillwater: Journal Article of the Oklahoma Agricultural Experiment Station (April, 1973), 45 pp.

(4) Downing, Leonard. "Comprehensive Water and Sewer Planning and Development of Rural Water Systems in Oklahoma." *Research Application in Rural Economic Development and Planning*. Research Report P-665, Stillwater: Agricultural Experiment Station, Oklahoma State University (July, 1972), pp. 198-201.

(5) Hirsch, Werner Z. *Urban Economic Analysis*. New York: McGraw-Hill, 1973.

(6) Madden, Patrick J. *Economies of Size in Farming*. Agricultural Economic Report No. 107. Washington, D.C.: Economic Research Service, U. S. Department of Agriculture (February, 1967).

(7) Eidman, Vernon R. "Measurement of Economies of Scale in Agricultural Production." (Term Paper for Agricultural Economics 210A), May, 1962, 27 pp.

(8) Stigler, George J. "The Economies of Scale." *The Journal of Law and Economics*, Vol. 1 (October, 1959), pp. 54-72.

(9) Johnston, J. *Statistical Cost Analysis*. New York: McGraw-Hill, 1960.

(10) Walters, A. A. "Expectations and the Regression Fallacy in Estimating Cost Functions." *The Review of Economics and Statistics*, Vol. XLII, No. 2 (May, 1960), pp. 210-215.

(11) Andrews, Richard A. "Economies Associated with Size of Water Utilities and Communities Served in New Hampshire and New England." *Water Resources Bulletin*, Vol. 7, No. 5 (October, 1971).

(12) Butler, James E., and Glenn V. Fuguitt. "Small-town Population Change and Distance from Larger Towns: A Replication of Hassinger's Study." Rural Sociology, Vol. 35, No. 3 (September, 1970), pp. 396-409.

(13) Wingo, Lowdon. "The Quality of Life: Toward a Micro-economic Definition." Urban Studies, Vol. 10, No. 1 (February, 1973), pp. 1-17.

(14) Brinkman, George. "Effects of Industrializing Small Communities." Journal of Community Development Society, Vol. 4, No. 1 (Spring, 1973), pp. 69-80.

(15) Wills, Walter J., and Donald D. Osburn. "Impact of Community Water Systems in Small Towns." Water Resources Center Research Report, No. 20, Urbana, Illinois (June, 1969), 16 pp.

(16) Smythe, Patrick E. Economic Impact of a Rural Water District. Manhattan: Dept. of Economics, Cooperative Extension Service, Kansas State University, Kansas, 1969.

(17) Hackett, Donald W. "A Conceptual Management Information System for the Marketing Oriented Firm." Oklahoma Business Bulletin, Bureau of Business and Economic Research, University of Oklahoma, Vol. 40, No. 7 (July, 1972), pp. 20-26.

(18) McNabb, Coy G., and Melvin G. Blase. Public Water for Rural Areas and Small Towns. Columbia: Extension Division, University of Missouri, MP105, 1969.

(19) Peterson, John J., Jr. Community Organization and Rural Water System Development. Mississippi: Water Resources Research Institute, Mississippi State University, State College, 1971, 55 pp.

(20) Morrison, Donald F. Multivariate Statistical Methods. New York: McGraw-Hill, 1967.

SELECTED BIBLIOGRAPHY

Ameen, J. S. Source Book of Community Water Systems. High Point, North Carolina, 1965.

Blase, M. G., W. Gottman and G. Coy McNabb. "Public Water Supply Districts: Evaluation of a New Institution." Land Economics, Vol. XLVIII (August, 1972), pp. 273-276.

Bottum, J. Carroll. "Community Development Operation." American Journal of Agricultural Economics, Vol. 50, No. 5 (Dec., 1968), pp. 1239-1246.

Boulding, Kenneth E. Economic Analysis. Rev. ed., New York: Harper & Brothers, 1948, pp. 671-690.

Bressler, R. G., Jr. "Research Determination of Economies of Scale." Journal of Farm Economics, Vol. XXVII, No. 3 (Aug., 1945), pp. 526-539.

Brinkman, George. "Effects of Industrializing Small Communities." Journal of Community Development Society, Vol. 4, No. 1. (Spring, 1973), pp. 69-80.

Childs, M. D. "An Economic Analysis of Plant Location by Community Size in Oklahoma." (Unpublished M.S. Thesis, Oklahoma State University, 1973).

Conover, W. J. Practical Non-parametric Statistics. New York: John Wiley, 1971.

Cosgrove, M. H., and Leroy J. Hushak. Costs and Quality of Water in Ohio Cities, Ohio Agricultural Research and Development Center, Research Bulletin 1052, April, 1972, 15 pp.

Dalkey, Norman C. Studies in the Quality of Life. Lexington Books, The Rand Corporation, 1972.

Economic Development Division, Economic Research Service, and U. S. Department of Agriculture, The Economic and Social Conditions of Rural America in the 1970's, Part I, May, 1971.

Environmental Protection Agency. Quality of Life Indicators: A Review of State-of-the-Art and Guidelines Derived to Assist in Developing Environmental Indicators. Environmental Studies Division, December, 1972.

Extension Service. Comprehensive Water and Sewer Plans: Muskogee County. Stillwater: Oklahoma State University, 1967.

Farris, Edwin J. "Economies of Scale in Crop Production." Journal of Farm Economics, Vol. XLIII, No. 5 (December, 1961), pp. 1219-1226.

Garrison, Charles B. "The Impact of New Industry: An Application of the Economic Base Multiplier to Small Rural Areas." Land Economics. Vol. XLVIII, No. 4 (November, 1972).

Hagle, Paul, et al. Basic Data and Projections for the Oklahoma Economy by Planning District. Research Foundation, Stillwater: Oklahoma State University, July, 1973.

Headley, J. Charles. "The Relation of Family Income and Use of Water for Residential and Commercial Purposes in the San Francisco-Oakland Metropolitan Area." Land Economics, Vol. XXXIX (November, 1963), pp. 441-449.

Henderson, J. M., and R. E. Quandt. Microeconomic Theory. 2nd ed. New York: McGraw-Hill, 1971.

Homan, A. G., and N. J. Dikeman, Jr. "County Personal Income in Oklahoma: 1960-1970." Bureau of Business and Economic Research. Norman: University of Oklahoma, (1971).

Howell, Herbert B. "Economies of Scale in Livestock Production." Journal of Farm Economics, Vol. XLIII, No. 5 (December, 1961), pp. 1229-1236.

Johnson, Glenn L. "Methodology for Managerial Input." Workshop on the Management Input in Agriculture. New Orleans: (April, 1963), pp. 1-20.

Johnston, J. Econometric Methods. New York: McGraw Hill, 1963.

Jolayne Service. A User's Guide to the Statistical Analysis System. Raleigh: Student Supply Stores, North Carolina State University, August, 1972.

Knudtson, Arvid C. "Estimating Economies of Scale." Journal of Farm Economics, Vol. XL, No. 3 (August, 1958), pp. 750-756.

Leftwich, Richard H. The Price System and Resource Allocation, 4th ed., Hinsdale: The Dryden Press, Inc., 1970.

Linaweaver, F. P., Jr., John C. Geyer and Jerome B. Wolff. A Study of Residential Water Use, U. S. Dept. of Housing and Urban Development, Federal Housing Administration, Washington, D.C., 1967.

Moore, Frederick T. "Economies of Scale: Some Statistical Evidence." Quarterly Journal of Economics, Vol. LXXVIII, No. 2 (May, 1959), pp. 232-245.

Oklahoma Industrial Development and Parks Department. Oklahoma Directory of Manufacturers and Products, 1969. Oklahoma City: 1969.

Oklahoma Tax Commission. Real Estate Assessment-Sales Ratio Study. Oklahoma City: 1971.

Orcutt, Guy H., et al. Microanalysis of Socioeconomic Systems: A Simulation Study. New York: Harper & Brothers, 1961.

Palmby, Raymond W. A Study of Rural Water Districts, Agricultural Extension Service, University of Minnesota, June, 1971, 23 pp.

Phillips, R. "Empirical Estimates of Cost Functions for Mixed Feed Mills in the Midwest." Agricultural Economics Research, Vol. VIII, No. 1 (Jan., 1956), pp. 1-8.

Shaffer, Ronald Earl. "The Net Economic Impact of New Industry on Rural Communities in Eastern Oklahoma." (Unpublished Ph.D. Thesis, Oklahoma State University, 1972).

Spaulding, Irving A. Household Water Use and Social Status, Agricultural Experiment Station, University of Rhode Island, Bulletin 392, 1967, 32 pp.

Staehle, Hans. "The Measurement of Statistical Cost Functions: An Appriasal of Some Recent Contributions." American Economic Review, Vol. XXXII (1942), pp. 321-333. Reprinted in Readings in Price Theory. AEA, ed., G. J. Stigler and K. E. Boulding, (1952).

Stigler, George J. The Theory of Price, rev. ed. New York: Macmillan, 1952, pp. 134-147.

Stober, W. J., and L. H. Falk. "A Benefit-Cost Analysis of Local Water Supply." Land Economics, (August, 1967), Vol. XLIII, pp. 328-335.

Stollsteinmer, J. F., R. G. Bressler, and J. N. Boles. "Cost Functions from Cross-Section Data-Fact or Fantasy?" Agricultural Economics Research, Vol. XIII, No. 3 (1961), pp. 79-88.

Tiebout, C. M. "The Pure Theory of Local Government Expenditures." Journal of Political Economy. Vol. 64 (1956), pp. 416-424.

U. S. Bureau of the Census. U. S. Population: 1950, 1960, 1970, Characteristics of the Population, Oklahoma, Washington, D. C.: U. S. Government Printing Office.

________________________. Census of Housing: 1960, 1970, Oklahoma. Washington, D.C.: U. S. Government Printing Office.

Walters, A. A. "Production and Cost Functions." Econometrica, Vol. 31 (1963), pp. 1-66.

Wright, F. B. Rural Water Supply and Sanitation. 2nd ed. New York: John Wiley, 1956.

Viner, Jacob. "Cost Curves and Supply Curves." Zeitschrift fur Nationalokonomie, Vol. III (1931), pp. 23-46. Reprinted in Readings in Price Theory, AEA, ed. G. J. Stigler and K. E. Boulding, (1952).

APPENDIX A

RURAL WATER DISTRICT DIRECTOR'S

SURVEY QUESTIONNAIRE

RWD DIRECTORS' SURVEY CONFIDENTIAL

SOCIAL AND ECONOMIC EFFECT OF RURAL WATER DISTRICTS

Department of Agricultural Economics
Agricultural Experiment Station
Oklahoma State University
Stillwater, Oklahoma
Summer 1972

1. Name of your rural water district____________________

   County____________________

2. Address of your rural water district____________________

3. Name of director____________________

4. When was the rural water district incorporated?____________________

5. When did users first get water (approximate date)?____________________

6. How many users did you have when the waterline first went into use?

   ____

7. How many users do you now have?____________________

8. Has the line been expanded? yes_____ no_____ If so, number of miles of line added____________________

   ____

9. Are you encouraging new customers? yes_____ no_____ If no, please explain why not?____________________

   ____

10. Does your water supply system adequately meet present demand? yes_____ no_____ If no, please explain____________________

    ____

11. Who reads the meters?____________________

12. How do you bill your customers?____________________

13. How do you collect the monthly bill?____________________

14. What are your major maintenance problems and how are they handled?

    ____

    ____

15. Do you have any problems with your water supply? (For example, quantity, odor, taste) yes_____ no_____ Comment:__________________

____

16. If you were to replan your rural water district, is there any way you could reduce the costs of operation and maintain the same quantity and quality of water? yes_____ no_____ If yes, please comment:

____

17. What advice would you give to a new district that is just being formed? ____

____

18. Please indicate which of the following apply as a result of the rural water district:

			Comments
increase in rate of building?	yes____	no____	________________
increase in population?	yes____	no____	________________
improved fire protection service?	yes____	no____	________________
increase in property value?	yes____	no____	________________
increase in livestock enterprises?	yes____	no____	________________
availability and use of household water using appliances such as dishwashers, clothes washers, heaters, dryers, etc.?	yes____	no____	________________
elimination of water hauling?	yes____	no____	________________
use of water spraying equipment such as for herbicides?	yes____	no____	________________
new job opportunities in the area served by your RWD?	yes____	no____	________________
new business firms in the area served by your RWD?	yes____	no____	________________
expansion of existing businesses in the area served by your RWD?	yes____	no____	________________

19. Has the RWD helped to keep people from moving out of your district? yes_____ no_____

20. Is the water district making its payments on time: yes_____ no_____
Comments:____

____

21. Would you be in favor of cooperating with other water districts in the county to handle billing and maintenance? yes_____ no_____
Comments:____

____

22. What is the number one complaint of your water users?________________________________

23. Do you have any general comments on the development or operation of your rural water district that have not been covered above: yes_____ no_____ If yes, please comment:________________________________

24. Rate the following between 0 and 10 as they are of importance to the management of your rural water district.

(a) good engineering of water system
(b) accurate projection of growth of community
(c) supply planning and use of large-size pipelines
(d) use of good meters
(e) minimum leakage of water
(f) cooperation of board members
(g) dynamic manager
(h) good public relations in the community
(i) regular payment of water rates
(j) salaried manager and bookkeeper
(k) education of manager and bookkeeper
(l) trained maintenance personnel
(m) well kept records

DDB:DO

mm 7/13/72

SOCIAL AND ECONOMIC EFFECT OF RURAL WATER DISTRICTS

Department of Agricultural Economics
Agricultural Experiment Station
Oklahoma State University
Stillwater, Oklahoma
May, 1973

Number of Your RWD ________________ County ____________________________

Year Began	Number of Customers	Total Water Sold In Gallons	Amount of Water Lost Due to Leakage In Gallons	Number of New Homes Built
1966				
1967				
1968				
1969				
1970				
1971				
1972				
1973				

Director/Manager ____________________ Address ____________________________

Secretary/Bookkeeper ________________ Address ____________________________

APPENDIX B

RURAL WATER DISTRICT CUSTOMERS'

SURVEY QUESTIONNAIRE

RWD WATER USERS' SURVEY CONFIDENTIAL

SOCIAL AND ECONOMIC EFFECTS OF RURAL WATER DISTRICTS

Department of Agricultural Economics
Agricultural Experiment Station
Oklahoma State University
Stillwater, Oklahoma
Summer, 1972

INSTRUCTIONS: Please check the answer or write in an answer as indicated.

1. Name and number of your Rural Water District____________________

2. Your mailing address and legal description if known______________

   ____

3. Were you one of the original water district members? yes____ no____

4. What year did you first get water from the system?_______________

5. What did it cost you to join the district and get the meter set (excluding the cost of the line from the meter to your house)?_____

6. What is your average water bill per month?______________________

7. What was your source of water before you joined the rural water district? cistern_____ own well_____ purchase from other sources _____ hauled water_____ how far hauled_________other______________ (specify)

8. Why did you join the rural water district? (check one or more) convenience____ cheaper than your previous source_____ better quality water_____ larger quantity available_____ others__________ specify

9. How would you compare this water with the water you were using before? better_____ as good as______ worse than_____

10. Are you able to use as much water as you need any time that you like now? yes_____ no_____ Comment:_____________________________

    ____

11. Since you joined the rural water district, what new uses in your home have you been making of the water? (check one or more) showers____ bathtubs____ flush toilet____ dishwasher____ aid conditioning with water cooling system (water cooler)____ humidifier____ hot water heater____ clothes washer____ swimming pool____ wading pool____ others (specify)____

12. Do you use water from the system (a) to wash your car? yes__ no__
(b) to water your garden? yes__ no__
(c) for lawn sprinkling? yes__ no__

13. Do you water livestock from the system? yes____ no____ If yes, what type of livestock? dairy___ beef___ horses___ hogs___ chickens___
How many of each type? dairy____ beef____ horses____ hogs____ chickens____

14. Did you have these livestock before the water system was installed? yes____ no____ Please comment if you have added livestock (why):

____

____

15. How many acres of land do you own in the tract which is serviced by the water system?__________ If you purchased the land after the system was installed, what was your purchase price?__________ If you owned the land before the water system was installed, has the rural water district increased the value of your land? yes____ no____ If yes, about how much per acre $_______ or about how much for your entire property $______________/

16. Have you built a new house or bought a mobile home since you joined the rural water district? yes____ no____ If yes, which? house_____ mobile home_____

17. If no new home, have you made any additions to your existing home? Yes_____ No_____ If yes, what were the additions?________________

____

18. Has there been any improvement in fire protection services? yes_____ no_____

19. Is your fire insurance now: lower?____ higher?____ same?____
If lower, how much are the annual savings? $______________

20. Do you know of new firms which came to locate in your community after your rural water district was established? yes____ no____
If yes, please list the name and address:________________________

____

21. Have any firms that were previously in your community expanded because of the rural water district? yes____ no____ If yes, please list the names and addresses:______________________________

____

22. Has there been any increase in job opportunities since the rural water district was established? yes_____ no_____ don't know_____

23. Since the rural water district was established, has the population in your district: increased_____ decreased_____ remained constant?______

24. Is your main source of income: farm____ nonfarm____ retired____
If nonfarm, what is your occupation?______________________________
place of employment?____
How far do you drive to work?_____________________

25. Please make any general comments you desire on the development and operation of the rural water district:_____________________________

____

____

____

____

____

____

DDB:DO

mm 6/28/72

APPENDIX C

REGRESSION EQUATIONS ESTIMATING THE AVERAGE FIXED AND THE AVERAGE VARIABLE COST FUNCTIONS FOR RURAL WATER DISTRICTS IN OKLAHOMA

Average Fixed Cost Functions for Rural Water

Districts that Purchase Treated Water

$$R = 95.1286 - \underset{(0.0522)^{*}}{0.1250M} + \underset{(0.00003986)}{0.00006459M^2} \qquad R^2 = .28 \tag{70}$$

$$R = 98.7168 - \underset{(0.1403)^{**}}{0.3311M} + \underset{(0.0007647)^{*}}{0.0008912M^2} + \underset{(0.001372)}{0.001969X} + \underset{(0.00000013)}{0.00000009X^2} - \underset{(0.00001963)}{0.00001682XM} \qquad R^2 = .34 \tag{71}$$

$$R = 1.4238 - \underset{(0.0003218)}{0.0003362X} + \underset{(0.0257)^{***}}{0.0731D} - \underset{(0.00000876)}{0.00000476D^2} \qquad R^2 = .82 \tag{72}$$

$$\text{Log } R = \text{Log } 5.5200 - \underset{(0.0564)^{*}}{0.2587 \log M} \tag{73}$$

$$\text{Log } R = \log 5.4539 - \underset{(0.1114)^{*}}{0.2739 \log M} + \underset{(0.0971)}{0.0154 \log X} \qquad R^2 = .38 \tag{74}$$

$$\text{Log } R = -\log 1.3447 - \underset{(0.0517)^{**}}{0.1591 \log M} + \underset{(0.0443)}{0.0417 \log X} + \underset{(0.0760)^{***}}{0.8568 \log D} \qquad R^2 = .88 \tag{75}$$

$$\text{Log } R = -\log 1.4278 - \underset{(0.0277)^{*}}{0.0712 \log X} + \underset{(0.0835)^{**}}{0.9028 \log D} \qquad R^2 = .84 \tag{76}$$

In these equations:

R = average fixed cost per customer;

M = number of customers;

X = volume of water produced and distributed annually;

D = density and terrain factor;

* means coefficient is significantly different from zero at ten percent probability level;

** means coefficient is significantly different from zero at five percent probability level;

*** means coefficient is significantly different from zero at one percent probability level;

values in parentheses are standard errors of estimate; and

R^2 = coefficient of multiple determination estimating the variation in costs accounted for by the regression equation fitted.

Regression Equations with Average Fixed Cost Per Thousand Gallons of Water (Q) as the Dependent Variable

$$Q = 2.7725 - \underset{(0.0000344)^{*}}{0.00008186X} \qquad R^2 = .21 \qquad (77)$$

$$Q = -4.4336 + \underset{(0.0001319)}{0.0001272X} + \underset{(0.003143)^{***}}{0.009344D} - \underset{(.0000093)^{***}}{0.0000025D^2} - \underset{(0.0000001)^{*}}{0.00000016XD} \qquad R^2 = .39 \qquad (78)$$

$$Q = 1.8522 - \underset{(0.0000424)^{***}}{0.0003348X} + \underset{(0.00000000)^{***}}{0.00000003X^2} + \underset{(0.004339)^{***}}{0.0206M} + \underset{(0.00002365)^{***}}{0.0001M^2} - \underset{(0.00000061)^{***}}{0.00000328XM} \qquad R^2 = .78 \qquad (79)$$

$$\text{Log } Q = \log 4.4361 - \underset{(0.0827)^{*}}{0.4513 \log X} \qquad R^2 = .47 \qquad (80)$$

$$\text{Log } Q = \log 1.2488 - \underset{(0.0885)^{***}}{0.4003 \log X} + \underset{(0.2667)}{0.3896 \log D} \qquad R^2 = .50 \qquad (81)$$

$$\text{Log } Q = \log 0.8000 - \underset{(0.0950)^{***}}{1.0096 \log X} + \underset{(0.1632)^{***}}{0.6377 \log D} + \underset{(0.1111)^{***}}{0.8585 \log M} \qquad R^2 = .83 \qquad (82)$$

$$\text{Log } Q = \log 5.8598 - \underset{(0.1136)^{***}}{1.0291} \log X + \underset{(0.1305)^{**}}{0.7731} \log M \qquad R^2 = .74 \tag{83}$$

Regression Equations with Average Cost Per Customer (T) as the Dependent Variable

$$\text{Log } T = \log 3.2903 + \underset{(0.1261)^{**}}{0.3696} \log X - \underset{(0.2164)}{0.0770} \log D - \underset{(0.1473)^{***}}{0.4706} \log M \qquad R^2 = .25 \tag{84}$$

$$\text{Log } T = \log 2.6796 + \underset{(0.1242)^{**}}{0.3720} \log X - \underset{(0.1425)^{**}}{0.4603} \log M \qquad R^2 = .24 \tag{85}$$

Regression Equations with Average Variable Cost Per Thousand Gallons of Water Produced and Distributed Annually (V) as the Dependent Variable

$$V = 0.8355 - \underset{(0.00001696)^{***}}{0.00009666X} + \underset{(.0000000)^{***}}{0.00000001X^2} + \underset{(0.001734)^{***}}{0.005955M} + \underset{(0.00000945)^{**}}{0.00002357M^2} - \underset{(0.00000024)^{***}}{0.00000079XM} \qquad R^2 = .63 \tag{86}$$

$$\text{Log } V = \log 3.3393 - \underset{(0.1270)^{***}}{0.6342} \log X - \underset{(0.2180)}{0.0830} \log D + \underset{(0.1484)^{***}}{0.5330} \log M \qquad R^2 = .45 \tag{87}$$

$$\text{Log } V = \log 2.6809 - \underset{(0.1251)^{***}}{0.6316} \log X + \underset{(0.1436)^{**}}{0.5441} \log M \qquad R^2 = .45 \tag{88}$$

Cost Functions for Rural Water Districts that Own Wells

Regression Equations with Average Fixed Cost Per Customer (R), as the Dependent Variable

$$R = 135.5044 - \underset{(0.3829)^{*}}{0.8769M} + \underset{(0.00077)^{*}}{0.0015M^2} \qquad R^2 = .67 \qquad (89)$$

$$\text{Log } R = \log 8.3736 - \underset{(0.1252)^{**}}{0.9385 \log M} \qquad R^2 = .85 \qquad (90)$$

$$\text{Log } R = \log 9.3985 - \underset{(0.1272)^{**}}{0.5054 \log X} - \underset{(0.1128)}{0.1360 \log D} \qquad R^2 = .72 \qquad (91)$$

Regression Equations with Average Fixed Cost Per Thousand Gallons of Water Produced and Distributed Annually (Q), as the Dependent Variable

$$Q = 2.3256 - \underset{(0.00005882)^{**}}{0.0002314X} + \underset{(0.0000000)^{**}}{0.00000001X^2} \qquad R^2 = .81 \qquad (92)$$

$$Q = 2.8124 - \underset{(0.00009236)^{***}}{0.0003164X} + \underset{(0.00000000)^{**}}{0.00000001X^2} - \underset{(0.00004005)}{0.00003773D} \qquad R^2 = .87 \qquad (93)$$

$$\text{Log } Q = \log 8.1776 - \underset{(0.0826)^{**}}{0.9453 \log X} \qquad R^2 = .93 \qquad (94)$$

$$\text{Log } Q = \log 8.4835 - \underset{(0.0904)^{***}}{0.9221 \log X} - \underset{(0.0801)}{0.7293 \log D} \qquad R^2 = .93 \qquad (95)$$

$$\text{Log } Q = \log 8.0033 - \underset{(0.2434)^{**}}{0.7643 \log X} - \underset{(0.3650)}{0.2893 \log M} \qquad R^2 = .93 \qquad (96)$$

Regression Equations with Average Variable Cost Per Customer (T) as the Dependent Variable

$$T = -28.3332 + 0.9963M - 0.0024M^2 \qquad (97)$$
$$(0.6712) \quad (0.0014) \qquad R^2 = .51$$

$$T = 118.8563 + 0.0263X + 0.00000174X^2 - 2.2214M \qquad (98)$$
$$(0.007837)^{***} (0.00000081)^{**} \ (0.96601)^{**}$$
$$+ 0.0145M^2 - 0.0003245MX$$
$$(0.00748)^{*} \ (0.0001498)^{**} \qquad R^2 = .95$$

$$\text{Log } T = \log 10.8607 - 1.4533 \log M \qquad (99)$$
$$(0.3098)^{*} \qquad R^2 = .69$$

$$\text{Log } T = \log 6.3508 + 1.4375 \log X + 0.3427 \log D \qquad (100)$$
$$(0.3752)^{***} \quad (0.1283)^{**}$$
$$- 3.7322 \log M$$
$$(0.5873)^{***} \qquad R^2 = .91$$

$$\text{Log } T = \log 8.4724 + 0.12333 \log X - 3.1889 \log M \qquad (101)$$
$$(0.4764) \quad (0.7145)^{**} \qquad R^2 = .82$$

Regression Equations with Average Variable Cost Per Thousand Gallons of Water Produced and Distributed Annually, (V), as the Dependent Variable

$$V = 2.0189 - 0.0001633X - 0.0000561D + 0.00000001D^2 \qquad (102)$$
$$(0.00007022)^{**} (.00003045)^{*} (0.00000000)^{*} \qquad R^2 = .90$$

$$V = 2.9630 + 0.0003198X + 0.00000006X^2 - 0.0437M \qquad (103)$$
$$(0.0001622)^{*} \ (0.00000002)^{***} (0.0200)^{**}$$
$$+ 0.0004105M^2 - 0.00000923XM$$
$$(0.0001548)^{***} (0.0000031)^{***} \qquad R^2 = .72$$

$$\log V = \log 9.9565 - 1.1561 \log X \qquad (104)$$
$$(0.2271)^{*} \qquad R^2 = .72$$

$$\log V = \log 6.4610 + \underset{(0.3805)}{0.4455} \log X + \underset{(0.1301)^{**}}{0.3477} \log D - \underset{(0.5956)^{***}}{2.7804} \log M \qquad (104)$$

$$R^2 = .93$$

APPENDIX D

10 - FACTOR MODEL ANALYSIS OF VARIABLES

AFFECTING MANAGEMENT OF RURAL

WATER DISTRICTS

FACTOR ANALYSIS

VARIABLE	MEAN	STANDARD DEVIATION
A	7.50000	1.83402
B	5.41667	1.92865
C	4.75000	1.42223
D	8.91667	1.37895
E	7.83333	1.11464
F	8.00000	1.41421
G	5.75000	1.21543
H	7.66667	1.61433
I	8.66667	1.43548
J	7.25000	1.65831
K	2.75000	1.21543
L	6.50000	1.16775
M	7.50000	1.24316

CORRELATION MATRIX

	A	B	C	D	E	F	G	H	I	J
A	1.00000	0.21846	0.01743	0.01797	-0.44470	0.35050	0.14274	0.49128	0.27625	-0.04484
B	0.21846	1.00000	0.30657	-0.12249	0.28897	0.03333	0.24238	0.07786	0.08756	0.36241
C	0.01743	0.30657	1.00000	-0.05794	0.14337	-0.18079	-0.09203	0.0	0.35623	0.76127
D	0.01797	-0.12249	-0.05794	1.00000	-0.24644	0.65264	0.52885	0.63980	0.44395	0.24847
E	-0.44470	0.28897	0.14337	-0.24644	1.00000	-0.40370	-0.16776	-0.63994	-0.32196	0.46723
F	0.35050	0.03333	-0.18079	0.65264	-0.40370	1.00000	0.42311	0.55748	0.22391	-0.03876
G	0.14274	0.24238	-0.09203	0.52885	-0.16776	0.42311	1.00000	0.60232	0.52105	-0.01128
H	0.49128	0.07786	0.0	0.63980	-0.63994	0.55748	0.60232	1.00000	0.57537	0.03396
I	0.27625	0.08756	0.35623	0.44395	-0.32196	0.22391	0.52105	0.57537	1.00000	0.38189
J	-0.04484	0.36241	0.76127	0.24847	0.46723	-0.03876	-0.01128	0.03396	0.38189	1.00000
K	0.06117	-0.37812	-0.51276	0.42037	-0.36907	0.31733	0.13846	0.46332	0.36474	-0.23679
L	0.16979	0.50456	0.19158	-0.53633	0.0	-0.44039	-0.41633	-0.14467	-0.43386	-0.07042
M	0.03987	-0.17062	0.07713	-0.50379	0.32803	-0.10342	-0.51141	-0.45299	-0.20377	0.06615

	K	L	M
A	0.06117	0.16979	0.03987
B	-0.37812	0.50456	-0.17062
C	-0.51276	0.19158	0.07713
D	0.42037	-0.53633	-0.50379
E	-0.36907	0.0	0.32803
F	0.31733	-0.44039	-0.10342
G	0.13846	-0.41633	-0.51141
H	0.46332	-0.14467	-0.45299
I	0.36474	-0.43386	-0.20377
J	-0.23679	-0.07042	0.06615
K	1.00000	-0.48038	0.09025
L	-0.48038	1.00000	-0.12524
M	0.09025	-0.12524	1.00000

CUMULATIVE PERCENTAGE OF EIGENVALUES

0.32598 0.52376 0.66795 0.77286 0.84843 0.90579 0.95289 0.97886 0.99526 0.99861

EIGEN VALUES

4.23769 2.57120 1.67447 1.36385 0.98237 0.74574 0.61223 0.33763 0.21318 0.04612
0.01551 0.00000 0.00000

FACTOR MATRIX

	1	2	3	4	5	6	7	8	9	10
A	0.35597	0.15843	-0.56513	-0.55716	0.25692	0.02791	-0.11511	0.36681	0.05548	-0.02294
B	-0.11478	0.69890	-0.37133	0.16199	0.43960	0.21862	0.19686	-0.20234	0.11402	-0.00927
C	-0.18712	0.81840	0.14440	-0.29367	-0.31463	-0.17668	-0.15049	-0.15155	-0.09244	-0.06049
D	0.80798	0.13153	0.29812	0.24918	0.00302	-0.32744	0.19590	0.11765	0.02410	-0.13722
E	-0.61313	0.26802	0.50412	0.25497	0.38718	0.14752	0.11817	0.19681	-0.06704	-0.02015
F	0.71945	-0.03359	-0.00361	-0.08521	0.48345	-0.42848	-0.08211	-0.20326	0.07887	0.03939
G	0.70173	0.25488	-0.00096	0.40596	0.18783	0.33355	-0.31305	-0.01860	-0.17531	-0.02616
H	0.87311	0.18572	-0.27457	-0.09495	-0.08328	0.00248	0.16187	0.00186	-0.28241	0.06051
I	0.65562	0.42980	0.21481	-0.27456	-0.26163	0.37935	-0.06965	-0.05172	0.20154	-0.01708
J	-0.05381	0.81584	0.46170	-0.16297	-0.00403	-0.13593	0.21296	0.12701	-0.00698	0.09972
K	0.59394	-0.49403	0.22813	-0.23848	-0.01366	0.26653	0.46532	-0.07273	-0.00601	-0.01094
L	-0.52891	0.23462	-0.74454	0.02961	-0.11199	-0.05395	0.29171	-0.04620	-0.06349	-0.05373
M	-0.44320	-0.22069	0.33505	-0.68780	0.34215	0.07603	-0.04974	-0.13678	-0.14845	-0.05895

ROTATED FACTOR MATRIX

	1	2	3	4	5	6	7	8	9	10
A	0.20946	0.00561	0.13064	-0.06219	0.14421	0.05707	0.02081	0.95416	0.00705	-0.00015
B	-0.17849	0.20487	0.03243	0.06193	0.92891	0.15449	-0.13278	0.11918	0.04232	0.02293
C	0.12202	0.92573	-0.10729	-0.08539	0.12038	0.00313	-0.29586	-0.01685	-0.00987	-0.08265
D	-0.03642	0.19044	0.64302	0.53634	-0.21977	0.23673	0.35284	-0.01579	-0.04605	-0.17326
E	-0.87996	0.15687	-0.16778	-0.20421	0.14595	-0.02564	-0.16320	-0.28005	-0.01906	0.00052
F	0.18617	-0.07313	0.93842	0.01053	0.01443	0.17997	0.10031	0.18437	0.00546	0.04150
G	0.02219	-0.04472	0.24829	0.30695	0.09453	0.90803	0.05077	0.06084	-0.01741	-0.00970
H	0.42626	0.14643	0.32295	0.34951	0.06182	0.39579	0.42435	0.35975	-0.31157	0.03383
I	0.25128	0.51820	0.04000	0.12424	-0.04844	0.51797	0.42884	0.19886	0.39250	0.00523
J	-0.39554	0.89796	0.09969	0.04995	0.11503	-0.01852	0.04669	0.00622	0.00409	0.08461
K	0.14233	-0.23771	0.18128	-0.06039	-0.21560	0.07780	0.91233	0.01288	0.02465	-0.00025
L	0.17459	-0.02788	-0.42509	0.12619	0.62108	-0.45486	-0.27665	0.14789	-0.27453	-0.07284
M	-0.18411	0.05747	-0.03174	-0.94152	-0.12631	-0.22411	0.07515	0.05571	-0.00553	-0.01924

FACTOR	VARIANCE	PERCENT
1	1.38736	10.68
2	2.12410	16.36
3	1.74395	13.43
4	1.48480	11.44
5	1.44449	11.12
6	1.62922	12.55
7	1.55006	11.94
8	1.23542	9.51
9	0.33189	2.56
10	0.05320	0.41

CHECK ON COMMUNALITIES

VARIABLE	ORIGINAL	FINAL	DIFFERENCE
A	0.99980	0.99980	0.00000
B	0.99958	0.99958	0.00000
C	0.99992	0.99992	0.00000
D	0.99995	0.99995	0.00000
E	0.99618	0.99618	0.00000
F	0.99916	0.99916	0.00000
G	0.99849	0.99849	0.00000
H	0.99779	0.99779	0.00000
I	0.99688	0.99688	0.00000
J	0.99819	0.99819	0.00000
K	0.99894	0.99894	0.00000
L	0.99961	0.99961	0.00000
M	1.00000	1.00000	0.00000

EIGEN VECTORS

	1	2	3	4	5	6	7	8	9	10
A	0.17292	0.09880	-0.41277	-0.47708	0.25922	0.03232	-0.14712	0.63127	0.12017	-0.10682
B	-0.05576	0.43586	-0.27122	0.13871	0.44352	0.25316	0.25159	-0.34823	0.24595	-0.04314
C	-0.09090	0.51039	0.10547	-0.25147	-0.31744	-0.20460	-0.19233	-0.26081	-0.20022	-0.28168
D	0.39250	0.08203	0.21774	0.21337	0.00305	-0.37918	0.25036	0.20248	0.05219	-0.63896
E	-0.29784	0.16715	0.36821	0.21832	0.39064	0.17083	0.15102	0.33870	-0.14520	-0.09384
F	0.34949	-0.02095	-0.00264	-0.07296	0.48777	-0.49618	-0.10494	-0.34980	0.17082	0.18339
G	0.34088	0.15895	-0.00070	0.34762	0.18951	0.38625	-0.40009	-0.03201	-0.37969	-0.12179
H	0.42414	0.11582	-0.20055	-0.08130	-0.08403	0.00287	0.20688	0.00320	-0.61165	0.28176
I	0.31848	0.26804	0.15690	-0.23510	-0.26397	0.43928	-0.08902	-0.08901	0.43651	-0.07953
J	-0.02614	0.50879	0.33722	-0.13955	-0.00407	-0.15740	0.27217	0.21859	-0.01513	0.46431
K	0.28852	-0.30809	0.16662	-0.20420	-0.01378	0.30864	0.59469	-0.12517	-0.01302	-0.05093
L	-0.25693	0.14632	-0.54381	0.02535	-0.11299	-0.06247	0.37282	-0.07950	-0.13751	-0.25020
M	-0.21529	-0.13763	0.24472	-0.58895	0.34521	0.08804	-0.06357	-0.23540	-0.32151	-0.27451

LISTING OF THE TRANSFORMEO INPUT DATA

1	1	1.35841	-0.08364	0.48330	-0.24803	0.95234	1.20481	-0.49381
1	8	0.68822	-1.85112	-0.55561				
2	1	1.18265	1.11587	0.02137	-0.23771	0.28916	-0.45435	0.01676
2	8	-1.22046	-0.53909	1.95840				
3	1	0.17694	2.08388	-0.63070	0.06286	-0.82303	-0.03212	1.08855
3	8	1.08307	0.05896	-1.35701				
4	1	0.29426	0.45135	-1.05021	1.59102	-0.89555	-0.17201	-1.50647
4	8	-0.27946	0.69490	0.37625				
5	1	-0.30983	-0.58745	1.59475	1.31027	-0.80126	-0.15236	1.92981
5	8	-0.40620	-0.32552	0.38806				
6	1	-0.31695	-0.47299	1.27313	-0.16027	-1.30625	1.49041	-1.31115
6	8	0.24287	0.57363	-0.07463				
7	1	-1.18527	-0.55010	-0.75248	-1.06340	-0.97399	-0.85411	-0.35322
7	8	-1.30524	-1.57580	-0.82878				
8	1	1.02856	-1.44553	-1.48341	-0.14287	0.36934	0.97893	1.07453
8	8	-0.86223	1.11960	-0.56882				
9	1	0.36419	0.41394	1.36884	-1.38351	0.67959	-1.09709	-0.33220
9	8	-0.53021	1.57390	-0.78885				
10	1	-1.65784	0.32967	-0.60734	-1.16684	0.45147	1.02143	0.50032
10	8	0.82531	0.37671	1.54511				
11	1	-1.37876	0.13836	0.07609	1.47513	2.10449	-0.17215	-0.42942
11	8	-0.25712	-0.05338	-0.63538				
12	1	0.44366	-1.39335	-0.29334	-0.03666	-0.04630	-1.76139	-0.18370
12	8	2.02144	-0.05280	0.54127				

ITERATION CYCLE	VARIANCE
0	0.166934
1	0.326911
2	0.427696
3	0.444144
4	0.450054
5	0.450910
6	0.451145
7	0.451307
8	0.451424
9	0.451499
10	0.451540
11	0.451561
12	0.451570
13	0.451573
14	0.451575
15	0.451575
16	0.451576
17	0.451576
18	0.451576
19	0.451576
20	0.451576
21	0.451576

VITA

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