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Design and operating criteria for rural water systems

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URAL homesteads 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 contractual 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 FHA Instruction 424.2, Exhibit A (1972), which has been superseded, required 300 gal of storage and a design flow rate of 2 gpm for each rural family.

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
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, 1140, 1520, and 1900 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.

**TABLE 1. MONTHLY USE RATIOS.**

<table>
<thead>
<tr>
<th>Month</th>
<th>Dairy/Class A</th>
<th>Class B/Class A</th>
<th>Class B/Class B</th>
</tr>
</thead>
<tbody>
<tr>
<td>February</td>
<td>1.66</td>
<td>0.45</td>
<td>0.85</td>
</tr>
<tr>
<td>March</td>
<td>2.02</td>
<td>0.64</td>
<td>0.89</td>
</tr>
<tr>
<td>April</td>
<td>2.04</td>
<td>0.56</td>
<td>0.84</td>
</tr>
<tr>
<td>May</td>
<td>1.69</td>
<td>0.53</td>
<td>0.88</td>
</tr>
<tr>
<td>June</td>
<td>2.30</td>
<td>0.41</td>
<td>0.81</td>
</tr>
<tr>
<td>July</td>
<td>1.60</td>
<td>0.25</td>
<td>0.59</td>
</tr>
<tr>
<td>August</td>
<td>1.72</td>
<td>0.38</td>
<td>0.55</td>
</tr>
<tr>
<td>September</td>
<td>1.97</td>
<td>0.44</td>
<td>0.54</td>
</tr>
</tbody>
</table>

*Average Use per Dairy Tap
†Average Use per Class A Tap
‡Average Use per Class B Tap

**FIG. 1 Monthly usage per tap.**

**FIG. 2 Monthly usage per 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.**
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 represents 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 CONCLUSIONS**

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 1330 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 inadequacy) chosen from Figs. 3 to 5 yield the results found in Table 3.
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.

References

1. Farmers Home Administration. 1972. Planning and developing community water and waste disposal facilities. USDA Instruction 424.2, Exhibit A.