

ECONOMICS OF GROUND-WATER DEVELOPMENT
IN THE HIGH PLAINS OF COLORADO

by

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COLORADO WATER RESOURCES



RESEARCH INSTITUTE

Colorado State University
Fort Collins, Colorado

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ECONOMICS OF GROUND WATER DEVELOPMENT
IN THE HIGH PLAINS OF COLORADO

to

Office of Water Resources Research
Department of the Interior

from

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Principal Investigator
Department of Economics

and

Colorado Water Resources Research Institute
Colorado State University
Fort Collins, Colorado
November 1969

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I. Project Objectives

1. To evaluate the economic consequences of various patterns of ground water development and use in the High Plains area of Colorado.
 - a. To determine the potential contribution of ground water development from alternative developmental patterns to the economic development of the study area.
 - b. To determine farm firm adjustment problems associated with (1) the introduction of irrigated farming and (2) the gradual lowering of the water table.
 - c. To determine the effects of agricultural adjustments on non-agricultural segments of the local economy at various rates of ground water development.
2. To examine the effects of alternative economic criteria as aids in establishing an institutional framework for guiding or regulating ground water development.

II. Project Results, Conclusions and Publications:

1. Objective one

The work planned under this objective has been completed. This work involved analyses of (a) on farm adjustments to ground water development, (b) the economic life of the ground water resource, and (c) secondary effects on the local economy of ground water development.

On farm adjustments

The Colorado High Plains near the Kansas border were divided into two areas--A in the northeast part of the state and B in the southeast. Two model farms were designed for Area A and three for Area B. Linear programming techniques were used to determine the optimum crop patterns for these model farms under a specific set of prices, yields and water availabilities. Optimum is defined as maximizing returns to management and labor.

On Farm A 1 with 220 acres irrigated, when sugar beets are raised and target (exceptional) yields are obtained, gross sales are \$60,336, costs are \$38,997 and return to management and labor is \$21,339. If only average yields are used, gross sales decline to \$43,693 and return to management and labor is \$4,696. If sugar beets are not included in the crop pattern, gross returns with target yields fall to \$47,536 and return to management and labor declines to \$13,290. When average yields are used, gross returns are \$30,873 and the loss to management and labor is \$3,373.

On Farm A 2, gross returns with sugar beets and target yields are \$108,956 and return to operator's management and labor is \$48,754. With average yields, gross return is \$80,100 and management and labor return is \$19,898. If sugar beets are dropped from the crop pattern, gross return is \$80,122 and return to management and labor becomes \$28,941 with target yields, but with average yields gross becomes \$51,192 and returns to operator management and labor are only \$11.

Shifting to Area B, management and labor returns on Farm B 1-- the small farm with 260 irrigated acres--are \$24,354 with sugar beets and target yields. If only average yields are obtained, management and labor receive \$7,260. When sugar beets are eliminated from the crops grown, management and labor receive \$16,430 with target yields, and a loss of \$672 when average yields are obtained.

On Farm B 2 with 400 irrigated acres, gross return with sugar beets and target yields is \$104,676 and return to management and labor is \$41,602. When average yields are obtained, gross returns become \$78,575 and return to management and labor drops to \$15,501. Elimination of sugar beets from the crop pattern gives gross returns of \$76,106 with target yields and return to management and labor of \$22,433. However, if no sugar beets are raised and only average yields are obtained, gross returns are \$50,000 but management and labor receive a loss of \$3,673.

Farm B 3, with 1,000 irrigated acres, shows the following results when analyzed with target and average yields. When sugar beets are included in the crop pattern and target yields are obtained, gross returns are \$220,575 and return to management and labor is \$115,423. With average yields and the same crop pattern, gross returns are \$162,394, management and labor returns \$57,242. Dropping sugar beets from the crop pattern reduces gross returns with target yields to \$164,060 and management and labor returns to \$76,434. The same crop pattern with average yields gives gross returns of \$105,799 and management and labor returns of \$18,173.

These budgets show two things of importance. First is the major role sugar beets play in making irrigated agriculture on the High Plains profitable. The greatest returns are obtained by including the maximum allowable acres in sugar beets in the crop pattern. The second is the extreme necessity to obtain high yields on crops, particularly the high value cash crops as sugar beets and beans.

Farmers who do not raise sugar beets and those who obtain yields approximately equal to the area averages will have a difficult time in meeting the costs associated with irrigation. Even where it is possible to cover all cash costs, interest and depreciation costs, the operator may have difficulty in obtaining any substantial return on his labor and management efforts.

Economic life of the aquifer

For this analysis the Colorado High Plains were divided into three areas and a model farm was specified for each area. Recursive linear programming was used to estimate the economic life of the aquifer in each area. This analysis was also based on a specific set of prices, yields and water availabilities. In addition, two assumptions were made retarding the rate of well development.

The economic life of irrigated agriculture was assumed to end when the return to management and labor reached zero. The results by areas are summarized in Table 1.

TABLE 1
INITIAL WATER DEPTHS, WATER DECLINES AND
LIFE OF THE AQUIFER, BY AREAS, AND LEVELS OF DEVELOPMENT

Rate of Development	Initial Depth to Water	Initial Saturated Thickness	Cummulative Water Decline	Economic Life of Aquifer
	(feet)	(feet)	(feet)	(years)
Area I				
Constant development ^{1/}	210	200	162	98
Increasing development ^{2/}	210	200	157	38
Area II				
Constant development	110	240	187	193
Increasing development	110	240	187	42
Area III				
Constant development	310	180	137	161
Increasing development	310	180	137	38

^{1/}This assumes that the number of wells will remain the same in the future as actually existed as of December 31, 1967.

^{2/}This assumes that the number of wells will increase every five years by the number which actually existed as of December 31, 1967.

If wells are restricted to the number which actually existed as of December 31, 1967, the model farms can irrigate profitably for approximately 100 years in Area I, 200 years in Area II, and 160 years in Area III. If well numbers increase every five years by the number which actually existed at the end of 1967, irrigation will be profitable for about 40 years in all three areas.

These estimates represent a minimum-maximum projection of the economic life of the ground water resource based on specific assumptions regarding well development, yields, prices, and costs. The projected minimum

life may overestimate the actual well development rate and likewise the projected maximum life may underestimate the increase in the number of wells.

Secondary effects

Kit Carson County was chosen as the study area for the analysis of secondary effects of ground water development. An input-output model was structured to represent the county's economy. The major banks in the county cooperated by furnishing the necessary data for the transactions table. These data were for 10 sample days during 1966.

Part of the results of this analysis are summarized in Table 2. The quantitative interrelationships among the sectors in Table 2 are too voluminous to include in this report. However, they can be summarized by saying that the entire Kit Carson County economy is highly related to the agricultural sectors. As a result, economic growth in irrigated agriculture is causing subsequent growth in the other sectors of the county's economy.

TABLE 2

DIRECT INCOME, DIRECT AND INDIRECT INCOME, AND INCOME MULTIPLIERS,
KIT CARSON COUNTY, COLORADO 1966

(1)	(2)	(3)	(4)
Sector	Direct income ^{1/} change	Direct & indirect income change ^{2/}	Income Multipliers ^{3/} Col. (3) - Col. (2)
		(dollars)	
Dryland farms	0.031469	0.072506	2.304045
Irrigated farms	.075949	.123758	1.629488
Eating & drinking establishments	.035229	.040074	1.137528
Retail stores other than automotive, etc.	.067373	.076506	1.135558
Manufacturing, auto machinery, service stations, etc.	.069403	.082830	1.193464
Construction, hardware, utilities, lumber, etc.	.056732	.072005	1.269213
Grain elevators, feed stores, etc.	.049430	.112643	2.278838
Personal services	.110328	.133188	1.207200
Professional services	.035546	.038764	1.090530
Social services	.103131	.144946	1.405455
Irrigation equipment and service	.152865	.304856	1.994282

^{1/}First round income received by local households as a result of one dollar of output by the sectors in Column (1).

^{2/}Total income received by local households as a result of one dollar of output delivered to final demand by the sectors in Column (1).

^{3/}Total local household income generated per dollar of direct income resulting from one dollar of output by the sectors in Column (1).

Theses and publications

The following theses and publications were financed directly by this project:

Barkley, Paul W. "Research in Ground Water Problems in the High Plains Region of Colorado," Water Resources and Economics Development of the West, Report No. 16, December 1967.

Grandin, Thomas B., Jr. "Economics of Irrigation Development on Farms in the High Plains of Colorado," unpublished master's thesis, Department of Economics, Colorado State University, Fort Collins, Colorado, 1967.

Tanner, David B. "The Secondary Effects of Ground Water Development," unpublished master's thesis, Department of Economics, Colorado State University, Fort Collins, Colorado, 1967.

Peterson, David H. "Economic Life of Irrigated Agriculture on the Colorado High Plains," unpublished master's thesis, Department of Economics, Colorado State University, Fort Collins, Colorado, 1969.

Rohdy, D. D., R. L. Anderson, T. B. Grandin, Jr., and D. H. Peterson. Pump Irrigation on the High Plains of Colorado, Colorado State University Experiment Station Bulletin (manuscript in final review).

Rohdy, D. D., David B. Tanner, and Paul W. Barkley. Secondary Benefits of Irrigation in Kit Carson County Colorado, Colorado State University Extension Service Bulletin (manuscript in process).

The following theses and publications are related to objective one but were not directly financed by the project:

Barkley, Paul W. and Thaine H. Allison, Jr. "Economic Base Studies in Resource Administration," Land Economics, Vol. XLIV, No. 4, pp. 470-479, November 1968.

Greer, Arthur J., Jr. "The Effect of Agricultural Change on Local Community Income," unpublished master's thesis, Department of Economics, Colorado State University, Fort Collins, Colorado, 1968.

Skold, Melvin D. and Arthur J. Greer, Jr., The Impact of Agricultural Change on a Local Economy in the Great Plains, Colorado State University Experiment Station Bulletin No. 106, October 1969.

2. Objective two

The work involving an institutional framework for guiding or regulating ground water development is nearing completion. The results will be released first in a doctoral dissertation.

Primary attention is focused on the amount and incidence of benefits and costs under alternative institutional arrangements for rationing access to or use of ground water. The analysis is concerned chiefly with the impact of these arrangements on income distribution, both within the agricultural sector and between agriculture and other sectors. The extent to which institutional arrangements create conflicts between water users and inhibit the orderly transfer of water among competing uses is examined in some detail.

Theses and publications

The following for the coming dissertation was financed directly by this project:

Willis, Reed W. "Legal and Institutional Aspects of Ground Water Development on the Colorado High Plains," unpublished doctoral dissertation, Dept. of Economics, Colorado State University. (in process).

The following thesis is related to objective two but was not directly financed by the project:

Peterson, D. K., "Management of Ground Water Resources in Kansas," unpublished master's thesis, Dept. of Economics, Colorado State University, 1968.

III. Professional Participation:

Paul W. Barkley was the principal investigator during the first two years of the project. When Barkley resigned his position at Colorado State University to accept a position at Washington State University, he was replaced as principal investigator by D. D. Rohdy. During the last two years of the project, R. L. Anderson and J. A. Munger also participated in the project.

ABSTRACT

ECONOMICS OF GROUND WATER DEVELOPMENT IN THE HIGH PLAINS OF COLORADO

Farmers using pump irrigation on the High Plains can make good returns from irrigating crops if they include sugar beets in the crop pattern and obtain high yields on all crops. High quality management is essential because average crop yields, or crop patterns without sugar beets, result in substantially lower net returns to management and labor. Irrigated agriculture on the High Plains can remain profitable for a minimum of approximately 40 years to a maximum of about 200 years depending on how fast the water is pumped from the underground aquifer. However, it should be pointed out that these estimates are based on current cost and return relationships. The secondary effects of ground water development are the greatest on local agricultural trade and service sectors. The magnitude of these effects was estimated with an input-output study in one county on the High Plains.

The income distribution effects of existing and alternative institutional arrangements for rationing water among competing users are examined for possible clues to reducing conflicts arising from the development and use of ground water.

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KEYWORDS--*ground water/*development/farm adjustments/*linear
programming/*economic life/aquifer/*secondary effects/*institutional
structure/water management/legal problems