Analyzing the Feasibility of Domestic Rural Water Supplies in Missouri With Emphasis on The Ozarks Region

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NOTICE

THE GENERAL LAYOUT, DETAILED PLANS, AND EQUIPMENT SPECIFICATIONS OF PUBLIC WATER SUPPLY SYSTEMS MUST BE PREPARED BY A REGISTERED ENGINEER ACCORDING TO MISSOURI STATE STATUTES AND REQUIREMENTS OF MISSOURI STATE DEPARTMENT OF NATURAL RESOURCES.

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ANALYZING THE FEASIBILITY OF DOMESTIC RURAL WATER SUPPLIES IN MISSOURI WITH EMPHASIS ON THE OZARKS REGION

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INTRODUCTION

At the end of 1977, there were 179 public water supply districts in Missouri serving both rural areas and 180 communities (4). 1/ These districts were mainly in western Missouri around Kansas City, central Missouri, and eastern Missouri around St. Louis. Only 33 districts were located in the Ozarks region. Eighteen of the 38 Ozarks counties had no rural public water supply districts. On the other hand, only 16 of the remaining 76 counties did not have at least one such district.

Many rural areas in the United States have experienced considerable growth in population during the 1970's. The Ozarks region has been a leader in this growth turnaround (1). Between 1970 and 1976, Missouri's population increased 2.3 percent (23). During the same period, population in Missouri's Ozarks region increased 12.8 percent, excluding Pulaski County with Fort Leonard Wood. Most of this Ozarks population increase occurred in rural, open-country areas. Of the total 92,670 Ozarks population increase from 1970 to 1976, 69 percent was in rural areas and 31 percent occurred in incorporated small towns and larger cities. As rural population increases, especially in the Ozarks, there will likely occur an increasing need for safe, rural drinking water.

Objectives

The primary objective of this report was to present a method by which community leaders and decision makers can perform a preliminary feasibility study of proposed rural and small town domestic water systems. Final feasibility and engineering studies are the responsibility of qualified registered engineers. Specific objectives included:

1. Estimation of construction cost items for water supply systems.
2. Estimation of operating costs for different types of systems.
3. Presentation of engineering aspects needed for a preliminary feasibility study.
4. Estimation of water supply requirements.
5. Calculation of water rates needed to pay all costs.
6. Application of the above analyses to a specific demonstration area.
7. Development of techniques that other community leaders and decision makers can use for analyzing proposed water supply systems.

The report focuses on the Ozarks region not only because of its recent population growth but also because of its unique geologic terrain. Construction costs are expected to be higher in the Ozarks than in

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1/ Numbers in parentheses refer to publications listed in the References section.

the remainder of the state. Data is also presented for the remainder of the state.

Data Sources

Costs of construction items were obtained from tabulations of contractors' bids received between August 1977 and November 1978 for 26 projects. Four projects were for small towns and four different projects were in the Ozarks region. Operating costs were obtained for 72 public water supply districts filing 1978 statements of income and expenses with the Farmers Home Administration (FmHA) of the U.S. Department of Agriculture. Eleven of these were in the Ozarks region.

Other sources of information included the Missouri Department of Natural Resources for data concerning treatment practices and well characteristics, "use and income estimates" filed with FmHA for data concerning the numbers of water hookups using specified gallons per month, and a 1977 questionnaire developed for a North Central Regional Study of Rural Water Systems for data concerning water rates and various characteristics of public water supply districts.

Characteristics of Missouri Water Districts

Average monthly consumption of water per hookup in 1978 was 4,522 gallons in the Ozarks' districts compared to 5,671 gallons in districts outside of the Ozarks (Table 1). 2/ This difference can be partly explained by the lower number of people per hookup in the Ozarks as compared to the rest of the state. Average water storage per hookup was almost identical between the two state areas. Average storage was equivalent to a 2.2 day supply in the Ozarks and to a 1.8 day supply elsewhere in the state. There were 11 hookups per mile of distribution pipeline in the Ozarks compared to almost six hookups per mile in the remainder of the state. 3/

PLANNING AND DESIGNING A WATER SYSTEM

Notice

Under Missouri state law, a registered engineer must prepare the general layout, detailed plans, and specifications for public drinking water systems. Domestic flow includes water for homes, farms, commercial, and industrial usage, but excludes flows for fire protection.

Water Demand

The first step in planning to install a community water supply system is to estimate the consumption rate and numbers of prospective users. Knowledge of the

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2/ The term "districts" also includes several small town systems financed by FmHA.

3/ For a discussion of some of the problems encountered by rural water systems, see reference (16).

TABLE 1. CHARACTERISTICS OF MISSOURI RURAL WATER DISTRICTS, 1977-78

ITEM 1/	TOTAL STATE	OZARKS REGION	REMAINDER OF STATE
Number of rural water districts	72	11	61
Average monthly consumption of water per hookup, gallons	5,504	4,522	5,671
Average population per hookup	4.8	4.0	4.9
Average well capacity per hookup, gallons per day	703	786	674
Average water storage per hookup, gallons	333	329	334
Percent by source and water treatment			
Own well source, no treatment	24	73	13
Own well source, treatment facilities	19	0	22
Purchase water not treated	6	9	5
Purchase treated water	51	18	60
Average number of hookups per mile of pipe, 1977 2/	6.7	11.1	5.7

1/ Includes only those filing current statements of income and expenses with Farmers Home Administration and having less than 1,600 hookups, except for the last item.

2/ Based on data collected for 1977 in a North Central Regional research project.

Source: Accounting statements filed with Farmers Home Administration in 1978 and also Missouri Dept. of Natural Resources, Census of Missouri Public Water Supplies, 1977, Jefferson City, Missouri.

present population, and its breakdown into residential size services, including households and most commercial establishments, and large size services, including industry and large commercial establishments, can help in estimating the total water demand of the community.

Most hookups in Missouri's rural water systems are for households and small commercial establishments. It is recommended that the water supply system should be designed for 10 to 30 years service life (2, p.10). Estimating the total water demand should include provisions for anticipated population and industrial changes (5,6). In many areas, rural population has grown considerably along the distribution systems of rural water districts.

Source of Water and Treatment

The three sources of water for rural supply systems are surface water (reservoirs, lakes, streams and rivers), ground water (wells), and purchased water. Purchased water is assumed to be purchased as a finished treated product.

Surface water necessitates the installation of a complete water treatment plant to remove all physical and chemical impurities in accordance with the National Interim Primary Drinking Water Regulations (18) and the Safe Drinking Water Act (PL 93-523).

Well water may require various treatments. Usually well water is relatively cheaper to treat because most of the impurities are removed by the natural filtering capacity of the aquifer. Many rural water supply systems with wells have only chlorinator units in their systems. It should be pointed out, however, that well water is not without its problems. Hardness, high mineral content, and salt are some impurities encountered. The number and types of water treatments practiced by cities, communities, and rural water districts having wells in the various groundwater production areas of Missouri are listed in Table 2.

Figure 1 shows the location of groundwater production areas. Most of the well water supplies in Production Area 4, the Ozarks, require no treatment practices at all; about one-fifth of the Ozarks well supplies require disinfection. Hypochlorinators can be used for this purpose. About one-half of the well water supplies in Production Area 5, the St. Francois Mountains, require disinfection. About one-fifth of the supplies in the St. Francois Mountains require more extensive treatment. Such treatment can be obtained by using factory built, package treatment plants with modules for aeration, chemical mixtures, sedimentation, filtration, and disinfection. Aeration tanks and package treatment plants will likely be needed for well water supplies in the other production areas of the state, especially for Production Areas 1 and 6.

The number and depth of wells needed to meet the daily demand depends on the hydrogeologic conditions of the aquifer. The Missouri State Geologic Survey and Water Resource Map (Figure 1) shows the ground water production areas and aquifers. In general, northwestern Missouri (designated "1") has low yield aquifers. In the past, domestic and small communities have been using this aquifer as their source of water. This same aquifer, however, is capable of supplying a large quantity of water along buried glacial valleys (20,pp. 2-4;g). Although the rest of the state is endowed with high yield aquifers, the quantity, quality, and depth vary from region to region and also within regions.

TABLE 2. WATER TREATMENT PRACTICES OF CITY AND DISTRICT WATER SUPPLIES HAVING WELLS ONLY, 1977

TYPE AND NUMBER OF TREATMENT PRACTICES	GROUND WATER PRODUCTION AREAS										
	1	2A	2B	3	4A	4B	4C	4D	4E	5	6
Number of well water supplies	72	20	15	54	78	36	100	6	19	18	17
Percent of well water supplies with:											
Aeration	86	75	40	54	1	0	10	0	5	22	65
Chemical dosage for coagulation, softening, or iron removal	67	5	33	26	1	3	4	17	0	0	47
Disinfection	97	90	80	65	6	22	26	17	11	56	71
Filters	88	15	67	63	3	3	13	17	0	28	65
Chemical dosage for corrosion correction or water stabilization	33	20	7	17	6	0	11	0	0	11	6
Mixing device or tank	33	5	7	13	1	3	3	17	0	0	18
Ammoniation	0	0	0	0	0	0	1	0	0	0	0
Recarbonation	14	0	0	2	0	0	3	17	0	0	6
Sedimentation	88	40	60	44	1	3	7	0	0	22	71
Chemical taste and odor control	3	5	0	0	3	0	4	0	0	6	0
Fluoride adjustment	6	0	0	13	1	3	3	17	0	0	0
Percent of well water supplies with:											
No practices	2	5	20	28	82	75	65	83	90	44	24
1 practice	3	10	0	6	15	22	19	0	5	33	6
2 practices	3	35	13	2	1	0	4	0	5	0	0
3 practices	1	40	27	11	0	0	4	0	0	0	6
4 practices	17	5	13	30	0	0	2	0	0	22	24
5 practices	44	0	27	9	0	3	3	0	0	0	24
6 practices	19	0	0	11	0	0	0	17	0	0	12
7 practices	7	5	0	4	1	0	1	0	0	0	6
8 practices	4	0	0	0	0	0	2	0	0	0	0

Source: Missouri Department of Natural Resources, Census of Missouri Public Water Supplies, 1977, Jefferson City, Missouri, 1978.

MISSOURI

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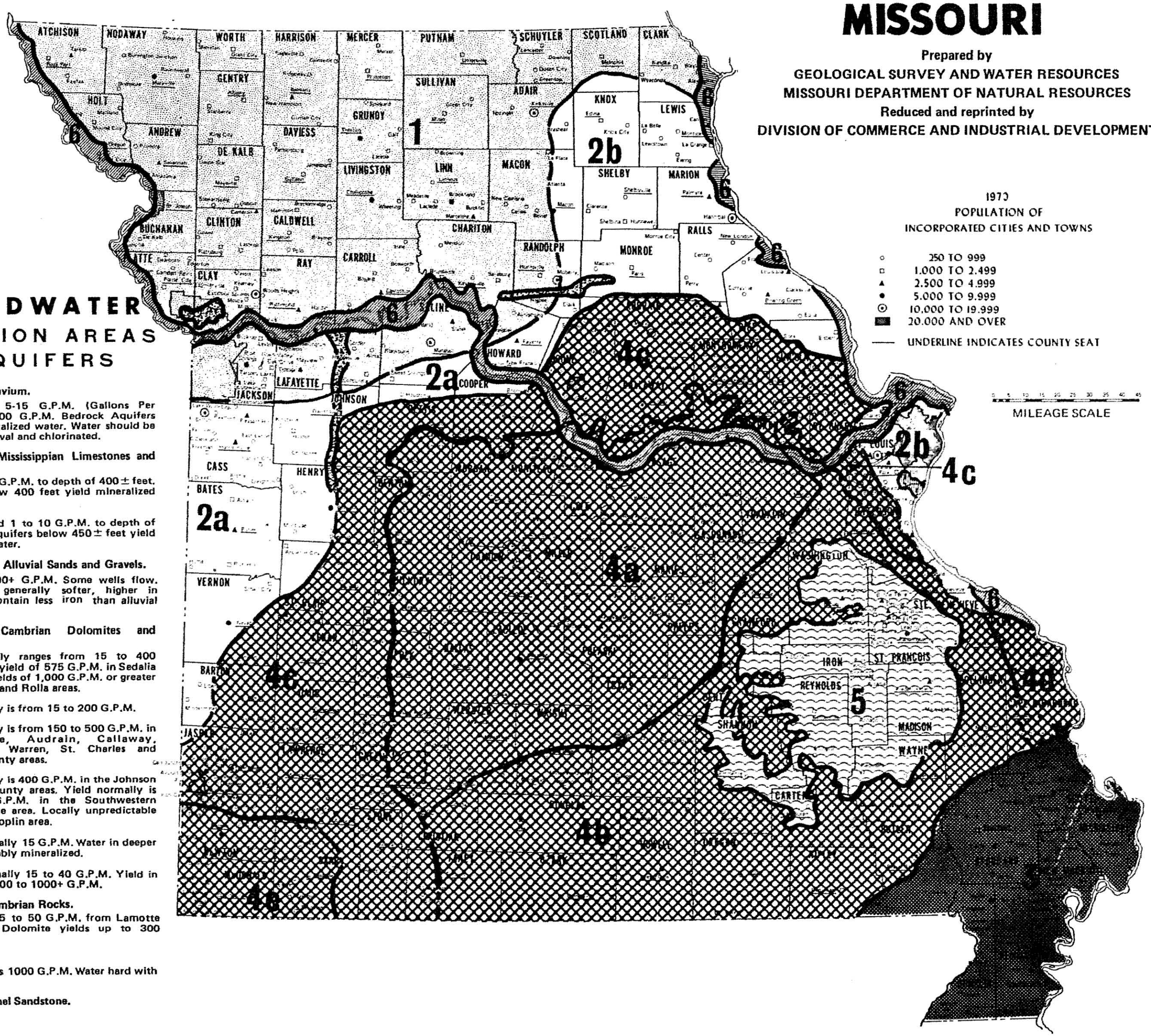


1970
POPULATION OF
INCORPORATED CITIES AND TOWNS

- ○ 250 TO 999
- □ 1,000 TO 2,499
- ▲ 2,500 TO 4,999
- ● 5,000 TO 9,999
- ⊙ 10,000 TO 19,999
- ■ 20,000 AND OVER

UNDERLINE INDICATES COUNTY SEAT

MILEAGE SCALE

GROUNDWATER
PRODUCTION AREAS AND AQUIFERS

1 Glacial Drift and Alluvium.
Yield is normally 5-15 G.P.M. (Gallons Per Minute). Range 0-500 G.P.M. Bedrock Aquifers generally yield mineralized water. Water should be treated for iron removal and chlorinated.

2 Pennsylvanian and Mississippian Limestones and Sandstones.
2a- Yield 1 to 15 G.P.M. to depth of 400± feet. Aquifers below 400 feet yield mineralized water.

2b- Yield localized 1 to 10 G.P.M. to depth of 450± feet. Aquifers below 450± feet yield mineralized water.

3 Cretaceous, Eocene; Alluvial Sands and Gravels.
Yield normally 1000+ G.P.M. Some wells flow. Cretaceous waters generally softer, higher in temperature, and contain less iron than alluvial waters.

4 Ordovician and Cambrian Dolomites and Sandstones.
4a- Yield normally ranges from 15 to 400 G.P.M. Local yield of 575 G.P.M. in Sedalia area. Local yields of 1,000 G.P.M. or greater in Springfield and Rolla areas.

4b- Yield normally is from 15 to 200 G.P.M.

4c- Yield normally is from 150 to 500 G.P.M. in the Boone, Audrain, Callaway, Montgomery, Warren, St. Charles and Jefferson County areas.

Yield normally is 400 G.P.M. in the Johnson and Pettis County areas. Yield normally is 25 to 40 G.P.M. in the Southwestern portion of the area. Locally unpredictable yields in the Joplin area.

4d- Yield is normally 15 G.P.M. Water in deeper aquifers probably mineralized.

4e- Yield is normally 15 to 40 G.P.M. Yield in Monett area 100 to 1000+ G.P.M.

5 Cambrian and Precambrian Rocks.
Yield is normally 45 to 50 G.P.M. from Lamotte Sandstone. Potosi Dolomite yields up to 300 G.P.M.

6 Alluvium
Yield locally exceeds 1000 G.P.M. Water hard with high iron content.

7 Pennsylvanian Channel Sandstone.

Figure 1

In most cases, it is very difficult to estimate the depth and yield of water-bearing strata. However, existing wells in the area can give community decision makers a good estimate of the depth, yield, and quality of the aquifer. A summary of existing well logs and their water quality and quantity for the various regions is shown in Table 3 and Figure 1. Additional information can be obtained from the Missouri Division of Geology and Land Survey in Rolla, Missouri.

Distribution System

All major water distribution items and their common use will be discussed. The distribution system includes all capital cost components such as water mains, lateral lines, service pipes, gate valves, other valves, water storage tanks, booster pumps and pump stations.

A registered engineer must prepare the detailed plans and specifications for public water supply systems. The following discussion is only meant to give community decision makers some idea of the major factors to include in feasibility studies and preliminary capital cost budgets.

We strongly recommend that the distribution system be installed on private lands, easements required, and not on public highway right-of-ways. In the event of major highway improvements, the water system may have to pay the costs of relocating water lines installed on public highway right-of-ways.

Storage Tanks

Storage tanks serve two purposes--storage of water for peak demand periods and also provision of acceptable water pressures in the distribution system.

Adequate water pressure is essential to maintain an acceptable quality of water in the distribution system. Low pressure in water mains produces favorable conditions for cross-connection by sewage and other pollutants through back-siphonage and faulty plumbing. Thus, preferred operating conditions at the service connections should not be less than 35 pounds per square inch (psi) or greater than 60 psi. Note that one psi is equal to 2.3 feet of water. The minimum acceptable pressure during peak demand should not be less than 20 psi and the maximum acceptable pressure should not be greater than 100 psi during low demand periods (5,6,9). If the difference in elevation between the tank and service connection is more than 230 feet (100 psi), pressure reducing devices should be installed.

One of the most desirable requirements for an economical distribution system is to locate storage tanks as near to the distribution area as possible. The farther the storage tanks are from the service area the longer water mains must be. Further advantages are that fluctuation of pressure in the lines is lessened and future expansion or development of the system is more economically achieved. Types of storage facilities are:

1. Elevated Tanks - Elevated tanks are used to store and maintain a uniform flow during the service period. They can be installed on high ground (top of a hill) or towered.
2. Standpipes - Standpipes are common in Missouri rural water supply systems. They are used to store water and to maintain uniform

TABLE 3. AVERAGE DEPTH AND CASING OF SELECTED WELLS IN MISSOURI

GROUNDWATER PRODUCTION AREA	WELL[1/] DEPTH, FEET	CASING DEPTH, FEET
3	752	691
4A	1,059	273
4B	989	436
4C	951	482
4D	905	391
4E	1,016	388
5	769	391

1/ Wells selected had yields greater than 50 gallons per minute and were located in or near towns.

Source: Missouri Division of Geological Survey and Water Resources, _Water Well Yield Map of Missouri and Well Data for Water Well Yield Map_, Rolla, Missouri, 1963.

pressure in the distribution system.

3. Pressure Tanks - In lieu of elevated tanks or standpipes, pressure tanks can serve the purpose. However, they are only recommended for a system with 50 or fewer houses or connections (9).

To accomodate pump breakdowns or unforeseen malfunctioning of the system, the capacity of elevated tanks and standpipes should be adequate to meet at least the average 24 hour water demand of the community. The choice between elevated tanks and standpipes is a matter of economics, ease of construction, topography, and population density in the service area. Generally, standpipes are easier and less costly to install than elevated towered tanks of the same capacity. Topography plays a major role in the selection. In an area where there is a major hill or mountain, elevated tanks without towers can be constructed atop the highest elevation. However, in rolling hill terrain, standpipes have been preferred. A topographic map of the service area can be used to determine locations for storage tanks. Telemetering devices are necessary to maintain the maximum and minimum water elevation or pressure in storage tanks. Telemetering can be provided by pressure induced or remote control electronic devices.

Pipes

Water pipes can be classified as mains, laterals, and service lines. Pipe sizes 6 inches or more in diameter are water mains. Their usual installation can be from the source (wells, treatment plants, etc.) to the storage tanks or from storage tanks to smaller branching laterals serving a few customers. Lateral lines are connections that branch out from the water mains. Their preliminary sizing can be done by estimating the number of houses or connections they intend to serve, including future growth. Service lines are pipes that branch out from the lateral, and in some instances from the water mains, and lead to the consumers' meters. It is recommended that the minimum size of service lines be 1 inch in diameter so as to accomodate future reduction of the pipe diameter because of incrustation. (5).

Polyvinyl chloride (PVC) is the most frequently used material in rural water supply pipes. Operating pressure in the water system should not exceed two-thirds of the pipes' rated working pressure (8). Class 160 PVC pipe is rated at 160 psi; class 200 is rated at 200 psi.

Although detailed engineering calculations are required to properly size pipe, Table 4 can be used to select pipe sizes for a preliminary feasibility study. Engineering factors include hills and elevation changes, friction in the pipe, discharge rates of pumps, and pressures throughout the system. Table 4 assumes that the minimum head of water is 100 feet, the height of water in a standpipe or elevated tank, and that the terrain is flat. The head of water is equal to the height of the storage facility plus the difference in ground elevations between the storage facility and the users' locations. Even though storage tanks are usually located on high hills, the assumption of flat terrain is approximately correct even in the Ozarks. For there may be users located on hills as high as the hill where the storage tank is located.

The procedure for using Table 4 is as follows:

TABLE 4. APPROXIMATE PIPE DIAMETER IN INCHES FOR A STORAGE TANK WITH MINIMUM 100 FT. HEAD

NO. CONNECTIONS	DISCHARGE GPM	DISTANCE IN FEET										
		500'	1000'	1500'	2000'	3000'	4000'	5000'	7500'	10,000'	15,000'	20,000'
10	39	2.0	2.5	2.5	2.5	3.0	3.0	3.0	4.0	4.0	4.0	4.0
20	56	2.5	3.0	3.0	3.0	3.0	4.0	4.0	4.0	4.0	6.0	6.0
30	69	2.5	3.0	4.0	4.0	4.0	4.0	6.0	6.0	6.0	6.0	6.0
50	90	2.5	4.0	4.0	4.0	4.0	4.0	6.0	6.0	6.0	6.0	6.0
80	115	3.0	4.0	4.0	4.0	4.0	6.0	6.0	6.0	6.0	6.0	6.0
100	129	3.0	4.0	4.0	4.0	6.0	6.0	6.0	6.0	6.0	6.0	8.0
150	158	4.0	4.0	4.0	4.0	6.0	6.0	6.0	6.0	6.0	6.0	8.0
200	184	4.0	4.0	6.0	6.0	6.0	6.0	6.0	6.0	8.0	8.0	8.0
250	206	4.0	4.0	6.0	6.0	6.0	6.0	6.0	6.0	8.0	8.0	8.0
300	226	4.0	4.0	6.0	6.0	6.0	6.0	6.0	6.0	8.0	8.0	8.0
400	263	6.0	6.0	6.0	6.0	6.0	6.0	8.0	8.0	8.0	8.0	10.0
500	295	6.0	6.0	6.0	6.0	6.0	8.0	8.0	8.0	8.0	10.0	10.0

Notes

1. Storage tank has 100 ft. minimum head.
2. Terrain slope has been neglected (0% slope).
3. Preferred minimum pressure of 35 psi is delivered to the consumer.
4. Domestic flow only, excludes fire flow.
5. Design Criteria: $GPM = 12\ (connections)^{0.515}$
6. Pipe sizes rounded to the next commonly available pipe sizes.
7. If estimated pipe size falls on the lower right hand corner of the table, plan to install additional storage tanks on those spots and proceed pipe sizing estimation therefrom or to locate storage tank on a spot that will minimize long water mains.

1. Estimate the total number of residential and small commercial connections to be served by the line. Make appropriate changes to accomodate for any large water-using commercial and industrial hookups. Also include expected growth in population and number of hookups for the next 10 to 30 years (2, p.10).
2. Estimate the distance in feet to the center of the service area. Estimated distance is approximately equal to the distance from the source (elevated tank or point of branching) to the most densely populated sector of the service area.
3. Determine the recommended pipe sizes using distance in feet and number of hookups in Table 4.
4. Repeat steps 2 and 3 to estimate the size of branching. Figure 2 depicts a simple water system and the usage of Table 4.

A nationwide survey conducted by the University of Missouri-Columbia, Department of Civil Engineering, showed that some rural water supply systems are experiencing water quality deterioration in their distribution systems. Consumer complaints of dark brown or red water and rotten egg odors in water have been reported. These problems are more prominently noticed in early morning hours during the first opening of faucets or after a prolonged nonuse of water in the household. Currently, research is being conducted under a Federal grant at the University of Missouri-Columbia to determine the extent and nature of water quality problems, the role of micro-organisms in causing changes observed in distribution systems, and remedial measures to control such problems (19).

Sulfur reducing organisms grow in distribution lines and dead ends where the atmosphere and nutrient requirements are ideal. Sulfur reducing organisms reduce sulfur compounds into hydrogen sulfide that emits the rotten egg odor. Iron reducing organisms reduce iron compounds including cast iron pipes that result in red turbid water.

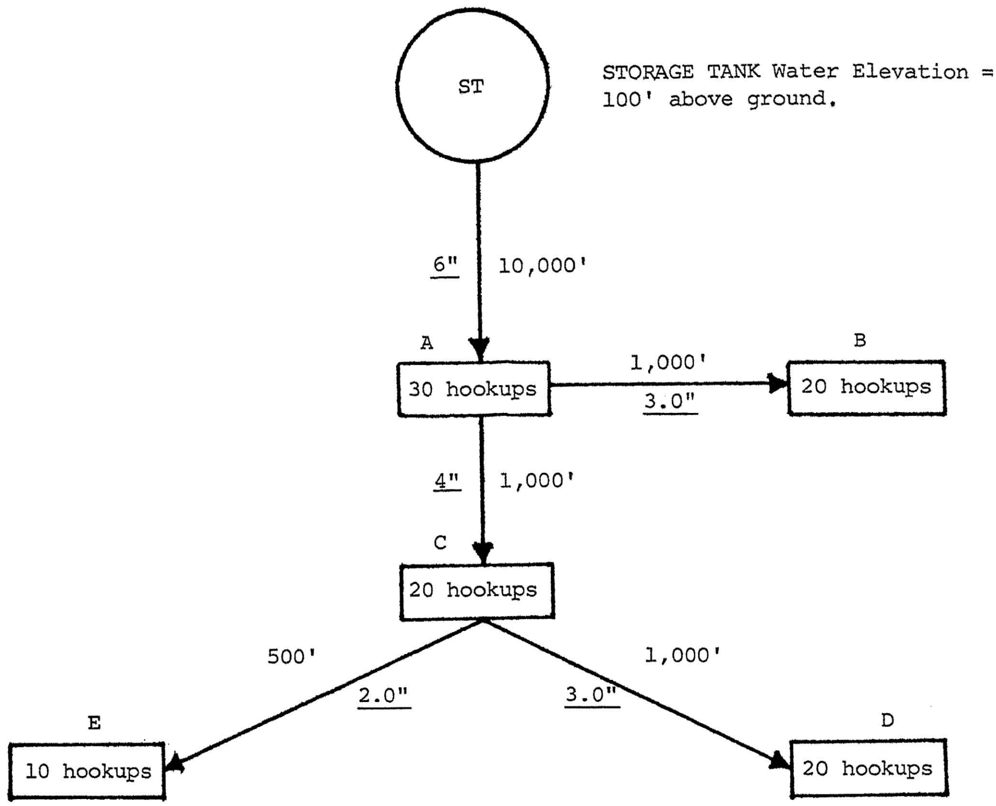
Although detailed guidelines will be published after the completion of the above research, the following measures can help to control or minimize water quality problems:

1. Ensure complete circulation of water through the distribution system by careful looping of the system.
2. Avoid having excessive dead-end points. Dead-end points create stagnant water where the atmosphere for deteriorating bacterial growth is ideal.
3. If dead ends are unavoidable, frequent flushing of water mains by opening flush valves can temporarily solve the problems.
4. Disinfect or chlorinate the water. Small supply systems which cannot afford to chlorinate regularly can do so at scheduled intervals.
5. Seek technical advice from pertinent state offices and agencies.

Check Valves and Backflow Preventers

Check valves are used to prevent water from flowing back down to the pumping station when pumping

FIGURE 2. ESTIMATION OF PIPE SIZES



Estimating Section Line "ST-A"

a) Maximum Head = 100' (use table 4)
b) Total number of hookups = 30 + 20 + 20 + 20 + 10 = 100 hookups
c) Distance to the center of service area = 10,000'
d) Enter table 4 at 100 hookups and read pipe size of 6 inches under 10,000 ft.
e) Repeat steps b through d for the other lines. Summary estimation is shown below.

Section Line	Total Connections	Distance (ft.)	Pipe size (inches)
ST-A	100	10,000	6.0
A-B	20	1,000	3.0
A-C	50	1,000	4.0
C-D	20	1,000	3.0
C-E	10	500	2.0

is terminated. In some instances, part of the influent lines (feed lines) to storage elevated tanks and standpipes also serve as part of the distribution system; therefore, check valves are installed in positions where they will not interfere with the supply of water from storage tanks to customers. In most cases there is a check valve on the discharge side of pumps.

In addition, backflow preventers or specialized check valves are installed at positions where there is a possibility of vacuum (induced negative pressures) in the lines due to water flowing back towards the pumping station. Backflow preventers are valves usually combining two check valves and a differential relief valve. Backflow preventers should be installed at hookups for industries, hospitals, and swimming pools. In the interest of public health, it is recommended that all meter hookups contain a serviceable, spring loaded check valve with a resilient seal to function as a backflow deterrent. 4/ Installation of such check valves at each consumer's connection can deter back-siphonage from household water containers, water heaters, and livestock watering tanks.

Altitude Valves

Altitude valves are used to maintain a constant elevation of water in storage tanks. Accessories for storage tanks should include altitude valves and telemetering devices.

Gate Valves

Gate valves are used to control the flow of water through the distribution system. Sufficient numbers of gate valves should be installed in the system so that inconvenience and health hazards are minimized during repair work. Portions of all major loops can be effectively isolated from the rest of the loop so that repair work in one section of the loop can be done without throwing large numbers of customers out of service for a prolonged time period. Gate valves can also be used on long dead-end branches to maintain water service to near customers on the branch while repair work is being performed at the far end of the branch. Gate valves can also be installed at all "T" connections. In addition, all household connections should have a built-in gate valve installed just before the individual water meter. This arrangement helps utility officials in controlling the supply of water to individual customers.

In general, gate valves can be installed in any location that gives the best possible control of the system consistent with cost limitations (2). However, they should not be placed below flood levels or below the groundwater table because intermittent negative pressure (e.g., vacuum created when the system is not operating) tends to suck in untreated water from the outside through the valve stem and packing.

4/ Conversation with Mr. Ernie Boughton, Missouri office of FmHA.

Air Release Valves and Vacuum Vents

Differing types of air release valves are used to remove pockets of air from the distribution system during the initial filling of the lines with water or to remove any subsequent accumulation of air bubbles in the lines during service. Entrained air not only reduces the discharging capacity of the pipes but also creates an atmosphere where deteriorating organisms can grow and affect water quality. Air pockets accumulate in the lines where there is a substantial change in grade. It is recommended that an air valve be installed at every major hilltop. (22, pp. 421-423). In addition, vacuum vents can be installed to prevent back siphonage of water. Vacuum vents allow air to enter lines under negative pressure so as to break the vacuum condition. A universal air valve combines three functions; namely, release of large volumes of air during filling of lines, release of small air pockets while the line is filled with water at correct pressures, and entrance of air to break a siphon caused by insufficient pressure in the water line.

Drain Valves

The main use of drain or flush valves is to empty the mains for cleaning or washing out stagnant water from dead ends or to remove colored water after repair work. Drain valves should not be connected to sewer lines and water released should be discharged to storm drainage, creeks, or streams. In most rural water districts, cleaning is done by opening flush hydrants or end-of-line cleanouts.

Blow-off Valves

These are used to release excessive pressure in the distribution lines. They can prevent the rupture of water mains due to pressure build-up on the lines.

Water Meters

Master meters are used to measure the total volume of water used by the community, while service meters gauge individual water used. Service lines from the meter are usually attached to mains or laterals by small valves buried underground, called corporation stops.

Distribution Line Crossing

Highways, turnpikes, streets, railways, and stream crossings are treated as separate bid items. With the exception of narrow streets, main and lateral crossings are made by boring and protecting the pipe with a protective steel or cast iron casing. Service line crossings are usually copper pipe.

COSTS AND REVENUE SOURCES

Construction Costs

Costs for items commonly used in Missouri's rural water districts were obtained from contractors' bids for new construction (Table 5). Costs include not only material but also labor and installation. Costs for items are complete. For example, pumphouse costs include electrical work and site development; standpipe costs include foundations; pipe costs include usual fittings like T's and elbows; gate valve and meter costs include protective boxes. All costs are adjusted to a December 1978 basis using the U.S. Department of Commerce's Composite Construction Cost Index. 5/ It should be noted that only a few bids were obtained for well construction, large check valves, elevated tanks, and steel ground storage tanks. Costs for these items may not be typical statewide.

No economies of construction associated with large scale projects versus small scale projects were detected. Average unit prices for 20 different construction items were compared for non-Ozarks projects costing $500,000 or less, more than $500,000 up to and including $1,000,000, and more than $1,000,000. For the 22 projects in the sample, there were no consistent savings in per unit costs for larger projects versus smaller projects. 6/

On the other hand, regional differences in construction costs were detected for service meters, distribution pipeline, and gate valves. These items, furnished and installed, cost more per unit in the Ozarks than in the remaining areas of the state. 7/ Rocky, mountainous terrain likely accounts for these cost differences. For example, based upon average unit prices for six different pipe sizes and classes, pipeline costs were 65 percent higher in the Ozarks than elsewhere in the state.

Other Capital Costs

Besides construction costs for materials and labor, several other capital costs were incurred. Based upon a sample of 15 districts with recent construction activity, other capital costs were estimated as proportions of total construction costs. Administrative, legal, bonding, and accounting fees averaged 2.5 percent of total construction costs. Basic engineering represented an additional 8.5 percent and inspection fees were 3.25 percent of construction costs. Interest on borrowed funds during construction averaged 3.25 percent and contingencies were budgeted at about 5.5 percent of total construction costs.

Operating Costs

Most of the Ozarks water districts, 73 percent, have drilled their own wells for a source of water. In

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5/ A more specific index for municipal sewer lines is calculated by the U.S. Environmental Protection Agency; however, it is published only quarterly instead of monthly. From Dec. 1977 to Dec. 1978, the composite construction cost index increased 13 percent while the EPA sewer cost index increased 11 percent.

6/ Most of the statistical t-values were less than 2.00 (21). Some of the larger t-values were associated with diseconomies. For example, three pipe sizes exhibited increasing average unit costs with larger projects. Only two pipe sizes exhibited decreasing average unit costs with larger projects.

7/ Most of the statistical t-values were greater than 2.00 with values ranging up to 4.71 (21).

TABLE 5. AVERAGE CONSTRUCTION COSTS OF COMMONLY USED ITEMS IN MISSOURI'S RURAL WATER SUPPLY DISTRICTS, DECEMBER 1978

ITEM DESCRIPTION[1/]	UNIT OF MEASURE[2/]	COST PER UNIT[3/]
I. WELLS AND PUMPS		
A. FOUR-INCH DISCHARGE WELLS		
12" hole & 8" casing with grouting	L.F.	$ 46.13
8" hole beyond casing	L.F.	16.65
4" discharge pipe & cable	L.F.	6.77
25 H.P. submersible pump	L.S.	8,872.21
B. EIGHT-INCH DISCHARGE WELLS		
16" hole & 12" casing with grouting	L.F.	62.08
12" hole beyond casing	L.F.	19.82
8" discharge pipe & suction shaft	L.F.	46.42
125 H.P. pump with surface motor	L.S.	12,514.40
C. PUMPHOUSE, COMPLETE	L.S.	36,756.09
D. MASTER METERS & BOXES	EA.	10,794.38
E. CHECK VALVES, DIAMETER		
6"	EA.	1,345.87
8"	EA.	1,869.90
II. TREATMENT PLANTS		
A. COMPLETE PACKAGE PLANTS[4/]		
9,600 GPD capacity (50 hookups)	L.S.	65,300.00
19,200 GPD capacity (100 hookups)	L.S.	75,000.00
96,000 GPD capacity (500 hookups)	L.S.	105,600.00
192,000 GPD capacity (1000 hookups)	L.S.	130,300.00
B. HYPOCHLORINATORS[5/]	L.S.	2,390.00
III. STORAGE		
A. ELEVATED TANKS		
50,000 gallons	L.S.	99,722.43
30,000 gallons	L.S.	93,347.54
B. STEEL GROUND TANKS		
1,000,000 gallons	L.S.	204,692.13
500,000 gallons	L.S.	140,641.05
C. STANDPIPES		
(16,733 to 41,364 gallons depending on terrain)		
8' diameter x 110' high	L.S.	58,963.11
D. TELEMETERING SET	L.S.	7,663.12

TABLE 5. (CONTINUED)

ITEM DESCRIPTION[1/]	UNIT OF MEASURE[2/]	COST PER UNIT [3/]
IV. DISTRIBUTION PIPE (Includes fittings & installation)		
A. SERVICE PIPE		
1" class 315 PVC pipe	L.F.	$ 1.68
1" copper highway bore	L.F.	6.10
B. CLASS 160 PVC PIPE		
2" diameter	L.F.	1.06
2½" diameter	L.F.	1.10
3" diameter	L.F.	1.49
4" diameter	L.F.	1.76
6" diameter	L.F.	2.69
8" diameter	L.F.	4.00
C. CLASS 200PVC PIPE		
2" diameter	L.F.	1.61
3" diameter	L.F.	2.25
4" diameter	L.F.	2.50
6" diameter	L.F.	4.23
D. REGIONAL ADJUSTMENT		
Ozarks	Percentage Increase	52%
Remainder of state	Percentage Decrease	-13%
V. DISTRIBUTION GATE VALVES		
A. DIAMETER		
2"	EA.	146.27
2½"	EA.	163.64
3"	EA.	187.02
4"	EA.	213.04
6"	EA.	257.38
8"	EA.	365.99
B. REGIONAL ADJUSTMENT		
Ozarks	Percentage Increase	13%
Remainder of state	Percentage Decrease	-2%
VI. DISTRIBUTION MISCELLANEOUS		
A. SERVICE METERS		
Ozarks	EA.	268.60
Remainder of state	EA.	198.80
B. AIR RELEASE VALVES	EA.	184.95
C. END OF LINE CLEANOUTS	EA.	167.51

TABLE 5. (CONTINUED)

ITEM DESCRIPTION[1/]	UNIT OF MEASURE[2/]	COST PER UNIT[3/]
(VI.....)		
D. FLUSH HYDRANTS	EA.	$346.72
VII. CROSSINGS (EXCLUDES WATER PIPE)		
A. HIGHWAY, BORING & STEEL CASING		
12" bore for 8" water line	L.F.	44.47
10" bore for 6" water line	L.F.	36.63
8" bore for 4" water line or less	L.F.	31.92
B. RAILROAD, BORING & STEEL CASING		
12" bore for 8" water line	L.F.	39.15
10" bore for 6" water line	L.F.	35.96
8" bore for 4" water line or less	L.F.	29.70
C. STREAMS, STEEL CASING & ANCHORING		
12" casing for 8" water line	L.F.	35.60
10" casing for 6" water line or less	L.F.	28.01

1/ Items and prices, except for treatment plants, were obtained from bid tabulations filed with FmHA. Bid openings were from August 1977 through November 1978. All items are complete with appurtenances, e.g., valve boxes, fittings, meter wells, and installed unless otherwise noted. It should be noted that only a few bids were obtained for well construction, large check valves, elevated tanks, and steel ground storage tanks. Cost per unit in these cases may be site specific and not typical statewide.

2/ L.F.=Lineal Feet; L.S.=Lump Sum; EA.=Each.

3/ All bid prices were adjusted to a December 1978 Composite Construction Cost Index of 185.4. This index is published in the U.S. Department of Commerce periodicals Survey of Current Business and Construction Review.

4/ Costs of package treatment plants were obtained from Reference No. 10. Plant capacity based on 5gpm/ft^2 filtration rate and 16 hours operation per day.

5/ 1978 prices obtained from Reference No. 15.

the remainder of the state, most of the water districts, 60 percent, purchase finished treated water from another utility (Table 1). Operating costs were acquired from accounting reports filed with FmHA for 1978. Average annual operating costs per hookup were

- $52.62 for non-Ozarks districts with their own wells and no treatment practices,
- $71.39 for Ozarks districts with their own wells and no treatment practices,
- $77.49 for non-Ozarks districts with their own wells and treatment practices, and
- $99.05 for districts purchasing treated water (Table 6).

This last category included two Ozarks districts. 8/

Noticeable cost differences included higher salary costs for Ozarks districts with wells and for other districts with treatment practices. In the Ozarks case, this may be partly explained by the higher amount spent on repairs and maintenance. In the latter case, higher salary costs likely reflect the need for treatment plant operators. Costs for utilities were lowest for those districts without wells which purchased treated water. On the other hand, these districts spent $43.70 per hookup for purchasing water and other items sold. Most districts purchasing water paid a flat rate per 1,000 gallons. The average rate was $0.56 per 1,000 gallons. 9/ Costs for supplies and chemicals were highest for those districts with treatment facilities.

Operating costs per hookup were nearly constant for districts purchasing treated water and for districts with wells and fewer than 700 hookups. No economies of large scale operation were detected for such districts. For districts with wells and more than 700 hookups, economies of size might possibly be attained with more than 1,000 hookups. However, our sample contained only a few such districts and no definite answer could be ascertained.

Revenue Sources

Sources of revenue include hookup fees, construction grants, and water sales.

Hookup or connection fees are flat fees charged customers when they sign a water users' agreement with the public water supply district. These fees are charged and collected prior to construction and have ranged from $25 to $225 for districts constructed during the 1970's. Typical hookup fees have increased from about $40 to $60 between 1971 and 1977. Currently, FmHA's recommended guideline for hookup fees is $60 or twelve months' minimum water bills, whichever is greater. 10/ For districts financed by FmHA, monies from hookup fees are usually set aside in an initial operations-maintenance fund and/or an initial bond reserve fund for loan repayment.

8/ Only the differences between total average costs for districts purchasing treated water and other system types exhibited t-values greater than 2.00 (21).

9/ North Central Regional Study of Water Supply Systems, Missouri questionnaires.

10/ Conversation with Mr. Eldrid Easterhaus, Missouri office of FmHA.

TABLE 6. AVERAGE ANNUAL OPERATING COST PER HOOKUP FOR MISSOURI RURAL WATER DISTRICTS, 1978

OPERATING COST ITEMS1/	OWN WATER SOURCE FROM WELLS, LESS THAN 700 HOOKUPS			PURCHASE FINISHED TREATED WATER	1978 INDEX VALUES5/
	NO TREATMENT PRACTICES		WITH TREATMENT PRACTICES REMAINDER STATE4/		
	OZARKS REGION2/	REMAINDER STATE3/			
Wages and salaries	$23.64	$17.77	$22.45	$16.63	S-212.5
Sales and payroll taxes	4.31	4.91	5.62	4.93	S-212.5
Accounting and legal fees	6.82	3.35	3.83	4.53	S-212.5
Utilities	9.26	7.37	11.57	5.37	U-216.0
Insurance	3.33	2.28	4.04	2.28	H-227.2
Repairs and maintenance	15.05	9.71	10.43	10.20	H-227.2
Supplies and chemicals	1.99	1.69	8.12	3.63	C-198.8
Office supplies	2.35	1.55	3.02	1.94	O-177.7
Cost of merchandise sold, incl. water	.13	.42	.08	43.70	U-216.0
Miscellaneous	4.51	3.57	8.33	5.84	O-177.7
Total annual operating cost per hookup	$71.39	$52.62	$77.49	$99.05	
Number of districts	5	6	7	35	

1/ Excludes interest payments and new meter connections.

2/ One district with 923 hookups had annual operating costs of $67.13 per hookup; and another district with 1,429 hookups had operating costs of $42.58 per hookup.

3/ One district with 881 hookups had annual operating costs of $69.22 per hookup; and another district with 1,494 hookups had operating costs of $52.64 per hookup.

4/ Five districts with more than 700 hookups had annual operating costs per hookup as follows: 737 hookups at $137.46 each; 951 hookups at $75.60 each; 1,058 hookups at $60.17 each; 1,251 hookups at $57.78 each; and 1,529 hookups at $64.59 each.

5/ These index values can be used to adjust costs for different time periods. Indices include:

S - Average hourly earnings, seasonally adjusted, services
U - Consumer prices, all urban consumers (CPI-U), fuel and utilities
H - Consumer prices, all urban consumers (CPI-U), homeownership
O - Consumer prices, all urban consumers (CPI-U), household furnishings and operation
C - Producer prices, chemicals and allied products

These indices are reported in the Monthly Labor Review published by the Bureau of Labor Statistics, U.S. Dept. of Labor and also in the Survey of Current Business published by the Bureau of Economic Analysis, U.S. Dept. of Commerce.

In some cases grants for construction purposes may be obtained from FmHA, other Federal agencies, or the Missouri Department of Natural Resources. On the average, districts receiving FmHA financing during the 1970's obtained about 30 percent of their construction and other capital funds through grants. 11/ About one-fifth of the districts received no grant funds. For districts receiving grants, there was considerable variation in the proportion of construction funded by grants, from about 5 percent to over 50 percent. Larger grant shares appeared to be associated with higher construction costs per hookup. Funding sources are discussed in Appendix B.

Average monthly water rates per 1,000 gallons in both the Ozarks and in the remainder of the state decreased as more water was purchased (Table 7). The minimum monthly water bill, usually stated as the charge for the first 1,000 gallons, was $5.47 in the Ozarks and $6.24 elsewhere in the state. The cost of each additional 1,000 gallons was less than or equal to that of the preceding 1,000 gallons so that by the 10,000th gallon the charge was only $0.76 in the Ozarks and $1.09 elsewhere in the state. Quite often, charges per 1,000 gallons declined until 6,000 gallons were purchased. Rates per 1,000 gallons usually remained constant after 6,000 gallons were purchased. Higher water rates in the non-Ozarks areas of the state can be attributed to purchases of water from other utilities and the usage of treatment facilities.

A common argument for using decreasing water rates is that all users should contribute to repayment of high fixed costs of construction whereas users of additional water should pay only the additional operating costs incurred. Thus, water rates per 1,000 gallons are high for all users at low volumes of water; and water rates per 1,000 gallons are low for high volumes of water. In a sense, all users pay high initial rates in order to secure the option of having a public water supply system at all. An economic argument for using decreasing water rates is based upon the relationship between high fixed costs and low variable costs. If consumers pay a price equal only to the incremental variable costs incurred, then a water supply system may not earn enough revenue to pay fixed costs. Declining block rates may enable the water system to earn sufficient revenues to pay all expenses and payments. With declining block rates, water users' payments approximate their total valuation of water rather than only their valuation of the last increment of water used. 12/

APPLICATION OF BUDGET ANALYSIS

In the following example, practical application of the material discussed so far for a rural water supply system will be demonstrated, including preliminary

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11/ North Central Regional Study of Water Supply Systems, Missouri questionnaires.

12/ For further discussion of water rates, see: (11, Chapter 5).

TABLE 7. AVERAGE MONTHLY WATER RATES FOR MISSOURI RURAL WATER DISTRICTS PER 1,000 GALLONS[1/]

NUMBER OF GALLONS	PER 1,000 GALLONS			CUMULATIVE		
	TOTAL STATE	OZARKS	REMAINDER OF STATE	TOTAL STATE	OZARKS	REMAINDER OF STATE
1,000	$6.10	$5.47	$6.24	$ 6.10	$ 5.47	$ 6.24
2,000	3.47	3.05	3.56	9.57	8.52	9.80
3,000	2.41	2.01	2.50	11.98	10.53	12.30
4,000	1.51	1.48	1.52	13.49	12.01	13.82
5,000	1.14	.98	1.17	14.63	12.99	14.99
6,000	1.06	.91	1.09	15.69	13.90	16.08
7,000	1.06	.91	1.09	16.75	14.81	17.07
8,000	1.06	.91	1.09	17.81	15.72	18.26
9,000	1.06	.91	1.09	18.87	16.63	19.35
10,000	1.03	.76	1.09	19.90	17.39	20.44
No. of Districts	39	7	32	39	7	32

1/ Based on data collected for 1977 in a North Central Regional research project.

design, determination of capital and operating costs, and calculation of water rates needed to breakeven. These preliminary calculations cannot replace the need for a registered engineer to prepare the final design, construction plans, and specifications as required by the Missouri Department of Natural Resources. Sample calculations are only intended to give local decision makers an approximation of the feasibility and capital needs of the community's and area's proposed water supply system. In order to make a preliminary design for a water system, community leaders and citizen groups need to:

1. Have a clear picture of the community including past, present, and future population, commercial, and industrial growth.
2. Acquire a topographic map of the area showing elevations of hills and valleys. (Such maps may be obtained from the U.S. Geological Survey Office in Rolla, Missouri.)
3. Acquire the most recent county highway map of the area showing all roads and buildings. (Such maps may be obtained from the Missouri State Highway Department in Jefferson City, Missouri.)
4. Read the technical section of this paper and study the major water supply components and their applications.

Study Area

The area selected for a demonstration of the budget analysis is a small, unincorporated town and its surrounding environs in northern Webster County in the Ozarks. Population in the rural and unincorporated areas of Webster County increased 25 percent from 1970 to 1976 (23). Webster County's population is projected to increase by 55 percent between 1975 and 1990 (3). No population projections have been made for small towns or rural areas within counties. No large commercial or industrial users of water were in the study area.

Water Requirements

A water supply system was developed for the unincorporated town and was extended into the surrounding areas with the limitation that there be five or more hookups or connections per mile of water line. The statewide average in 1977 was 6.7 hookups per mile of pipe as noted in Table 1. A 1974 county highway map, latest available, was used to determine the location of houses and other buildings. Local community leaders and citizens should be consulted concerning the location of newer houses and the prospect of large commercial or industrial users of water moving into the area.

Form A depicts the procedure used to estimate the number of potential hookups for sizing pipe, the gallons of water used per day for sizing water treatment plants, and the minimum water storage required. The design period for treatment plants and pipe distribution system is 15 years. Storage facilities are designed for current water usage. Future expansion and development of additional wells and storage tanks can be made without major changes in the existing system; modification of undersized pipes is costly and inconvenient for water users.

FORM A. ESTIMATING REQUIREMENTS FOR A DOMESTIC RURAL WATER SUPPLY SYSTEM

I. NUMBER OF HOOKUPS FOR SIZING PIPE

A. No. of present households and small commercial establishments = 201

B. No. of future household and small commercial establishments

201 x .55 = 111
(Enter no. of present hookups I,A) (Population growth rate 1975-1990) 1/

C. No. of large water users, e.g., industry and large commercial establishments

Name	Gallons per month
None	0
	(+)

D. Subtotal gallons 0

E. Household equivalent of industrial use = ______ ÷ 5504 = (+) 0
(I,D above)

F. Total no. of comparable planned hookups for using table 4, pipe sizing = 312
Hookups for Planning

FORM A. (CONTINUED)

II. ESTIMATING SIZE OF WATER TREATMENT FACILITIES

A. Small water users

201 (I,A above) + 111 (I,B above) = 312 x 4522 (Gallons per month, Table 1) ÷ 30.4 = 46,410

B. Large water users

0 (I,D above) ÷ 30.4 = (+) 0

C. Total gallons per day = 46,410 Gallons per day

III. ESTIMATING DAILY WATER STORAGE REQUIREMENTS

A. No. of present households and small commercial establishments

201 (I,A above) x 4522 (Gallons per month, Table 1) ÷ 30.4 = 29,899

B. Large water users

0 (I,D subtotal, gallons per month, above) ÷ 30.4 = (+) 0

C. Current water storage requirements 29,899 Gallons

1/ Division of Budget and Planning, Estimates and Projections of Population in Missouri, 1970 to 1990, Jefferson City: Missouri State Office of Administration, Sept. 1977.

As noted in Form A, 201 households and small commercial establishments are identified which can be serviced by a public water supply system. By 1990, an additional 111 hookups are expected, an increase of 55 percent. There are no current large water users in the area and it is assumed that there are no large industries committed to locate in the area in the foreseeable future. Consequently, the pipeline distribution system is designed for 312 hookups as of 1990. If a complete treatment plant facility is needed, it is estimated that the 312 present and future hookups would use 46,410 gallons per day (GPD). Storage facilities should contain at least a one-day supply of water. As noted earlier, most districts' storage facilities contain about a two-day supply of water. It is estimated that the current 201 hookups will use 29,899 gallons per day.

Preliminary Design

Figure 3 shows the general layout of the distribution system with pipe sizes. Figure 4 shows the general layout with valves, hydrants, and other accessories. Calculations are made based upon the technical section presented earlier and the following assumptions:

1. Initially the proposed system would have only one well located at a relatively low elevation with respect to the surrounding hills. This well has a 4 inch discharge pipe.
2. Initially the district would erect one standpipe, 8 feet in diameter by 110 feet high, on top of a high hill. Minimum effective storage capacity of this standpipe is 16,733 gallons with flat terrain and maintenance of 20 psi pressure at all users' connections. Maximum storage capacity of this standpipe is 41,364 gallons if it is located on a hill at least 66 feet higher than all users' connections.

The distribution system includes six loops and six large dead-end branches. The pipe between the well and the standpipe is only 4 inches in diameter. Generally, the size of the pipe from the well to a nearby standpipe is no larger than the well's discharge or suction pipe and no smaller than 4 inches in diameter. 13/ Pipe sizes depicted in Figure 3 for the remainder of the system are calculated using Table 4. The number of houses currently along each section of pipe is increased by 55 percent to estimate pipe sizes large enough for future growth. Branch extensions along major highways are 4-inch-diameter pipe, slightly oversized, to allow for farther extensions in the future.

As depicted in Figure 4, all dead ends of 3-inch or 4-inch pipe are equipped with flush valves for

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13/ Pipe sizes between the well and the standpipe larger than the well's discharge pipe lower the velocity of the moving water, in effect also the pressure, which reduces the height to which water can be raised. Given a pump's capacity in gallons per minute, the velocity of water is inversely related to pipe sizes. Pressure and velocity are directly related.

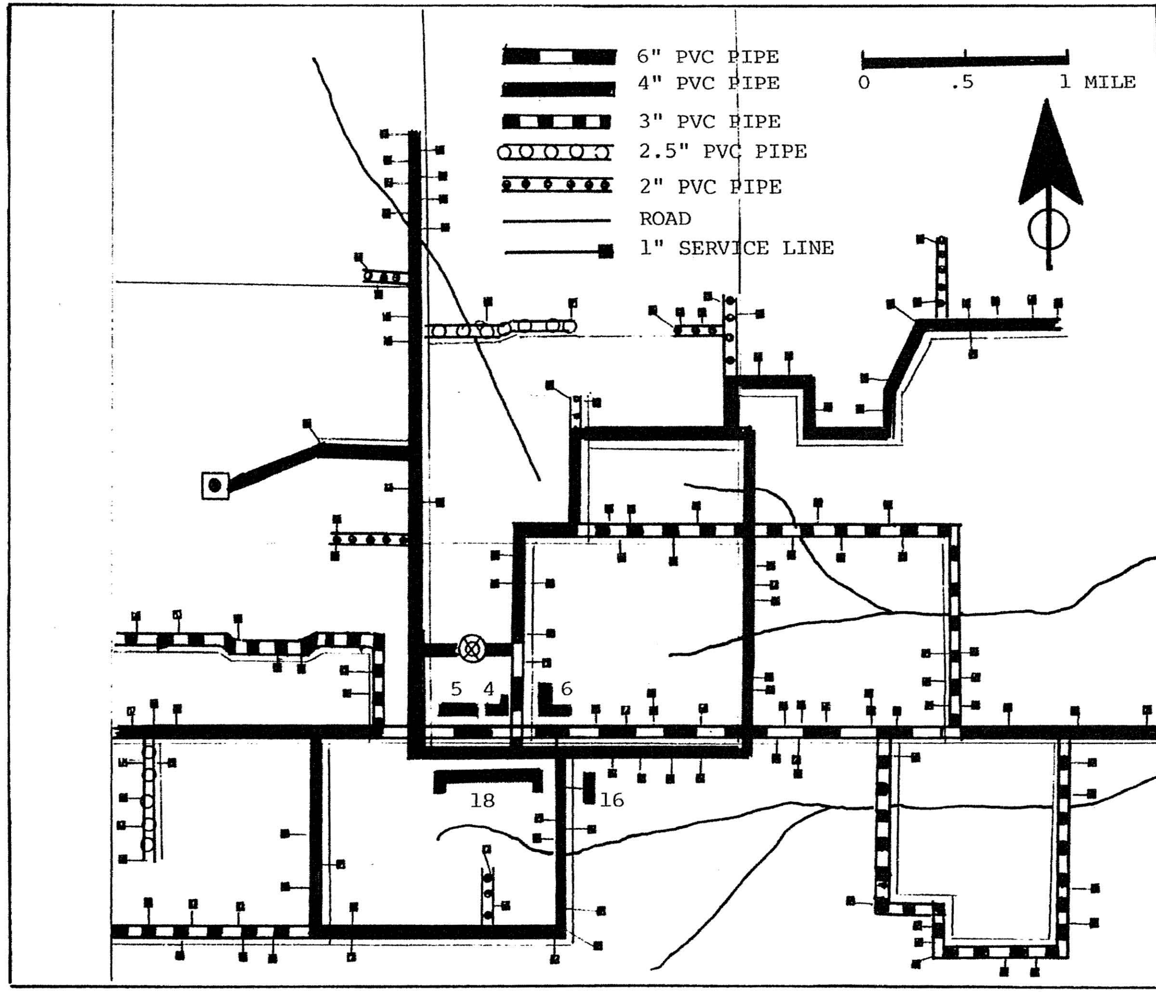

FIGURE 3: PRELIMINARY DOMESTIC WATER SUPPLY SYSTEM EXAMPLE--DISTRIBUTION LINES. (FINAL LAYOUT, PLANS, AND SPECIFICATIONS MUST BE PREPARED BY A REGISTERED ENGINEER)

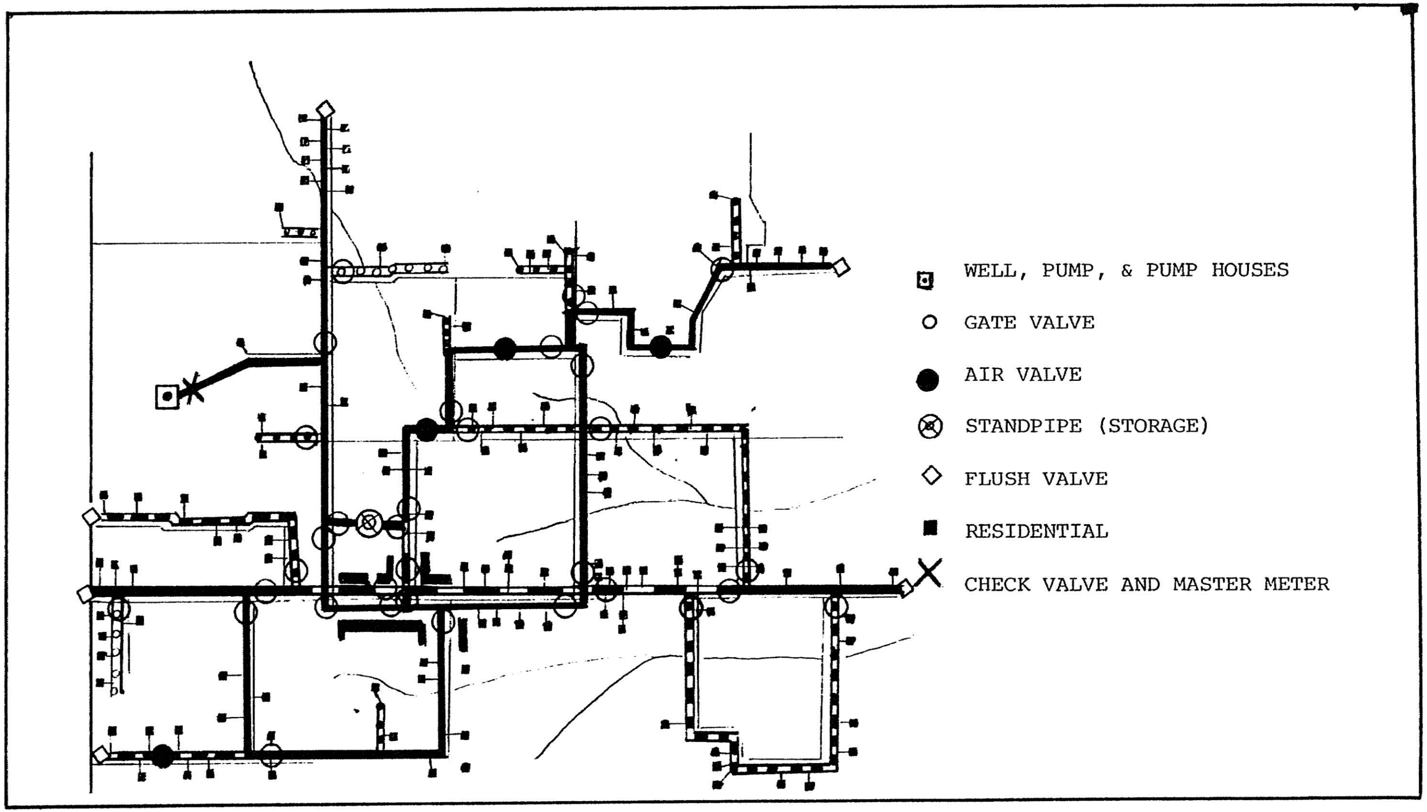

FIGURE 4: PRELIMINARY DOMESTIC WATER SUPPLY SYSTEM EXAMPLE--VALVES AND OTHER ACCESSORIES. (FINAL LAYOUT, PLANS, AND SPECIFICATIONS MUST BE PREPARED BY A REGISTERED ENGINEER)

intermittent flushing of stagnant water. Air release valves are installed at all major peaks in elevation. Gate valves are installed in all loops, at major "T" branches, and also at the approximate middle of the long northern branch. The maximum length of pipe that can be separately isolated is about three miles long, the southeastern loop serving 10 houses. On the other hand, isolation lengths are considerably shorter in the town's built-up area.

Capital Costs

As totalled in Form B, construction costs of the water system are estimated to be $781,213. Construction costs are adjusted to a March 1979 price base using the U.S. Department of Commerce's Composite Construction Cost Index. Other capital costs amount to $179,679. Total project costs are $960,892.

Several assumptions are made in the estimation of construction costs. The pump price is for a 25 horsepower submersible pump. Given the depth of the well, a larger horsepower pump may be required. Well depth is based upon typical municipal wells in Production Area 4A as noted in Figure 1 and Table 3. A hypochlorinator is included; however, only about one-fifth of the water districts in Production Area 4 practice chlorination. Regarding service pipe, it is assumed that the average service line from the distribution pipe to the meter is 150 feet and that 40 hookups each need 35 feet of copper highway bore also. Highway crossings are assumed to average 40 feet each for 6 inch water lines and 35 feet each for smaller water lines. Stream crossings are approximated to average 25 feet each.

Operating Costs

Annual operating costs are estimated to be $75.88 per hookup as calculated in Form C. All costs are adjusted to a March 1979 price base by means of the consumer price indices and other indicated indices. Costs per hookup are for an Ozarks district with its own well and no treatment practices. The hypochlorinator is not expected to increase costs very much. 14/

Breakeven Water Rates

For rural water supply systems funded by FmHA, water rates need to be set high enough to cover three types of costs: (1) annual repayment of bond principal and interest, (2) an additional 10 percent of the annual bond repayment, and (3) operating and maintenance costs. The 10 percent additional payment is held by the water system as a bond reserve fund. After 10 years, the 10 percent additional payment continues and is held by the water system as a replacement and extension fund, similar to a depreciation account.

If the project's capital costs are funded with a 100 percent loan from Farmers Home Administration (FmHA), typical Ozarks water rates listed in Table 7 need to be increased 205 percent to cover all capital

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14/ If a complete package treatment plant were used, we suggest that the cost for supplies and chemicals be based upon the $8.12 per hookup for districts with treatment practices (Table 6).

FORM B. ESTIMATION OF CONSTRUCTION AND OTHER CAPITAL COSTS FOR A DOMESTIC RURAL WATER SUPPLY SYSTEM, March 1979
(Month, Year)

ITEM DESCRIPTION	UNIT OF MEASURE	ENTER AMOUNT OF ITEM FROM SAMPLE LAYOUT (X)	MULTIPLY AMOUNT BY ITEM COSTS (=)	TOTAL ITEM COSTS	SUBTOTAL AND TOTAL COSTS
I. WELLS AND PUMPS (See Table 3 & Fig. 1)					
A. FOUR INCH DISCHARGE					
Casing depth	L.F.	273	$ 46.13	$12,593.49	
Difference between casing & well depth	L.F.	786	16.65	13,086.90	
90% of well depth	L.F.	953	6.77	6,451.81	
25 H.P. pump	L.S.	1	8,872.21	8,872.21	
B. EIGHT INCH DISCHARGE					
Casing depth	L.F.		62.08		
Difference between casing & well depth	L.F.		19.82		
90% of well depth	L.F.		46.42		
125 H.P. pump	L.S.		12,514.40		
C. PUMPHOUSE	L.S.	1	36,756.09	36,756.09	
D. MASTER METERS	EA.	1	10,794.38	10,794.38	
E. CHECK VALVES					
6" diameter	EA.	1	1,345.87	1,345.87	
8" diameter	EA.		1,869.90 (+)		
F. SUBTOTAL				89,900.75	89,900.75
II. TREATMENT PLANTS (See Table 2 & Fig. 1)					
A. PACKAGE PLANTS (See Form A, future needs)					
9,600 gpd	L.S.		65,300.00		
19,200 gpd	L.S.		75,000.00		
96,000 gpd	L.S.		105,600.00		
192,000 gpd	L.S.		130,300.00		
B. HYPOCHLORINATORS	L.S.	1	2,390.00 (+)	2,390.00	
C. SUBTOTAL				2,390.00	2,390.00

	ITEM DESCRIPTION	UNIT OF MEASURE	ENTER AMOUNT OF ITEM FROM SAMPLE LAYOUT	(X)	MULTIPLY AMOUNT BY ITEM COSTS	(=)	TOTAL ITEM COSTS	SUBTOTAL AND TOTAL COSTS
III.	STORAGE (See Form A, present needs)							
A.	ELEVATED TANKS							
	50,000 gal.	L.S.			$ 99,722.43			
	30,000 gal.	L.S.			93,347.54			
B.	GROUND TANKS							
	1,000,000 gal.	L.S.			204,692.13			
	500,000 gal.	L.S.			140,641.05			
C.	STANDPIPES							
	8' dia. x 110' high	L.S.	1		58,963.11		58,963.11	
D.	TELEMETERING	L.S.	1		7,663.12	(+)	7,663.12	
E.	SUBTOTAL						66,626.23	66,626.23
IV.	DISTRIBUTION PIPE (Sizing for future needs)							
A.	SERVICE PIPE							
	1" pvc 315	L.F.	30,150		1.68		50,652.00	
	1" copper bore	L.F.	1,400		6.10		8,540.00	
B.	PVC 160							
	2" diameter	L.F.	6,000		1.06		6,360.00	
	2½" diameter	L.F.	7,920		1.10		8,712.00	
	3" diameter	L.F.	43,600		1.49		64,964.00	
	4" diameter	L.F.	80,000		1.76		140,800.00	
	6" diameter	L.F.	18,480		2.69		49,711.20	
	8" diameter	L.F.			4.00			
C.	PVC 200							
	2" diameter	L.F.			1.61			
	3" diameter	L.F.			2.25			
	4" diameter	L.F.			2.50			
	6" diameter	L.F.			4.23	(+)		
D.	SUBTOTAL						329,739.20	
E.	MULTIPLY BY REGIONAL ADJUSTMENT Ozarks 1.52, or Other areas .87					(X)	1.52	
F.	ADJUSTED SUBTOTAL						501,203.58	501,203.58

FORM B. (CONTINUED)

ITEM DESCRIPTION	UNIT OF MEASURE	ENTER AMOUNT OF ITEM FROM SAMPLE LAYOUT	(X)	MULTIPLY AMOUNT BY ITEM COSTS	(=)	TOTAL ITEM COSTS	SUBTOTAL AND TOTAL COSTS
V. GATE VALVES							
A. DIAMETER							
2"	EA.	2		$146.27		292.54	
2½"	EA.	2		163.64		327.28	
3"	EA.	6		187.02		1122.12	
4"	EA.	18		213.04		3834.72	
6"	EA.	5		257.38		1286.90	
8"	EA.			365.99	(+)		
B. SUBTOTAL						6,863.56	
C. MULTIPLY BY REGIONAL ADJUSTMENT Ozarks 1.13, or Other areas .98					(X)	1.13	
D. ADJUSTED SUBTOTAL						7,755.82	7,755.82
VI. MISCELLANEOUS							
A. SERVICE METERS (See Form A, present needs)							
Ozarks	EA.	201		268.60		53,988.60	
Other areas	EA.			198.80			
B. AIR RELEASE VALVES	EA.	4		184.95		739.80	
C. CLEANOUTS	EA.			167.51			
D. FLUSH HYDRANTS	EA.	6		346.72	(+)	2,080.32	
E. SUBTOTAL						56,808.72	56,808.72
VII. CROSSINGS							
A. HIGHWAY							
12" bore	L.F.			44.47			
10" bore	L.F.	160		36.63		5,860.80	
8" bore	L.F.	910		31.92		29,047.20	

FORM B. (CONTINUED)

ITEM DESCRIPTION	UNIT OF MEASURE	ENTER AMOUNT OF ITEM FROM SAMPLE LAYOUT	(x)	MULTIPLY AMOUNT BY ITEM COSTS	(=)	TOTAL ITEM COSTS	SUBTOTAL AND TOTAL COSTS
(VII...)							
B. RAILROAD							
12" bore	L.F.	______		39.15		______	
10" bore	L.F.	______		35.96		______	
8" bore	L.F.	______		29.70		______	
C. STREAMS							
12" casing	L.F.	______		35.60		______	
10" casing	L.F.	225		28.01	(+)	6,302.25	
D. SUBTOTAL						41,210.25	(+) 41,210.25

VIII. ADJUSTMENTS TO TOTAL CONSTRUCTION COSTS

A. TOTAL UNADJUSTED CONSTRUCTION COSTS				765,895.35
B. ENTER CURRENT COMPOSITE CONSTRUCTION COST INDEX	189.0	(÷)	185.4 = (x)	1.02
C. ADJUSTED CONSTRUCTION COSTS				$ 781,213.26
D. OTHER CAPITAL COSTS (Percentage of VIII, C)	(Enter VIII, C)			
Administrative and legal	781,213.26	x	.0250 =	19,530.33
Basic engineering	781,213.26	x	.0850 =	66,403.13
Inspection	781,213.26	x	.0325 =	25,389.43
Interest during construction	781,213.26	x	.0325 =	25,389.43
Contingency	781,213.26	x	.0550 = (+)	42,966.73
E. TOTAL PROJECT COSTS				$ 960,892.31

FORM C. ESTIMATION OF ANNUAL OPERATING COSTS FOR A DOMESTIC RURAL WATER SUPPLY SYSTEM,

TYPE Ozarks, Well, No Treatment AS OF March 1979.
(From Table 6) (Month, Year)

OPERATING COST ITEMS	ENTER CURRENT INDEX VALUES	(÷)	DIVIDE BY INDEX VALUES TABLE 6	(X)	ENTER AND MULTIPLY PER HOOKUP COSTS TABLE 6	(=)	ADJUSTED ANNUAL COSTS PER HOOKUP
A. SALARIES	(223.9 Average hourly earnings, services	÷	212.5)	X	$ 23.64	=	$ 24.91
B. TAXES	(223.9 Average hourly earnings, services	÷	212.5)	X	4.31	=	4.54
C. FEES	(223.9 Average hourly earnings, services	÷	212.5)	X	6.82	=	7.19
D. UTILITIES	(225.9 CPI-U fuel and utilities	÷	216.0)	X	9.26	=	9.68
E. INSURANCE	(248.2 CPI-U homeownership	÷	227.2)	X	3.33	=	3.64
F. REPAIRS AND MAINTENANCE	(248.2 CPI-U homeownership	÷	227.2)	X	15.05	=	16.44
G. SUPPLIES & CHEMICALS	(209.5 Producer prices, chemicals & allied products	÷	198.8)	X	1.99	=	2.10
H. OFFICE SUPPLIES	(187.4 CPI-U household furn. & operation	÷	177.7)	X	2.35	=	2.48
I. COST OF WATER & MERCHANDISE	(225.9 CPI-U fuel and utilities	÷	216.0)	X	.13	=	.14
J. MISCELLANEOUS	(187.4 CPI-U household furn. & operation	÷	177.7)	X	4.51	=	(+) 4.76
K. TOTAL ANNUAL OPERATING COSTS PER HOOKUP							$75.88

and operating costs. Water rates, necessary to breakeven with a 100 percent loan, range from a minimum monthly bill of $16.68 for the first 1,000 gallons to $53.04 per month for 10,000 gallons. Form D demonstrates the calculation of total monthly costs and breakeven water rates.

The maximum grant share that FmHA can make is 75 percent. If only 25 percent of the project's capital costs are funded by a FmHA loan, breakeven water rates will be only 19 percent higher than the average water rates for Ozarks districts. Rates would range from a minimum monthly bill of $6.51 to a monthly charge of $20.69 for 10,000 gallons. FmHA loans are discussed in Appendix B.

FORM D. CALCULATION OF TOTAL MONTHLY COSTS AND BREAKEVEN WATER RATES FOR A DOMESTIC RURAL WATER SUPPLY SYSTEM

			WITH 100% LOAN	WITH 25% LOAN AND 75% GRANT
I.	TOTAL MONTHLY COSTS			
A.	Total project costs (Form B: VIII, E)		$ 960,892.31	$ 960,892.31
B.	Loan factor		(x) 1.00	(x) .25
C.	Loan amount		$ 960,892.31	$ 240,223.08
D.	Amortization factor (Appendix A)		(x) .062490	(x) .062490
E.	Annual loan repayment		$ 60,046.16	$ 15,011.54
F.	Additional 10 percent bond reserve/replacement fund		(x) 1.10	(x) 1.10
G.	Annual loan and bond reserve payment		$ 66,050.78	$ 16,512.69
H.	Annual operating costs per hookup (Form C:K)	$ 75.88		
I.	Total no. of current hookups (Form A: IA + IE)	(x) 201		
J.	Total annual operating costs	$ 15,251.88	$(+) 15,251.88	$(+) 15,251.88
K.	Total annual capital, bond reserve, and operating costs		$ 81,302.66	$ 31,764.57
L.	Divide		(÷) 12	(÷) 12
M.	Total monthly costs		$ 6,775.22	$ 2,647.05

II. MONTHLY REVENUE BASED UPON AVERAGE WATER RATES

A. Enter and calculate the following:

Number of gallons	Total number hookups (I,I Above) 1/		Proportion of hookups 2/		Cumulative water rates Table 7		Monthly water revenue
1,000	201	x	.26	x	5.47	=	$ 285.86
2,000	201	x	.14	x	8.52	=	$ 239.75
3,000	201	x	.16	x	10.53	=	$ 338.64
4,000	201	x	.15	x	12.01	=	$ 362.10
5,000	201	x	.12	x	12.99	=	$ 313.32
>5,000	201	x	.17	x	20.05 3/	=	(+) 685.11

			WITH 100% LOAN	WITH 25% LOAN AND 75% GRANT
B.	Total monthly revenue	$ 2,224.78	(-)$ 2,224.78	(-)$ 2,224.78
C.	Excess costs (or profit)		$ 4,550.44	$ 422.27

FORM D. (CONTINUED)

ITEMS			WITH 100% LOAN	WITH 25% LOAN AND 75% GRANT
III. WATER RATE ADJUSTMENT FOR BREAKEVEN REVENUE				
A. ADJUSTMENT FACTOR				
Monthly costs IM Above			6,775.22	2,647.05
Monthly revenue IIB Above			(÷) 2,224.78	(÷) 2,224.78
Adjustment factor			3.05	1.19
B. BREAKEVEN MONTHLY WATER RATES				
Enter cumulative water rates, Table 7				
1,000 gallons	5.47	x adj. factor	16.68	6.51
2,000 gallons	8.52	x adj. factor	25.99	10.14
3,000 gallons	10.53	x adj. factor	32.12	12.53
4,000 gallons	12.01	x adj. factor	36.63	14.29
5,000 gallons	12.99	x adj. factor	39.62	15.46
6,000 gallons	13.90	x adj. factor	42.40	16.54
7,000 gallons	14.81	x adj. factor	45.17	17.62
8,000 gallons	15.72	x adj. factor	47.95	18.71
9,000 gallons	16.63	x adj. factor	50.72	19.79
10,000 gallons	17.39	x adj. factor	53.04	20.69
Enter rate per 1,000 gallons for 10,000 gallons, Table 7				
Each 1,000 gallons more than 10,000 gallons	.76	x adj. factor	2.32	.90

1/ Conservatively assumes that large water users are distributed like a comparable number of residential users. Only a few water districts reported some meter connections larger than residential service.

2/ Determined from a sample of 18 operational water districts filing "use and income estimates" with FmHA.

3/ For the Ozarks region, use a cumulative rate of $20.05 for 13,541 average gallons per user of more than 5,000 gallons per month. For the remainder of the state, use a cumulative rate of $31.67 for 20,300 average gallons per user of more than 5,000 gallons per month. Water rates per 1,000 gallons in excess of 10,000 gallons were assumed to be those listed in Table 7 for 10,000 gallons.

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APPENDIX A

Amortization factors for various repayment periods and interest rates for the calculation of annual loan payment

Interest rate	Years to repay 15	20	25	30	35
5	.096342	.080243	.070952	.065051	.061072
6	.102963	.087185	.078227	.072649	.068974
7	.109795	.094393	.085811	.080586	.077234
8	.116830	.101852	.093679	.088827	.085803
8½	.120420	.105671	.097712	.093051	.090189
9	.124059	.109546	.101806	.097336	.094636
9½	.127744	.113477	.105959	.101681	.099138
10	.131474	.117460	.110168	.106079	.103690

Note: The amortization factor for a loan of 33 years at 5 percent interest is .062490.

FEDERAL FUNDING FOR RURAL WATER DISTRICTS

Rural communities have for years attempted to solve their water problems with limited financial resources. The return of many people to rural America from the cities has accentuated the need for adequate water facilities. To help rural communities find practical solutions to these problems, President Carter established an interagency task force to study the problems of rural water and sewer facility development. The task force is made up of representatives from Farmers Home Administration of the U.S. Department of Agriculture, the Economic Development Administration of the U.S. Department of Commerce, the Department of Housing and Urban Development, and the Environmental Protection Agency.

The purpose of this brief section is to introduce the reader to programs of these agencies that offer aid to rural communities for developing adequate water facilities. This section is not intended to be a complete description of the programs, nor is it meant to serve as a substitute for direct contact with any of the Federal agencies. The programs summarized here are described in greater detail in _How to Apply for Federal Assistance for Rural Water/Sewer Development_ and also the _1978 Catalog of Federal Domestic Assistance_.

Farmers Home Administration

FmHA provides loans or grants for water facilities development, reservoirs, or improvement. The objective of the Water and Waste Disposal Systems for Rural Communities program (Catalog No. 10.418) is to provide basic human amenities, alleviate health hazards, and promote the orderly growth of the rural areas of the nation by meeting the need for new and improved rural water and waste disposal systems. Funds provided under this program may be used to finance the installation, repair, improvement or expansion of a rural water system including distribution lines, wells, pumping facilities, and related costs. Applicants for the program must meet the following eligibility criteria:

1. The applicant must be a public body such as a town, county, district, or authority; a nonprofit corporation; or an Indian tribe; serving a rural area that does not include an area in any city having a population in excess of 10,000.
2. The applicant must have the legal authority to borrow and repay funds, to pledge security for a loan, and to construct and operate the facility.
3. The applicant must be unable to secure the needed funds elsewhere at reasonable rates.
4. The applicant's proposed project must be economically feasible and cost-effective.

FmHA loans generally have a 35-year term with only interest payable during the first two years and both interest and principal payable during the remaining 33 years. The current interest rate is 5 percent. A bond stipulation also requires an additional 10 percent payment to be held by the water system as a bond reserve fund and replacement fund. The maximum grant share that FmHA can make is 75 percent of the capital costs. The purpose of grants is to enable communities to have reasonable water rates. Grant shares are determined by a set of rules which include the community's median family income, and average user charges of similar water systems. However, all such grants are subject to the availability and appropriation of monies by the Federal Government. Communities interested in the FmHA program should contact FmHA district offices in St. Joseph, Trenton, Kirksville, Clinton, Columbia, Springfield, Lebanon, Ellington, or Sikeston.

Economic Development Administration

EDA provides project grants and direct loans through its Economic Development-Grants and Loans for Public Works and Development Facilites (Catalog No. 11.300). The goal of the program is to help restore economic health to areas burdened with high unemployment and low family incomes. This objective is achieved in part by improving water and sewer facilities so that new industry might be attracted to the area. Eligible applicants include states and their subdivisions, Indian tribes, or nonprofit organizations representing an EDA-designated area, Economic Development District, or Economic Development Center. For an area to be EDA-designated, it must have high unemployment and low family income.

Department of Housing and Urban Development

HUD provides loans and grants for the development of water and sewer systems through several programs. Eligible applicants include States, counties, and local governments. In general, cities with less than 50,000 population are eligible under the Small Cities Program (Catalog No. 14.219). Grants are awarded to communities having the greatest needs as evidenced by poverty and substandard housing. Water and sewer projects are eligible for assistance when the goal of the project is to correct existing deficiencies and thereby promote the public health or safety of low to moderate income persons.

APPENDIX C

FEDERAL AND STATE RURAL WATER SUPPLY REGULATIONS

Missouri statutes for county (rural) water systems are governed by Revised Missouri Statutes Sections 247.010 through 247.220 (14). Rural water supply districts are entitled to all rights and subject to all restrictions applying to political subdivisions of the State. Section 247.030, as amended in 1967, delineates the territory, annexation limitations, and relations with neighboring water districts. According to this section:

1. The territory may be wholly within one or in more than one county.
2. It may take in school districts or part of school districts.
3. Cities which lack a waterworks system may be included.
4. Territory must be contiguous.
5. No two districts may overlap, but an annexation procedure is provided for an "exchange" of land between adjacent districts.

The rest of the sections state procedures for establishing a water supply district, management and operation of a system, election of water district board members and their power, methods and sources of funding, setting water fee rates, and auditing regulations. A summary of the bill is in Reference No. 14.

In December, 1974, Congress enacted the Safe Drinking Water Act (PL 93-523) to help ensure that dependable water was supplied by all public water systems. A public water system, as defined by the National Interim Primary Drinking Water Regulations (18), is a system that serves 25 individuals at least 60 days out of a year. The Missouri 79th General Assembly enacted Public Water Supply Law (State Bill No. 509) to enforce the Safe Drinking Water Act and the National Primary Drinking Water Regulations. This law empowers the Department of Natural Resources (DNR) to make rules and regulations, in compliance with the Act, for the maintenance of safe, quality water dispensed to the public.

The DNR, as authorized by the General Assembly, regulates water quality and quantity. In general, all plans for the installations and extensions of rural water supply systems which may include treatment, storage, and distribution are submitted to DNR for approval. Final construction plans and specifications must be made by a registered engineer.

The DNR publications, "A Guide for the Design and Construction of Groundwater Supplies, Storage, and Distribution Facility" and "A Guide for the Design of Treated Water Supply and Storage" give detailed design standards and recommendations. Areas covered in these guidelines include:

1. Submission of plans for approval.
2. Source of raw water.
3. Water consumption and demand projections.
4. Treatment and disinfection.
5. Pumping, storage, distribution and pres-

sure design standards.

6. Biological, chemical and physical water quality requirements of "finished" water.

In addition, "Ten State Standards for Water Works" gives similar requirements (9).

Other than turbidity and chlorine tests, DNR will perform all biological, chemical, and trace metals tests free of charge. Samples of water can be shipped to DNR central laboratory and sampling procedures can be acquired from DNR branch offices. Details and information about the Safe Drinking Water Act, State statutes, and technical help are available from DNR in Jefferson City, or from any of the four regional offices, which are in Kansas City, St. Louis, Springfield, and Macon.

Further technical and administrative help can be received from the following Federal and State agencies:

Agency Name & Address	Expected Help
Department of Natural Resources Division of Environmental Quality P.O. Box 1368 Jefferson City, MO 65101	Planning, design, approval, financing, testing, and operator training.
Missouri State Geological Survey P.O. Box 250 Rolla, MO 65401	Technical--wells and geologic problems.
Farmers Home Administration U.S. Dept. of Agriculture 555 Vandiver Drive Columbia, MO 65201	Planning, finance, and operation.

APPENDIX D

FIRE FLOW AND PROTECTION

Previous sections of this report concern water supply for domestic flows only, that is, for households, farms, commercial establishments, and industries. Usage of a system for fire protection requires detailed calculations of fire flows of water over and above that needed for domestic usages.

It is most imperative that fire flows do not reduce water pressures below 20 psi at any location in the distribution system at any time. The rural water supply system should obtain from the fire protection organization an agreement that at no time will the pressure be lowered to less than 20 psi at any location in the distribution system and that the fire protection organization will hold the water supply system harmless from any and all liabilities or damages resulting from inadequate pressures or insufficient capacities of water. The rural water system is advised to consult with a registered engineer and an attorney before allowing usage of the system for fire flows.

Pumps, storage facilities, and pipes must be sized to accommodate both maximum domestic usage and a planned maximum fire flow at pressures of 20 psi or more. Fire pumpers drawing water from undersized mains may not only lower pressures below 20 psi but may also collapse water lines. The minimum size of water mains serving fire hydrants is 6 inches in diameter (9). Eight-inch diameter pipe is the recommended minimum size for long lengths or where mains are dead-ended and not looped (13).

The recognized authority for determining fire flows is the state Insurance Services Office (9). This office has defined 10 classes of fire protection for insurance purposes with Class One offering the most fire protection and Class Ten having the least adequate or no fire protection. Communities with no water supply could qualify for a Class Nine rating provided other requirements are met (13). However, a recognized water supply is needed for Classes One through Eight. To be recognized for minimum fire protection purposes, the water supply system should be able to deliver at least 250 gallons per minute for two hours or at least 500 gallons per minute for one hour (13). Additional information about fire protection requirements can be obtained from the Insurance Services Office in St. Louis, Mo.

For communities without a minimum recognized water supply, several alternatives may be considered for providing some fire protection. However, these alternatives may not affect the above insurance ratings.

First, if the local fire department uses soft intake hoses to connect fire pumpers to hydrants and if fire department personnel are well trained in the usage of hydrants and pressure gauging systems, then fire pumpers could possibly be connected directly to branch lines of less than 6 inches in diameter without damaging the water system.

Second, the provision of hydrants on water distribution pipes could allow for at least the gravity filling of fire equipment tanks without direct pumping connections. However, even this option could lower water pressures below 20 psi, especially on dead-ended water mains. Flush hydrants with inflow and valve connections smaller than the distribution pipe may minimize this hazard. Additional information about rural fire protection may be obtained from the University of Missouri Fire Training Program.

Some rural water systems which provide fire flows have had the additional construction costs of fire protection financed by general obligation bonds issued by municipalities protected. These bonds are then repaid with property tax receipts. The value of the fire protection received is assumed to be proportional to the value of the property protected. The extra costs of providing fire flows are paid by property owners, not by domestic water users (11).

APPENDIX E

FORM A. ESTIMATING REQUIREMENTS FOR A DOMESTIC RURAL WATER SUPPLY SYSTEM

I. NUMBER OF HOOKUPS FOR SIZING PIPE

A. No. of present households and small commercial establishments = ________

B. No. of future household and small commercial establishments

________ x ________ = ________

(Enter no. of present hookups I,A) (Population growth rate 1975-1990) 1/

C. No. of large water users, e.g., industry and large commercial establishments

Name	Gallons per month
	(+)

D. Subtotal gallons ________

E. Household equivalent of industrial use = ________ ÷ 5504 = (+) ________

(I,D above)

F. Total no. of comparable planned hookups for using table 4, pipe sizing = ________

Hookups for Planning

FORM A. (CONTINUED)

II. ESTIMATING SIZE OF WATER TREATMENT FACILITIES

A. Small water users

______ + ______ = ______ x ______ ÷ 30.4 = ______

(I,A above) (I,B above) (Gallons per month, Table 1)

B. Large water users

______ ÷ 30.4 = (+) ______

(I,D above)

C. Total gallons per day = ______

Gallons per day

III. ESTIMATING DAILY WATER STORAGE REQUIREMENTS

A. No. of present households and small commercial establishments

______ x ______ ÷ 30.4 = ______

(I,A above) (Gallons per month, Table 1)

B. Large water users

______ ÷ 30.4 = (+) ______

(I,D subtotal, gallons per month, above)

C. Current water storage requirements ______

Gallons

1/ Division of Budget and Planning, Estimates and Projections of Population in Missouri, 1970 to 1990, Jefferson City: Missouri State Office of Administration, Sept. 1977.

FORM B. ESTIMATION OF CONSTRUCTION AND OTHER CAPITAL COSTS FOR A DOMESTIC RURAL WATER SUPPLY SYSTEM, ____________________
(Month, Year)

ITEM DESCRIPTION	UNIT OF MEASURE	ENTER AMOUNT OF ITEM FROM SAMPLE LAYOUT	(X)	MULTIPLY AMOUNT BY ITEM COSTS	(=)	TOTAL ITEM COSTS	SUBTOTAL AND TOTAL COSTS
I. WELLS AND PUMPS (See Table 3 & Fig. 1)							
A. FOUR INCH DISCHARGE							
Casing depth	L.F.	______	$	46.13		$______	
Difference between casing & well depth	L.F.	______		16.65		______	
90% of well depth	L.F.	______		6.77		______	
25 H.P. pump	L.S.	______		8,872.21		______	
B. EIGHT INCH DISCHARGE							
Casing depth	L.F.	______		62.08		______	
Difference between casing & well depth	L.F.	______		19.82		______	
90% of well depth	L.F.	______		46.42		______	
125 H.P. pump	L.S.	______		12,514.40		______	
C. PUMPHOUSE	L.S.	______		36,756.09		______	
D. MASTER METERS	EA.	______		10,794.38		______	
E. CHECK VALVES							
6" diameter	EA.	______		1,345.87		______	
8" diameter	EA.	______		1,869.90	(+)	______	
F. SUBTOTAL						______	______
II. TREATMENT PLANTS (See Table 2 & Fig. 1)							
A. PACKAGE PLANTS (See Form A, future needs)							
9,600 gpd	L.S.	______		65,300.00		______	
19,200 gpd	L.S.	______		75,000.00		______	
96,000 gpd	L.S.	______		105,600.00		______	
192,000 gpd	L.S.	______		130,300.00		______	
B. HYPOCHLORINATORS	L.S.	______		2,390.00	(+)	______	
C. SUBTOTAL						______	______

ITEM DESCRIPTION	UNIT OF MEASURE	ENTER AMOUNT OF ITEM FROM SAMPLE LAYOUT	(X)	MULTIPLY AMOUNT BY ITEM COSTS	(=)	TOTAL ITEM COSTS	SUBTOTAL AND TOTAL COSTS
III. STORAGE (See Form A, present needs)							
A. ELEVATED TANKS							
50,000 gal.	L.S.	______		$ 99,722.43		______	
30,000 gal.	L.S.	______		93,347.54		______	
B. GROUND TANKS							
1,000,000 gal.	L.S.	______		204,692.13		______	
500,000 gal.	L.S.	______		140,641.05		______	
C. STANDPIPES							
8' dia. x 110' high	L.S.	______		58,963.11		______	
D. TELEMETERING	L.S.	______		7,663.12	(+)	______	
E. SUBTOTAL						______	______
IV. DISTRIBUTION PIPE (Sizing for future needs)							
A. SERVICE PIPE							
1" pvc 315	L.F.	______		1.68		______	
1" copper bore	L.F.	______		6.10		______	
B. PVC 160							
2" diameter	L.F.	______		1.06		______	
2½" diameter	L.F.	______		1.10		______	
3" diameter	L.F.	______		1.49		______	
4" diameter	L.F.	______		1.76		______	
6" diameter	L.F.	______		2.69		______	
8" diameter	L.F.	______		4.00		______	
C. PVC 200							
2" diameter	L.F.	______		1.61		______	
3" diameter	L.F.	______		2.25		______	
4" diameter	L.F.	______		2.50		______	
6" diameter	L.F.	______		4.23	(+)	______	
D. SUBTOTAL						______	
E. MULTIPLY BY REGIONAL ADJUSTMENT Ozarks 1.52, or Other areas .87					(X)	______	
F. ADJUSTED SUBTOTAL						______	______

ITEM DESCRIPTION	UNIT OF MEASURE	ENTER AMOUNT OF ITEM FROM SAMPLE LAYOUT	(X)	MULTIPLY AMOUNT BY ITEM COSTS	(=)	TOTAL ITEM COSTS	SUBTOTAL AND TOTAL COSTS
V. GATE VALVES							
A. DIAMETER							
2"	EA.	______		$146.27		______	
2½"	EA.	______		163.64		______	
3"	EA.	______		187.02		______	
4"	EA.	______		213.04		______	
6"	EA.	______		257.38		______	
8"	EA.	______		365.99	(+)	______	
B. SUBTOTAL						______	
C. MULTIPLY BY REGIONAL ADJUSTMENT Ozarks 1.13, or Other areas .98					(X)	______	
D. ADJUSTED SUBTOTAL						______	______
VI. MISCELLANEOUS							
A. SERVICE METERS (See Form A, present needs)							
Ozarks	EA.	______		268.60		______	
Other areas	EA.	______		198.80		______	
B. AIR RELEASE VALVES	EA.	______		184.95		______	
C. CLEANOUTS	EA.	______		167.51		______	
D. FLUSH HYDRANTS	EA.	______		346.72	(+)	______	
E. SUBTOTAL						______	______
VII. CROSSINGS							
A. HIGHWAY							
12" bore	L.F.	______		44.47		______	
10" bore	L.F.	______		36.63		______	
8" bore	L.F.	______		31.92		______	

ITEM DESCRIPTION	UNIT OF MEASURE	ENTER AMOUNT OF ITEM FROM SAMPLE LAYOUT	(x)	MULTIPLY AMOUNT BY ITEM COSTS	(=)	TOTAL ITEM COSTS	SUBTOTAL AND TOTAL COSTS
(VII...)							
B. RAILROAD							
12" bore	L.F.	________		39.15		________	
10" bore	L.F.	________		35.96		________	
8" bore	L.F.	________		29.70		________	
C. STREAMS							
12" casing	L.F.	________		35.60		________	
10" casing	L.F.	________		28.01	(+)	________	
D. SUBTOTAL						________	(+) ________

VIII. ADJUSTMENTS TO TOTAL CONSTRUCTION COSTS

A. TOTAL UNADJUSTED CONSTRUCTION COSTS ________

B. ENTER CURRENT COMPOSITE CONSTRUCTION COST INDEX ________ (÷) 185.4 = (x) ________

C. ADJUSTED CONSTRUCTION COSTS $________

D. OTHER CAPITAL COSTS (Percentage of VIII, C) (Enter VIII, C)

	(Enter VIII, C)			
Administrative and legal	________	x	.0250 =	________
Basic engineering	________	x	.0850 =	________
Inspection	________	x	.0325 =	________
Interest during construction	________	x	.0325 =	________
Contingency	________	x	.0550 =	(+) ________

E. TOTAL PROJECT COSTS $________

FORM C. ESTIMATION OF ANNUAL OPERATING COSTS FOR A DOMESTIC RURAL WATER SUPPLY SYSTEM,

TYPE ________________ AS OF ________________.
(From Table 6) (Month, Year)

OPERATING COST ITEMS	ENTER CURRENT INDEX VALUES	(÷)	DIVIDE BY INDEX VALUES TABLE 6	(X)	ENTER AND MULTIPLY PER HOOKUP COSTS TABLE 6	(=)	ADJUSTED ANNUAL COSTS PER HOOKUP
A. SALARIES	(_____	÷	212.5)	X	$_____	=	$_____
	Average hourly earnings, services						
B. TAXES	(_____	÷	212.5)	X	_____	=	_____
	Average hourly earnings, services						
C. FEES	(_____	÷	212.5)	X	_____	=	_____
	Average hourly earnings, services						
D. UTILITIES	(_____	÷	216.0)	X	_____	=	_____
	CPI-U fuel and utilities						
E. INSURANCE	(_____	÷	227.2)	X	_____	=	_____
	CPI-U homeownership						
F. REPAIRS AND MAINTENANCE	(_____	÷	227.2)	X	_____	=	_____
	CPI-U homeownership						
G. SUPPLIES & CHEMICALS	(_____	÷	198.8)	X	_____	=	_____
	Producer prices, chemicals & allied products						
H. OFFICE SUPPLIES	(_____	÷	177.7)	X	_____	=	_____
	CPI-U household furn. & operation						
I. COST OF WATER & MERCHANDISE	(_____	÷	216.0)	X	_____	=	_____
	CPI-U fuel and utilities						
J. MISCELLANEOUS	(_____	÷	177.7)	X	_____	=	(+) _____
	CPI-U household furn. & operation						
K. TOTAL ANNUAL OPERATING COSTS PER HOOKUP							$_____

FORM D. CALCULATION OF TOTAL MONTHLY COSTS AND BREAKEVEN WATER RATES FOR A DOMESTIC RURAL WATER SUPPLY SYSTEM

		WITH 100% LOAN	WITH ______ LOAN AND ______ GRANT
I. TOTAL MONTHLY COSTS			
A. Total project costs (Form B: VIII, E)		$ ______	$ ______
B. Loan factor		(x) 1.00	(x) ______
C. Loan amount		$ ______	$ ______
D. Amortization factor (Appendix A)		(x) ______	(x) ______
E. Annual loan repayment		$ ______	$ ______
F. Additional 10 percent bond reserve/replacement fund		(x) 1.10	(x) 1.10
G. Annual loan and bond reserve payment		$ ______	$ ______
H. Annual operating costs per hookup (Form C:K)	$ ______		
I. Total no. of current hookups (Form A: IA + IE)	(x) ______		
J. Total annual operating costs	$ ______	$(+) ______	$(+) ______
K. Total annual capital, bond reserve, and operating costs		$ ______	$ ______
L. Divide		(÷) 12	(÷) 12
M. Total monthly costs		$ ______	$ ______

II. MONTHLY REVENUE BASED UPON AVERAGE WATER RATES

A. Enter and calculate the following:

Number of gallons	Total number hookups (I,I Above) 1/		Proportion of hookups 2/		Cumulative water rates Table 7		Monthly water revenue
1,000	______	x	.26	x	______	=	$ ______
2,000	______	x	.14	x	______	=	$ ______
3,000	______	x	.16	x	______	=	$ ______
4,000	______	x	.15	x	______	=	$ ______
5,000	______	x	.12	x	______	=	$ ______
>5,000	______	x	.17	x	______ 3/	=	(+) ______

		WITH 100% LOAN	WITH LOAN AND GRANT
B. Total monthly revenue	$ ______	(-) $ ______	(-) $ ______
C. Excess costs (or profit)		$ ______	$ ______

ITEMS			WITH 100% LOAN	WITH ______ LOAN AND ______ GRANT
III. WATER RATE ADJUSTMENT FOR BREAKEVEN REVENUE				
A. ADJUSTMENT FACTOR				
Monthly costs IM Above			______	______
Monthly revenue IIB Above			(÷) ______	(÷) ______
Adjustment factor			______	______
B. BREAKEVEN MONTHLY WATER RATES				
Enter cumulative water rates, Table 7				
1,000 gallons	______	x adj. factor	______	______
2,000 gallons	______	x adj. factor	______	______
3,000 gallons	______	x adj. factor	______	______
4,000 gallons	______	x adj. factor	______	______
5,000 gallons	______	x adj. factor	______	______
6,000 gallons	______	x adj. factor	______	______
7,000 gallons	______	x adj. factor	______	______
8,000 gallons	______	x adj. factor	______	______
9,000 gallons	______	x adj. factor	______	______
10,000 gallons	______	x adj. factor	______	______
Enter rate per 1,000 gallons for 10,000 gallons, Table 7				
Each 1,000 gallons more than 10,000 gallons	______	x adj. factor	______	______

1/ Conservatively assumes that large water users are distributed like a comparable number of residential users. Only a few water districts reported some meter connections larger than residential service.

2/ Determined from a sample of 18 operational water districts filing "use and income estimates" with FmHA.

3/ For the Ozarks region, use a cumulative rate of $20.05 for 13,541 average gallons per user of more than 5,000 gallons per month. For the remainder of the state, use a cumulative rate of $31.67 for 20,300 average gallons per user of more than 5,000 gallons per month. Water rates per 1,000 gallons in excess of 10,000 gallons were assumed to be those listed in Table 7 for 10,000 gallons.