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# Water Use Trends in South Dakota

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by

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ABSTRACT: This report traces the demand for water in various sectors of the economy of South Dakota. Expected trends in water demand are projected. The conclusions show that from 1960 to 1985 the overall demand for water withdrawals increased at an annual rate of 3.275 percent. The public supplied water for industrial and commercial use sector and the irrigation sector of increased at the highest rates.

* This report is the second in a series of four reports concerning water institutions and laws in South Dakota and the Upper Midwest States and water use trends in South Dakota and Upper Midwest States. The four reports are entitled:

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"Water Use trends in South Dakota" Economics Research Report 91-6 Economics Department South Dakota State University August 1991;

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# WATER USE TRENDS IN SOUTH DAKOTA

## INTRODUCTION

Agriculture in South Dakota has undergone extensive change over the last 50 years. From 1940 to 1987, the total number of farms has decrease by 50 percent and the total number of acres in farms has increased 12 percent. However, total irrigated farms and total acres irrigated have both increased dramatically, 93 and 569 percent, respectively. Since 1974, total irrigated farms increased by 74 percent and total irrigated acres increased by 138 percent (U.S. Department of Commerce). In 1985, over 756,000 acre feet of water withdrawals for offstream water use was conducted in South Dakota. Primary uses are irrigation, domestic, and industrial (U.S. Department of the Interior, 1988). The amount of water used is increasing as population grows, as farmers implement the use of irrigation to reduce risk, and as the state's economy becomes more diverse. Within South Dakota there is both geographic and temporal variability, resulting in various degrees of water scarcity relative to the quantities demanded. The allocation method for the available water must be appropriate for these variations.

### Current System of Water Allocation in South Dakota

In 1955, the South Dakota Legislature passed a major water act which transformed the state's water law. All water was declared the property of the people. The right to use this water became subject to the appropriation statutes. All water was to be applied to the fullest beneficial use. Conservation was to be practiced when in the context of reasonableness and beneficial use. Mining, withdrawal of a quantity of water greater than the source's estimated yearly recharge, was not permitted. Thus, the state was to hold its water in trust for the peoples' use and benefit. Usufructuary rights

gave users of water the opportunity to acquire a right to use water under one or both of the established doctrines of water allocation. The state held the right to determine the use of its water, provided that the regulation was reasonable and not arbitrary, and that the approved uses were within the general welfare of the public.

## FACTORS AFFECTING SOUTH DAKOTA WATER SUPPLY

The supply of water in a specified area, like any other natural resource, can be divided into three subgroups: physical, technological, and economic. The physical supply is the total amount of water. The technological supply is the amount of water that can be recovered with the use of all known technology. The economic supply is the amount of water that can be recovered given all economic constraints. Society uses only a small portion of the total physical supply because of technological and economic constraints on both quantity and quality.

Regional shortages exist as a result of uneven distribution of these supplies. The cost of obtaining water in some cases is less through regional, or intrabasin transfer of water supplies. Three cases of such transfers have occurred in South Dakota, and are summarily discussed in this section. Other regional problems caused by municipal growth and river basin shortages are also discussed.

### Ground Water

The physical supply of ground water is large in South Dakota. Total known physical supplies are over 3.97 billion acre feet of recoverable water (Allen, et al and Hedges et al). This is equivalent to a one acre column of water that is 752,000 miles high (or an area of 3.97 billion acres with one

foot of water). Based on the total water use in South Dakota for 1985, 816.75 thousand acre feet, the total physical supply of ground water would last over 4,800 years, assuming no recharge, no use of surface water, and no change in the annual rate of use. With the same assumptions, the 1975 rate of use in South Dakota, 665.5 thousand acre feet, would last over 5,900 years. Keeping all assumptions the same, in the ten years between 1975 and 1985, the rate of use increased such that an 18-20 percent reduction in the life span of the physical ground water supply occurred. Future increases in the rate of use would further reduce the projected life span.

This analysis is not realistic, though. Water use in South Dakota is not limited by the assumptions used above. Surface water accounts for the majority of the water used, ground water sources are recharged, and there are economic and technological constraints to using this abundant physical supply of ground water.

Some regions of South Dakota have vast physical supplies of water that are economically and technologically feasible to obtain and which are in excess of the region's quantity demanded. In other regions the quantity demanded exceeds the economic supply, thus leaving the region short of water. Three such regions are the city of Rapid City, the Upper James River Basin, and the city of Sioux Falls.

Water is important to economic development within a municipality. Rapid City has been trying to obtain additional water rights for several years. The city holds primary rights to the waters of Lake Pactola, a man-made lake developed through a federal project. Low rainfall and snowmelt recharge levels and increases in the use of water by Rapid City and the area's irrigators have drastically reduced the quantity of water in the reservoir.

Recreation uses have placed additional demands on the water supply. Substantial economic losses have resulted from the decreased irrigation and recreational uses of water in the Rapid City area (Hatch, personal communication).

The drought of the summer of 1989 caused total restrictions on irrigation water use in the Upper James River Basin, first north of Huron, then north of Mitchell. Low supplies of water in Sand Lake, ND, the feeder reservoir to the James River, necessitated these bans to maintain downstream flows. The decision to manage the shortage on a geographical basis precluded the priority dates of the water rights involved (Hatch). Southern Basin water rights were thus more valuable than the northern rights because of their sustained right to use water during the time of shortage (Davidson, personal communication).

A third region of water shortage is the municipality of Sioux Falls. Continued population and industrial growth places strains on the municipal water system supply. The summers of 1988, 1989 and 1990 included periods of water rationing. New wells outside of the city in the Big Sioux Aquifer are being drilled and are intended to meet the short term needs of the city. A longer term plan includes the use of the Missouri River as a source (Hatch).

## Transfers of Water Rights -- Changes in Use

Since 1962, three transfers of water rights involving a change in use have occurred in South Dakota. Two are transfers of irrigation rights to a municipality and one is the transfer of irrigation rights to a rural water system. New uses are primarily domestic. These transfers are important in demonstrating that regional shortages, based on the quantities supplied and

demanded, exist, and that a transfer can move water to a higher valued use reducing the negative effects of a regional shortage.

The first transfer occurred in 1962. The city of Belle Fourche transferred an irrigation water permit from city owned farm land to the municipal system. The city faced the responsibility of providing water to a growing community, including nearby missile bases (City of Belle Fourche).

In 1987, Homestake Mining Company transferred an irrigation water right to the City of Spearfish for use in the municipal system. The diversion point was changed and withdrawals were limited to the period April 1 through October 31 as per the previous irrigation permit (Homestake).

The third transfer involves a private irrigator of rural Brookings County, South Dakota who transferred approximately 40 acres of land, the water rights to such land, and the water rights of an adjoining 23 acres, to the Brookings-Deuel and Kingbrook Rural Water Systems. The 23 acres, henceforth without irrigation rights, were placed in the federal Conservation Reserve Program. Use of this water by the rural water system is limited to withdrawals during the period April 1 to September 30, as per the previous irrigation permit. This transfer was feasible through SDCL § 46-5-34.1, allowing transfers of irrigation water rights to municipalities or rural water systems (Brookings-Deuel).

The physical supply of water within the boundaries of South Dakota is very large and is not a constraint to economic growth in the state. The true constraint is the cost of putting the available water resources to use and the value of using them. Technological and economic constraints, restricting the use of unevenly distributed and varying quality water resources, increase the cost of water and thus less is available for use.

As the area of focus moves from a global perspective, where supply is constant and inelastic, to a more localized region, the elasticity increases and the usable supply fluctuates as the cost of putting available water resources to use changes. Pollution, both natural and manmade, decreases the usable supply of water. Technological and economic constraints further limit the quantity of polluted water actually used. As technology improves the efficiency and reduces the cost of water purification, greater quantities of water resources are available for use.

## TRENDS IN WATER DEMAND

An analysis of the growth rates of the various sectors of water use within the state illustrates the changing demand for water in South Dakota. The purpose of this analysis is to develop a reasonable estimate of future water demand in South Dakota, based on state water use projections.

### Description of the Sectors of Water Use

The focus of the growth rate analysis of water use data will be in the categories of population, total water use, water delivered for irrigation, rural water for domestic and livestock use, public supplied water withdrawals, and total self supplied industrial water use. These categories represent the combination of the most reliable data and the breadth of water uses necessary to make conclusions regarding regional and statewide demand for water.

The data are divided into four sectors of water use: irrigation, rural, public supplied and self supplied. These sectors represent the categories of all uses of water as defined by the U.S. Geological Survey (U.S. Department of the Interior, 1988). The sectors are defined as:

Irrigation water - "artificial application of water on lands to assist in the growing of crops and pastures or to maintain vegetative growth in recreational lands, such as parks and golf courses".

Rural water - "water used in suburban or farm areas for domestic and livestock needs. The water generally is self supplied and includes domestic use, drinking water for livestock, and other uses, such as dairy sanitation, evaporation from stock-watering ponds, and cleaning and waste disposal".

Public supplied - "water withdrawn by public and private water suppliers and delivered to groups of users. Public suppliers provide water for a variety of uses, such as domestic, commercial, thermoelectric power, industrial, and public water use".

Public water - "water supplied from a public water supply and used for such purposes as fire fighting, street washing, and municipal parks and swimming pools".

Self supplied water - water withdrawn from a surface or ground water source by a user rather than being obtained from a public supply.

Industrial water - "water used for industrial purposes such as fabrication, processing, washing, and cooling, and includes such industries as steel, chemical and allied products, mining, and petroleum refining. The water may be obtained from a public supply or may be self supplied".

The water use sector that has the greatest impact on the total use of water in the western states is irrigation. An understanding of the farm sector is important in comprehending the trend of irrigation water use. The Farm Data consist of an analysis of the growth in several farm related categories defined by the U.S. Department of Commerce in the Census years from 1940 to 1987: the number of farms, harvested acres, irrigated farms, acres irrigated and irrigated cropland harvested. The categories are defined as:

"Farms" - the total number of farms in the state that year.

"Harvested acres" - the total number of acres harvested on the farms.

"Irrigated farms" - the number of farms where irrigation was used on some portion of the land during that year.

"Acres irrigated" - the total number of acres that were irrigated on the irrigated farms.

"Irrigated cropland harvested" - the total number of acres of irrigated cropland that was harvested.

These categories represent direct and indirect indicators of substantial change in water use. For instance, an increase in the number of irrigated farms while the total number of farms decreases, indicates an increase in the proportion of existing farms that use irrigation. All of these factors relate to indirect indicators of water use. When combined with the irrigation Water Use Data, a more accurate projection of water use can be made. Irrigation accounts for over two-thirds of the water use in the state. Therefore, its impact on the overall trend of water use is substantial.

Trends

An exponential growth function is used to project the trends of water use in South Dakota. The growth rate of the dependent variable is proportional to the unit change in the independent variable. The factor of proportionality is the coefficient of the independent variable. The estimated least squares method is used to predict the coefficient value. The dependent variables are the categories such as population or water delivered for irrigation. The independent variable is the progression of time, or rather, the year. The data used in this analysis are obtained from census data collected every several years, thus representing a sample of the total data. The specific functional relationship of the model is of the form:

$Y = ae^{bX}$ where $Y$ = dependent variable (a category, such as water use)

$a$ = constant

$e$ = exponential

$b$ = X-coefficient (growth rate)

$X$ = independent variable (the census year)

$$\ln Y = \ln a + bX$$
$$d(\ln Y) = d(\ln a) + d(bX)$$
$$d(\ln Y)/dX = b = (\text{percent change } Y)/(\text{change } X)$$

Using ordinary least squares, the results of each regression analysis include the X-coefficient, the R-square, and the level of significance. The X-coefficient is the most important result of the model. The independent variable, the census year, for each of the dependent variables, is regressed such that the X-coefficient, b, results. This coefficient, when multiplied by 100, results in an annual percent rate of growth of the dependent variable, or category. Predictions of future growth of the dependent variable are based on the X-coefficient and the degree of reliability of the data.

The R-square is a measure of the proportion of the variation in the dependent variable explained by the explanatory or independent variable. A high $R^2$ (roughly greater than 0.6) indicates a strong predictive capacity of the dependent variable by the independent variable. The level of significance is another measure of the reliability of the X-coefficient. It is measured from a t ratio.

Tables 1 and 2 consist of the results of South Dakota's water use and farm regression analysis. In Table 1, for the population category, the X-coefficient value indicates a 0.14 percent increase in population in South Dakota per year. The R-square value, 0.4122 indicates the X-coefficient's goodness-of-fit and the level of significance of the X-coefficient follows. The other categories are also read in the same manner. The Farm Data Analysis Table 2 display rates of change per year for farm size, harvest and irrigation data. It is read the same way as the Water Use Data tables.

Table 1 indicates that the rate of use of water in South Dakota is increasing in all water use sectors. Per capita water use is increasing as a

Table 1: Estimated Use of Water in South Dakota, 1960-85

| Sector of Water Use | X coefficient | R Squared | level of signific. |
|---|---|---|---|
| General | | | |
| population | 0.00137 | 0.4122 | 0.80 |
| water use per capita | 0.02333 | 0.7855 | 0.98 |
| total water withdrawals | 0.03275 | 0.7950 | 0.98 |
| total water consumed | 0.03138 | 0.8084 | 0.98 |
| Irrigation Sector | | | |
| water delivered | 0.04386 | 0.8933 | 0.99 |
| water consumed | 0.04631 | 0.8484 | 0.99 |
| Rural Sector | | | |
| domestic & livestock use | 0.00303 | 0.0079 | < 0.80 |
| domestic & livestock consumption | 0.02936 | 0.2680 | 0.80 |
| Public Supplied Sector | | | |
| total water withdrawals | 0.02080 | 0.7240 | 0.95 |
| water withdrawal per capita | 0.01039 | 0.3609 | < 0.80 |
| water delivered for: | | | |
| industrial & commercial use | 0.04475 | 0.5555 | 0.90 |
| domestic & public use | 0.01651 | 0.2826 | < 0.80 |
| Self Supplied Industrial Sector | | | |
| total water use | 0.04078 | 0.2099 | < 0.80 |
| total water consumption | 0.01780 | 0.1105 | < 0.80 |
| thermoelectric use | 0.07253 | 0.6895 | 0.95 |
| thermoelectric consumption | -0.03611 | 0.0687 | < 0.80 |
| other industry use | 0.03852 | 0.1778 | < 0.80 |
| other industry consumption | 0.01325 | 0.0288 | < 0.80 |

Source: U.S. Department of the Interior. Geological Survey. 1951, 1957, 1961, 1968, 1970, 1972, 1977, 1983, 1988.

Table 2: Farm Data Analysis for South Dakota

| Category of Farm Data | X coefficient | R Squared | level of signific. |
|---|---|---|---|
| farms | -0.01627 | 0.9869 | 0.99 |
| harvested acres | -0.00277 | 0.1208 | < 0.80 |
| irrigated farms | 0.01886 | 0.7624 | 0.99 |
| acres irrigated | 0.04337 | 0.9305 | 0.99 |
| irrigated cropland harvested | 0.04572 | 0.9449 | 0.99 |

Source: U.S. Department of Commerce. Bureau of the Census. 1940, 1945 1950, 1954, 1959, 1964, 1969, 1974, 1978, 1982, 1987.

result of population growth and significant increases in the use of water, particularly in the following sectors: water delivered for irrigation, public supplied water delivered for industrial and commercial use, and self supplied industrial water for thermoelectric use. All sectors and subsectors show increases in the use of water except for self supplied industrial water consumption through thermoelectric use. This may suggest an increase in the efficiency of thermoelectric use of water. The total number of farms and the total number of acres in farms are decreasing in South Dakota (See Table 2). The number of irrigated farms, acres irrigated and acres of irrigated cropland harvested are increasing. The individual rates at which this is occurring indicate that the farms that are using irrigation are irrigating more acres of their land each year, resulting in a significant increase in the number of acres of irrigated cropland that are harvested. A one percent increase in the number of irrigated farms occurs at the same time as a 4.5 percent increase in the number of acres of irrigated cropland harvested. The growth rate of irrigation cropland harvested is greater than the growth rate of irrigated acres, suggesting that the more irrigated acres are being harvested than in previous years. A one percent increase in acres irrigated occurs at the same time as a 1.05 percent increase in irrigated cropland harvested.

In summary, the demand for water in South Dakota is increasing at a significant rate. All water using sectors are increasing their demand for water. As the largest water use sector in South Dakota, irrigation water use is sensitive to shortages of water. The demand for water is expected to increase in the future with considerable growth in both irrigation and total water use. Continual increases in the percent of farms using irrigation should result in increases in water use. Movement toward an equilibrium level

of both the ratio of irrigated farms to total farms and the ratio of irrigation water use to total water use is expected. The demand for water in South Dakota will increase continuously until this stage is reached.

## SUMMARY

Circumstances regarding water use in South Dakota are changing. Within the last several years water shortages have occurred in the two largest urban communities and through the agricultural production area. South Dakota laws do not allow for mobile water rights except the transfer of irrigation rights to a municipality or to a rural water system. This exception is the most important type of transfer because it represents the largest supply of water and the most highly valued use of water. Even greater flexibility in water allocation will be necessary in the future, though, as demand continues to increase and supply remains relatively inelastic due to economic and technological infeasibility.

Even though irrigated acres have declined from 1982 to 1987 (3.9 percent), it is expected a modest increase through time as more droughts occur. With respect to municipal, industrial and commercial demand for water it is expected the long run demand for water to continue to increase and not at a modest rate but much larger. Within South Dakota the vast physical supplies of water can meet the expected demands for water for years to come if economic and technological limitations are overcome. The quantity of water supplied can be increased through water development but limitations exist, particularly on large scale developments. The quantity of water demanded can be reduced by eliminating waste in current uses. Thus, by increasing the available supply and decreasing the demand, then shortages will occur less

frequently. As all water use sectors and categories continue to increase the demand for water, the uneven distribution of supplies and varying quantities and qualities of water will persist in restricting the amount of water available for use. Changes in water use, delivery, investment, transfers, and laws will continue to change the trend of water demand in the state.

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