# MUNICIPAL WATER DEMAND STUDY
# OKLAHOMA CITY
# and
# TULSA OKLAHOMA

**June 1984**

**Publication 123**

**By**

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**Administrative Officer**

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**OKLAHOMA WATER RESOURCES BOARD**

**TULSA OFFICE**

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Abstract

By using a multiple regression model, this longitudinal study analyzes the methods and results of the factors which influence water consumption in Oklahoma City and Tulsa, Oklahoma. The results indicate that average price and per capita income were predictive variables for Oklahoma City's water demand, while only per capita income was found to be a predictor for consumption in Tulsa.

In the past, most states and municipal public water supply systems utilized population to forecast future water demands (Howe and Linaweaver, 1971). This projection technique assumed that water use was only affected by this variable. Although this constituent is important in the planning process, it clearly does not account for all of the variation in quantity demanded.

The goal of this study is to define and analyze the postulated social, environmental and economic factors which influence consumption and provide decision-makers with a tool for projecting their long-term municipal water demands.

Background

Water has played a pivotal role in the economic growth of both Oklahoma City and Tulsa. While Oklahoma City's economy revolves around the wholesale and retail trades, personal services, manufacturing and government services, Tulsa's is based on oil and gas activities, wholesale and retail trades, manufacturing services and construction. Oklahoma City is the state's capitol and largest city. Along with Tulsa, these two Standard Metropolitan Statistical Areas (SMSA) represent approximately one-half of Oklahoma's three million residents.

Water is available to Oklahoma City from both ground water and stream water resources. Due to the large quantities of water required, the city relies primarily upon surface water--with ground water used as a backup or special application role. Oklahoma City receives its water from the North Canadian River through Lakes Hefner and Overholser and Lake Atoka in

southeastern Oklahoma. Water from Atoka is transported via a 90-mile pipeline to Lake Stanley Draper, where it is stored. In the 1960's, Oklahoma City began leasing storage in Canton Reservoir, upstream of Lake Overholser, to supplement its North Canadian system. Upon completion of McGee Creek Reservoir, under construction in Atoka County, the city will be provided additional supply through its existing Atoka pipeline.

Tulsa is no less fortunate in having an adequate supply for its water demands. Since 1924, Spavinaw Creek has been the major source of water for the city of Tulsa. The two city-owned lakes, Spavinaw and Eucha, are located approximately fifty miles east of Tulsa in northeastern Oklahoma. Spavinaw Lake, the smaller of the two municipal lakes, was the first major transbasin water supply facility constructed in Oklahoma. To augment the storage of the Spavinaw system, Eucha was constructed three miles upstream. In the mid-1950's, a connection was made to Lake Hudson to provide an emergency supply--which was used by the city for the first time during the spring and summer drought of 1981. The city of Tulsa has additional water supply through a pipeline connection to Lake Oologah. Completed in 1977, this supply line pumps water to the A. B. Jewell Reservoir for treatment and distribution.

## Model and Method

As was noted previously, several elements are anticipated to affect the consumption of municipal water supplies. The model applied in the study assumes that the quantity of water demanded is a function of average price per unit, per capita income of users, precipitation, temperature and number of households per unit of population. A logarithmic regression analysis will produce elasticities that demonstrate the comparative effects of variations of these factors upon the amount of municipal water consumed.

Data illustrative of these variables were gathered from sources and methods discussed below.

The Oklahoma City and Tulsa Municipal Water Departments provided their records, which included summary information on treated water production (pumpage) and water revenues collected for each year from 1961 through 1980. Customers served by both water utilities are predominantly residential users, with some commercial and industrial consumption included. Until recently, data was not available from either city by class of user. Therefore, no attempt was made to distinguish or analyze water demand by user class.

A standard measure for the dependent variable, annual per capita water consumption, is water pumped per capita per year. This measure is derived by dividing total yearly water production by the corresponding population served by the system. As noted above, production figures were supplied by the utilities, while population data was obtained from "Census" documents and the Oklahoma Employment Security Commission. Population figures employed in the study were Oklahoma and Tulsa County totals. Since both utilities do not serve all retail customers within their county, entities which are not supplied by either city were excluded from the aggregates. Precluded from Oklahoma County figures were Bethany, Del City, Midwest City and Edmond, while Sand Springs, Broken Arrow and Collinsville were removed from Tulsa County totals.

A conventional pricing system is utilized by both Oklahoma City and Tulsa. Water rates are based on metered consumption of each retail customer. A fee is assessed for a set minimum amount ("block") of water, with the price per block decreasing as the quantity of water use increases. Since the rates are not identical and inadequate data exists to determine the increments of water in each rate structure, a new measure of price had

to be selected. The variable designated was the "average price of water per thousand gallons." This measure was obtained by dividing total yearly revenue collected by that year's corresponding water delivered (in thousands of gallons). The quotient was then deflated using the consumer price index (100 for 1967), which produced the average real charge per thousand gallons.

Income data was provided by the Center for Economic and Management Research at the University of Oklahoma and the city of Tulsa's Department of City Development and Metropolitan Chamber of Commerce. The measure for per capita income was derived by dividing total personal income by population and then deflating this number to constant 1967 dollars.

Similar to other semiarid regions of the country, a large portion of Oklahoma City's and Tulsa's water use is for lawn and garden irrigation. Since this sprinkling serves as a substitute for rainfall, climatic factors are important variables affecting the consumption of municipal water over time. Weather data on average monthly precipitation and temperature were obtained from National Oceanic and Atmospheric Administration publications.

The recent national population shifts from eastern and midwestern cities to the "Sunbelt" has caused a change in Oklahoma City's and Tulsa's household size and composition. This alteration in population has created a movement away from single family houses toward a larger proportion of multi-family dwellings. To take this trend into account, the study observed how the number of households per thousand population affects water demand. The measure was obtained by dividing the number of persons per household by the population and then dividing the quotient by the population figure and multiplying by one thousand.

Results

Initially, the variables were individually studied using conventional

## Conclusion

The most notable fact to emerge here was, the importance of constant per capita income in determining water consumption. Whether considered alone or included with other variables, the income factor was always found to be a significant determinant of water demand. For policy makers, this would imply that, the planning effort for future water use could be improved by incorporating income data into projected water needs.

Inferences regarding average real price are more difficult to make. Although the variable was found to be significant in each city when used, alone it did not have as high a correlation value as income and was not found to be significant in Tulsa, when joined to other variables. However, mention should be made of the consistent, even dramatic, decline of real average price of water in both cities over a twenty year period. Public officials, intending to use the pricing mechanism to achieve some level of income or consumption, should be keenly aware of the eroding effects of inflation on the implementation of such strategies.

As a single explanatory variable for Tulsa, the number of households per thousand population was found to be as significant and as highly correlated to water consumption as per capita income. In Oklahoma City, the statistic relating to households was significant, though not as highly correlated as other factors. However, when this variable was combined with others the expected sign changed and/or it became statistically insignificant. This, in turn, caused it to be dropped from the model.

Environmental factors were not found to be correlated to water use. It is thought that this is, in major part, due to the inability to separate the various classes of water users within the category of total water use.

TABLE I

Coefficients of Determination and Regression Coefficients Using Simple Linear Regression Relating Price, Income, Rainfall, Temperature, and Households per Thousand Population to Water Consumption in Tulsa and Oklahoma City.

| | TULSA | | OKLAHOMA CITY | |
|---|---|---|---|---|
| | Regression Coefficient | $r^2$ | Regression Coefficient | $r^2$ |
| Average Price | 135677.5750 (A) | .84 | 75184.9585 (A) | .90 |
| Per Capita Income | 19.9856 (A) | .92 | 11.8424 (A) | .89 |
| Rainfall | 161.6799 (B) | .00 | 671.0562 (B) | .00 |
| Temperature | 3667.9478 (C) | .14 | 549.8456 (B) | .00 |
| Households | 390.0237 (A) | .91 | 348.3495 (A) | .85 |

(A) Statistically significant from 0 at the 1% probability level.

(B) Statistically not significant from 0 at the 10% probability level and/or sign contrary to expectations.

(C) Statistically significant from 0 at the 10% probability level.

TABLE II

Coefficients of Determination, Regression Coefficients, and Logarithmic Regression Coefficients Relating Price and Per Capita Income to Water Consumption in Tulsa and Oklahoma City.

| | TULSA | | | OKLAHOMA CITY | | |
|---|---|---|---|---|---|---|
| | Average Price Coefficient | Per Capita Income Coefficient | $r^2$ | Average Price Coefficient | Per Capita Income Coefficient | $R^2$ |
| Linear Equation | * | 19.9857 | .92 | -40140.4186 | 6.1852 | .94 |
| Logarithmic Equation | * | 1.1414 | .91 | -.3031 | .5793 | .93 |

*Average price found to be not statistically different from zero.

# APPENDIX

ANNUAL PER CAPITA WATER CONSUMPTION
* (Y VARIABLE)

| YEAR | OKLAHOMA CITY | TULSA |
|---|---|---|
| 1961 | 31,987 | 49,126 |
| 1962 | 34,508 | 50,500 |
| 1963 | 37,175 | 54,059 |
| 1964 | 38,579 | 52,907 |
| 1965 | 37,521 | 53,740 |
| 1966 | 39,399 | 54,247 |
| 1967 | 36,298 | 49,869 |
| 1968 | 37,792 | 51,741 |
| 1969 | 41,440 | 55,115 |
| 1970 | 43,892 | 57,646 |
| 1971 | 45,484 | 56,968 |
| 1972 | 51,691 | 59,810 |
| 1973 | 48,507 | 60,179 |
| 1974 | 51,101 | 64,740 |
| 1975 | 50,830 | 67,186 |
| 1976 | 53,861 | 70,088 |
| 1977 | 54,007 | 74,491 |
| 1978 | 55,745 | 80,994 |
| 1979 | 54,407 | 85,097 |
| 1980 | 60,268 | 90,362 |

* Treated water pumped into the distribution system divided by the total population served by the system.

PRICE OF WATER PER THOUSAND GALLONS
(dollars)
$X_1$

| YEAR | OKLAHOMA CITY | TULSA |
|---|---|---|
| 1961 | .56815 | .38268 |
| 1962 | .57514 | .41372 |
| 1963 | .54994 | .39000 |
| 1964 | .54155 | .38406 |
| 1965 | .55305 | .37701 |
| 1966 | .52876 | .36742 |
| 1967 | .59891 | .35949 |
| 1968 | .57258 | .34410 |
| 1969 | .53241 | .34723 |
| 1970 | .52499 | .34849 |
| 1971 | .54475 | .34268 |
| 1972 | .44585 | .30381 |
| 1973 | .43276 | .24826 |
| 1974 | .39714 | .22081 |
| 1975 | .36890 | .20803 |
| 1976 | .36315 | .23055 |
| 1977 | .36654 | .21194 |
| 1978 | .32953 | .19922 |
| 1979 | .29425 | .17129 |
| 1980 | .27161 | .16759 |

Method: Deflated revenue collected for one year divided by that year's corresponding water delivered. The quotient is multiplied by one thousand, which equals the average real charge per thousand gallons.

PER CAPITA INCOME*
(dollars)
$X_2$

| YEAR | OKLAHOMA CITY | TULSA |
|---|---|---|
| 1961 | 2,438 | 2,923 |
| 1962 | 2,515 | 2,945 |
| 1963 | 2,674 | 3,086 |
| 1964 | 2,826 | 3,221 |
| 1965 | 2,961 | 3,337 |
| 1966 | 3,150 | 3,401 |
| 1967 | 3,254 | 3,440 |
| 1968 | 3,458 | 3,537 |
| 1969 | 3,475 | 3,526 |
| 1970 | 3,507 | 3,489 |
| 1971 | 3,578 | 3,455 |
| 1972 | 3,725 | 3,623 |
| 1973 | 3,832 | 3,817 |
| 1974 | 3,896 | 3,961 |
| 1975 | 3,870 | 4,104 |
| 1976 | 4,025 | 4,276 |
| 1977 | 4,253 | 4,457 |
| 1978 | 4,498 | 4,634 |
| 1979 | 4,604 | 4,788 |
| 1980 | 4,664 | 4,809 |

*Data is deflated to constant (1967) dollars.

AVERAGE MONTHLY PRECIPITATION
(inches)
$X_3$

| YEAR | OKLAHOMA CITY | TULSA |
|---|---|---|
| 1961 | 2.90 | 4.28 |
| 1962 | 2.26 | 3.62 |
| 1963 | 2.15 | 2.40 |
| 1964 | 2.43 | 3.71 |
| 1965 | 2.01 | 2.56 |
| 1966 | 2.13 | 2.24 |
| 1967 | 2.15 | 3.08 |
| 1968 | 2.96 | 2.98 |
| 1969 | 2.43 | 2.50 |
| 1970 | 4.44 | 2.84 |
| 1971 | 2.28 | 4.70 |
| 1972 | 2.30 | 2.96 |
| 1973 | 3.48 | 5.82 |
| 1974 | 3.29 | 4.94 |
| 1975 | 2.94 | 3.73 |
| 1976 | 1.51 | 2.83 |
| 1977 | 2.38 | 3.46 |
| 1978 | 2.60 | 3.18 |
| 1979 | 3.43 | 3.53 |
| 1980 | 2.03 | 2.78 |

AVERAGE MONTHLY TEMPERATURE
(degrees F)
$X_4$

| YEAR | OKLAHOMA CITY | TULSA |
|---|---|---|
| 1961 | 59.00 | 58.06 |
| 1962 | 59.10 | 58.20 |
| 1963 | 61.00 | 61.60 |
| 1964 | 60.30 | 61.10 |
| 1965 | 61.70 | 61.90 |
| 1966 | 59.90 | 59.50 |
| 1967 | 60.40 | 59.30 |
| 1968 | 58.20 | 58.60 |
| 1969 | 59.20 | 59.70 |
| 1970 | 59.50 | 59.40 |
| 1971 | 59.30 | 60.20 |
| 1972 | 59.60 | 59.60 |
| 1973 | 59.20 | 60.00 |
| 1974 | 59.90 | 60.10 |
| 1975 | 58.90 | 59.50 |
| 1976 | 59.70 | 59.20 |
| 1977 | 61.40 | 61.70 |
| 1978 | 59.70 | 59.80 |
| 1979 | 58.10 | 59.30 |
| 1980 | 61.30 | 62.70 |

NUMBER HOUSEHOLDS PER 1,000 POPULATION

$X_5$

| YEAR | OKLAHOMA CITY | TULSA |
|---|---|---|
| 1961 | 336.70 | 333.33 |
| 1962 | 338.98 | 335.57 |
| 1963 | 340.14 | 337.84 |
| 1964 | 341.30 | 340.14 |
| 1965 | 344.83 | 341.30 |
| 1966 | 347.22 | 342.47 |
| 1967 | 347.22 | 342.46 |
| 1968 | 350.88 | 344.83 |
| 1969 | 350.87 | 344.82 |
| 1970 | 352.11 | 344.83 |
| 1971 | 350.88 | 354.61 |
| 1972 | 354.60 | 363.63 |
| 1973 | 361.01 | 373.13 |
| 1974 | 371.74 | 383.14 |
| 1975 | 377.35 | 390.62 |
| 1976 | 383.14 | 398.41 |
| 1977 | 390.62 | 408.16 |
| 1978 | 395.26 | 414.94 |
| 1979 | 401.61 | 413.22 |
| 1980 | 403.23 | 411.52 |

Method: Persons per household, divided by population figures. The quotient is divided by the population figure and then multiplied by one thousand.

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