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Design and Operating Criteria for Rural Water Systems

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MEMBER
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RURAL homesites in the United States require the availability of high quality water. One means of meeting this need is with the rural water district, a system composed of tank storage and a pipe network serving a number of homes. The tanks are filled by pumping during periods of minimal water use and serve as the immediate water source for homes.

Optimum design requires consideration of not only immediate needs and economic factors but also the possibility of expansion at some future date. Accurate prediction of monthly usage rates is sometimes necessary to set contractural needs. Daily water use per person must be known to appropriately choose the size of the storage tank. Peak use rates are important for proper selection of pipe sizes. The temporal distribution of demand is important in determining available pump operating periods for filling of storage with a minimum of interference and has a bearing on pump and pipe selection.

This paper presents the results of a study (Goodwin, 1975) describing design criteria for projects serving dairies and domiciles. Homes are divided into two different economic groups and design recommendations are made for each group.

LITERATURE REVIEW OF AVAILABLE DESIGN CRITERIA

Hermann (1971) noted that water use was affected by the market value of the residence, along with other factors. Stotlenberg (1971) found an average monthly use of 10 978 L (2,900 gal) per service in twenty rural community water systems in Illinois. Johnson (1968) found an average monthly use of 13 249 L (3,500 gal) per service for several rural systems in Kansas. The hydrology committee of ASAE (Yung 1960) recommended an average daily requirement of 189 to 284 L (50 to 75 gal) per person per day. Lineweaver (1963) indicated that an inverse relationship exists between the number of people per dwelling unit and the average daily per capita use and cited values ranging from 323 L/day for two persons per dwelling to 179 L/day (85 to 47 gal/day) for five persons per dwelling. FHA Instruction 424.2, Exhibit A (1972), which has been superseded, required 300 gal of storage and a design flow rate of 2 gpm for each rural family.

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EXPERIMENTAL DESIGN AND PROCEDURE

Rural Water District No. 3, Payne County, OK, is a system designed under FHA specifications. The storage tower was designed for storage of 1 060 L (280 gal) per service. It was assumed that water availability from the tower was never a limiting factor on consumptive use. Three main laterals service approximately 120 residences and two dairies on the system. A calibrated 5.08 cm (two in.) Badger nutating disk water meter was installed in each of these mains in such a manner as to minimize pressure loss while measuring flow. A Sodeco Printing Impulse Counter, and Impulse Transmitter, were utilized to record the cumulative number of seconds after midnight of each successive 380 L (100 gal) of water usage. Error introduced by the measuring and timing instrumentation was estimated to be less than ±5 percent.

DETERMINATION OF MONTHLY USE RATES PER TAP AND PER PERSON

It was recognized that families often consume in proportion to their financial resources (Johnson 1968). A "windshield" survey of the residences was accomplished. Homes similar in economic value were grouped together. Thus, there were five financial "levels" represented. Monthly water use of each family (tap) was obtained from the district operator from February through September, 1974. A one-way statistical analysis of the monthly water use of the different economic strata per tap and per person was performed. Using the least significant difference at the 5 percent level as a criterion, no difference was found in the upper four levels. The four levels were merged into one large group and separated from that of the lower valued homes. The average monthly usage per tap and per person for these economic groups are shown in Figs. 1 and 2. Ratios of the monthly use of the different groups are shown in Table 1.

DETERMINATION OF DAILY USE RATES PER TAP AND PER PERSON

The Badger and Sodeco instrumentation was used to calculate average daily demands per lateral from February through September. Knowing which homes were serviced by which laterals, monthly use ratios were utilized to develop values of use per tap. From these, cumulative frequency histograms were prepared which indicate representative consumptive use. These are

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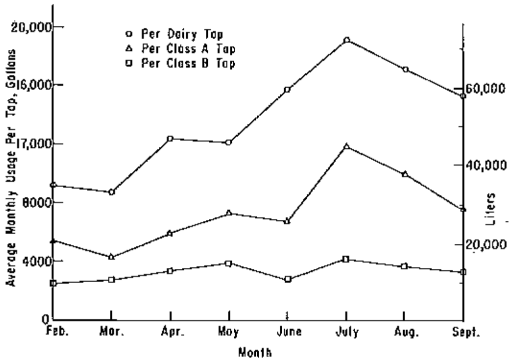

FIG. 1 Monthly usage per tap.

shown in Figs. 3, 4, 5. An analysis of variance showed no significant difference in the usage for the different days of the week at the 5 percent level.

DETERMINATION OF PEAK USE RATES PER TAP AND PER PERSON

The printout of the counter was also used to determine daily peak flow rates for quantities of 380, 760, 1 140, 1 520, and 1 900 L (100, 200, 300, 400, and 500 gal) for each main lateral. Application of monthly use ratios allowed development of the histograms shown in Figs. 6 to 11.

DETERMINATION OF TEMPORAL DISTRIBUTION OF DEMAND AND OPTIMUM PUMPING PERIOD

Hydrographs were prepared for daily usage per customer. In order to discover which periods of time are best for pumping to fill storage, an analysis was made of the percent of time that the level of usage exceeded 0.9 and 0.45 L (0.5 and 0.25 gpm) per minute per tap.

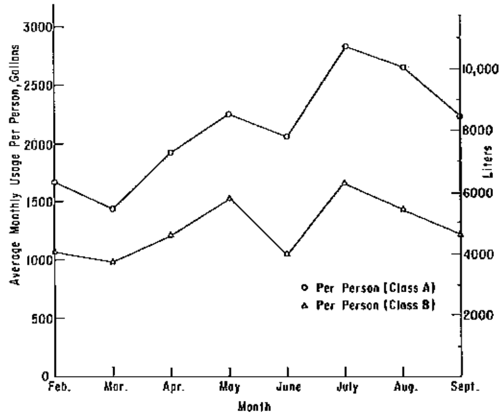

FIG. 2 Monthly usage per person.

TABLE 1. MONTHLY USE RATIOS.

	Per tap		Per person
Month	Dairy/ class A*	Class B/ class A†	Class B/ class A‡
February	1.65	0.45	0.65
March	2.02	0.64	0.69
April	2.04	0.56	0.64
May	1.69	0.53	0.68
June	2.30	0.41	0.51
July	1.60	0.35	0.59
August	1.72	0.38	0.55
September	1.97	0.44	0.54

*Average Use per Dairy Tap / Average Use per Class A Tap

†Average Use per Class B Tap / Average Use per Class A Tap

‡Average Use per Class B person / Average Use per Class A person

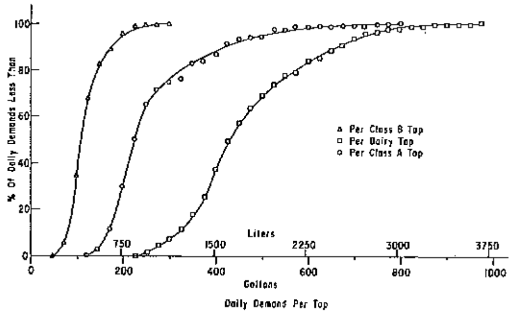

FIG. 3 Cumulative frequency curves of daily demand per dairy tap, per Class A tap, and per Class B tap.

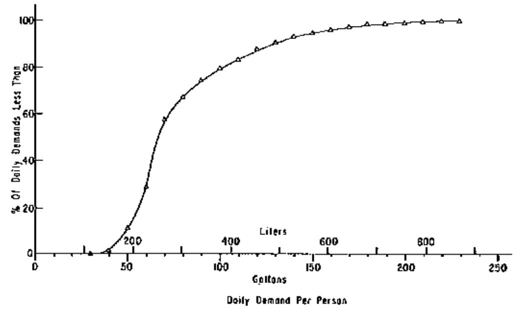

FIG. 4 Cumulative frequency of daily demand per person.

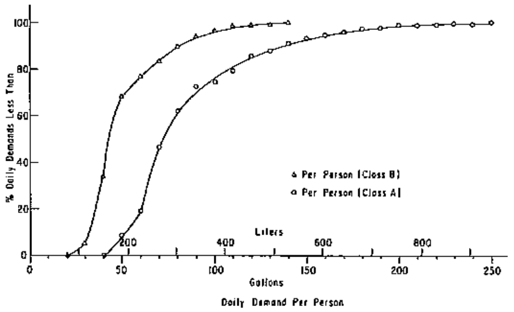

FIG. 5 Cumulative frequency curves of daily demand per person [Class A residence], and per person [Class B residence].

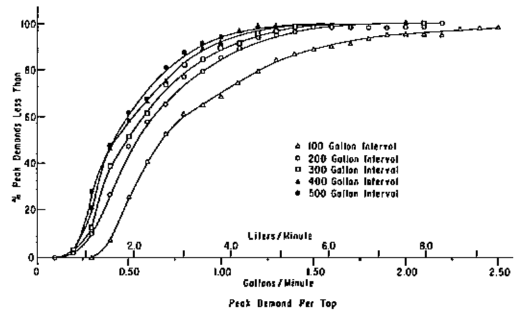

FIG. 6 Cumulative frequency curves of peak demands per tap.

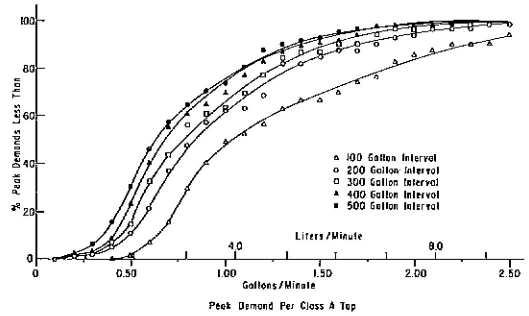

FIG. 7 Cumulative frequency curves of peak demands per Class A tap.

TABLE 2. MONTHLY WATER USE.

	Average monthly use per tap		Average monthly use per person	
	(gal)	(liters)	(gal)	(liters)
Dairy	8768-19183	33318-72895		
Class A	4357-11983	16557-45535	1424-2821	5411-10720
Class B	2537-4160	9641-15808	989-1664	3758-6323
Original Design	3500	13300		

For systems designed for 7.6 L (2 gal) per minute per tap use rate, a value of 1.9 L (0.5 gal) per minute representes a flow rate below which the pressure loss is less than 1/16 of its value. Pressure increases in the line due to pumping should cause a minimum of disturbance to system users during a period of such low usage. A study of the hydrographs indicated that pumping to storage from 10 p.m. to 7 a.m. would cause the least disturbance to the customers.

SUMMARY AND CONCLUSTIONS

Monthly usage data were collected on Rural Water District No. 3, Payne County, OK, from February to September, 1974. Statistical analysis indicated significant differences between two economical classes of homes. A summary of monthly usage data is found in Table 2.

Perusal of Fig. 3 allows the design engineer to determine what the storage amount should be. For example, if the engineer decides that he wants the consumptive use of only 15 percent of the days to exceed the planned daily storage amount and only Class A customers will exist on the line, then a storage amount of 1 330 L (350 gal) per tap per day will be appropriate. This graph can be used with interpolation to design for a mix of customers. Optimal design values (based on 15 percent expected inadaquacy) chosen from Figs. 3 to 5 yield the results found in Table 3.

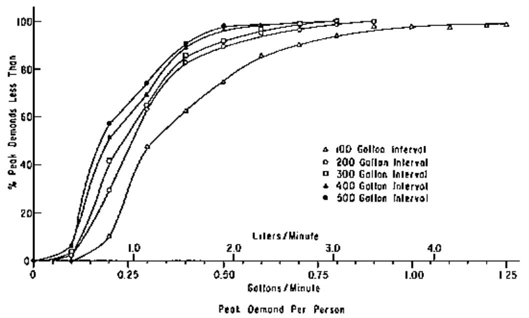

FIG. 9 Cumulative frequency curves of peak demand per person.

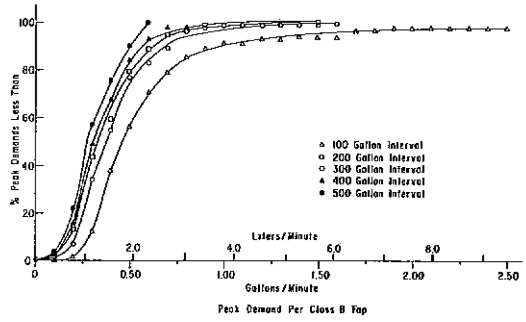

FIG. 8 Cumulative frequency curves of peak demands per Class B tap.

TABLE 3. DAILY WATER USE.

	Daily use per tap		Daily use per cow or person	
	(gal)	(liters)	(gal)	(liters)
Dairy	600	2780	12	46
Class A	350	1330	150	570
Class B	200	760	90	342
Tested mix of A and B	340	1292	100	380
Original design	150	570		

Optimal values of demand per tap to be used in pipe size determination were obtained from Figs. 6 to 11 and are found in Table 4 below.

TABLE 4. DESIGN FLOWRATES.

	gpm per tap	Lpm per tap	gpm per person	Lpm per person
Class A	1.3 - 1.8	4.9 - 6.8	0.5 - 0.7	1.9 - 2.7
Class B	0.6 - 0.9	2.3 - 3.4	0.3 - 0.6	1.1 - 2.3
Tested mix of A and B	1.0 - 1.5	3.8 - 5.7	0.6 - 0.8	2.3 - 3.0
Original design	2.0	7.6		

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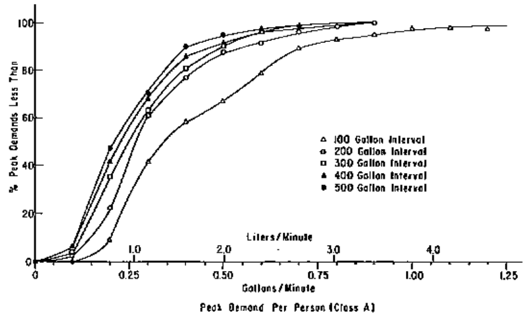

FIG. 10 Cumulative frequency curves of peak demand per person [Class A residence].

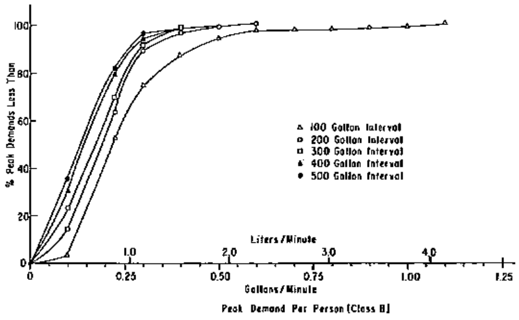

FIG. 11 Cumulative frequency curves of peak demand per person [Class B residence].

Rural Water Systems

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The optimal period for off-peak pumping for a residential system was found to be from 10 p.m. to 7 a.m. The FMHA suggested design value of 7.57 Lpm/tap is satisfactory in that it permits some system expansion before design values of pressure drops are reached. If this system is typical, design values of tank capacities should be about doubled. This will subsequently require either larger pump capacity or more hours per day of pumping, or both. If water is purchased from cities, average monthly usage per tap during the warmest months may reach 45 600 L (12,000 gal) which should be considered in any contractual arrangement.

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