Colorado
High Plains
Advisory Committee

Colorado
Department of
Agriculture

1525 Sherman Street
Denver, Colorado 80203
(303) 839-3218

# High Plains Study

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December 29, 1983

COLORADO HIGH PLAINS STUDY: SUMMARY REPORT

Enclosed is a copy of the summary report of the Colorado portion of the six-state High Plains-Ogallala Aquifer Study. This document contains a summary of the Colorado research results as well as the Colorado recommendations and the six-state recommendations.

Jim Rubingh

JIM RUBINGH, RESOURCE ANALYST
Colorado Department of Agriculture

JR:bcw

Enclosures

Colorado
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# High Plains Study



July 1983

## SELECTED HIGH PLAINS STUDY PUBLICATIONS

PUBLICATIONS BELOW ARE AVAILABLE FROM THE COLORADO WATER RESOURCES RESEARCH INSTITUTE, BULLETIN ROOM, 171 AYLESWORTH HALL SW, COLORADO STATE UNIVERSITY, FORT COLLINS, COLORADO 80523. TELEPHONE: (303) 491-6198. NO CHARGE FOR ABSTRACTS.

- An Economic Input-Output Study of the High Plains Region of Eastern Colorado, John McKean, et al., Department of Economics, Colorado State University. Technical Report No. 29. February 1982. 115 pages. An analysis of the 11-county economy in eastern Colorado above the Ogallala Aquifer. $7.00.

- Energy Production and Use in Colorado's High Plains Region, Emn McBroom, Colorado Office of Energy Conservation. Technical Report No. 30. February 1982. 167 pages. 40-year projections of oil and natural gas production and use in the Colorado High Plains region. $7.00.

- Community and Socio-Economic Analysis of Colorado's High Plains Region, Robert Burns, Colorado Department of Local Affairs. Technical Report No. 31. February 1982. 107 pages. Analyzes the impacts of aquifer depletion upon the economic and social structure of the Colorado High Plains region. $7.00.

- Projected Population, Employment, and Economic Output in Colorado's Eastern High Plains, 1979-2020, John McKean, Department of Economics, Colorado State University. Technical Report No. 33. February 1982. 57 pages. 40-year projections of population, employment, and economic activity for the 11-county region in eastern Colorado above the Ogallala Aquifer. $7.00.

- Energy and Water Scarcity and the Irrigated Agricultural Economy of the Colorado High Plains: Direct Economic-Hydrologic Impact Forecasts (1979-2020), Robert Young, Department of Economics, Colorado State University. Technical Report No. 34. February 1982. 371 pages. 40-year projections of irrigated and dryland acreage, agricultural production and value, returns to land and management, energy used for irrigation, groundwater use, saturated thickness, and depth to groundwater within the Colorado High Plains region. $7.00.

PUBLICATIONS BELOW ARE AVAILABLE FROM THE RESOURCE ANALYSIS SECTION, COLORADO DEPARTMENT OF AGRICULTURE, 1525 SHERMAN STREET, DENVER, COLORADO 80203. TELEPHONE: (303) 866-3219.

- Ogallala Aquifer: A Time For Action, Colorado Department of Agriculture, et al. November 1981. 12 pages. A newspaper summary of Colorado research results and options for action. No charge.

- Ogallala Aquifer: A Time For Action, Colorado Department of Agriculture, et al. January 1982. 4 pages. A newspaper summary of 20 draft recommendations for action developed by an advisory committee of eastern Colorado citizens. Inserts on final recommendations and their status are included. No charge.

- Six-State High Plains Ogallala Aquifer Regional Resources Study, High Plains Associates (Camp Dresser and McKee, Inc.) Austin, Texas. March 1982. 500 pages. This report summarizes research projections from the six study states on agricultural production, groundwater use, energy use, and associated economic, social, and environmental factors under several 40-year scenarios. $3.00 for postage and handling.

- Six-State High Plains Ogallala Aquifer Regional Resources Study: Summary, High Plains Associates (Camp Dresser and McKee, Inc.) Austin, Texas. July 1982. 86 pages. $2.00 for postage and handling.

- A Summary of Results of the Ogallala Aquifer Region Study, with Recommendations to the Secretary of Commerce and Congress, High Plains Study Council. December 1982. 61 pages. $2.00 for postage and handling.

- Colorado High Plains Study: Summary Report, Colorado Department of Agriculture. Approximately 60 pages. A summary of Colorado research results and recommendations for action. $2.00 for postage and handling.

(over)

COPIES OF THE FOLLOWING PUBLICATIONS HAVE BEEN DISBRIBUTED TO SELECTED UNIVERSITIES, CITY LIBRARIES, AND GOVERNMENT AGENCIES IN COLORADO. (LIST AVAILABLE UPON REQUEST.)

- Six-State High Plains Ogallala Aquifer Regional Resources Study: Water Transfer Elements, U.S. Army Corps of Engineers. September 1982. The summary report and five appendices describe the feasibility and costs of four possible interstate routes for transfering water from the Missouri, Mississippi, and Arkansas-White-Red Rivers to the six-state High Plains region. The final appendix provides guidance in preparing reconnaissance level designs, cost estimates, and environmental assessments for large water transfer facilities.

- Energy Price Projections, Black and Veatch Consulting Engineers, Kansas City, Missouri. April 1980. 95 pages. This report describes the energy commodity price projections developed by Black & Veatch for use in the six-state study.

- Energy Regulatory Analysis, Black & Veatch Consulting Engineers, Kansas City, Missouri. February 1981. 145 pages. This report presents the results of an investigation of Federal and state statutes and regulatory programs which are considered to be influential in the historical development & the present and future status of U.S. energy markets.

- Energy Production Impacts Assessment, Black & Veatch Consulting Engineers, Kansas City, Missour September 1981. 239 pages. This report presents projections of the water resource and economic impacts of energy production in the High Plains region.

- New Energy Supply Technology Assessment, Black & Veatch Consulting Engineers, Kansas City, Missouri. March 1982. 222 pages. This report presents the results of an evaluation of new energy supply technologies and an assessment of their potential for implementation in the High Plains Study Area.

- Interbasin Water Transfer Assessments, High Plains Associates (Camp Dresser and McKee, Inc.) Austin, Texas. March 1982. 64 pages.

- National and Regional Price Impact Assessment, Arthur D. Little, Inc., Cambridge, Massachusetts March 1982. 165 pages.

- Agricultural and Water Use Management and Technology Assessments, High Plains Associates (Camp Dresser and McKee, Inc.) Austin, Texas. March 1982. 180 pages.

- Environmental and Socioeconomic Impacts Assessment, High Plains Associates (Camp Dresser and McKee, Inc.) Austin, Texas. March 1982. 103 pages.

- Local Water Supply Augmentation Assessment, High Plains Associates (Camp Dresser and McKee, Inc.) Austin, Texas. March 1982. 40 pages.

- Institutional Assessment, High Plains Associates (Camp Dresser and McKee, Inc.) Austin, Texas. March 1982. 253 pages.

- Summary of Factors Used in Calculating Farm Level Production Costs and Revenues, Arthur D. Little, Inc., Cambridge, Massachusetts. January 1982. 134 pages.

- Dryland Farming Assessment, Arthur D. Little, Inc., Cambridge, Massachusetts. March 1982. 303 pages.

- Assessment of Nonagricultural Development Potential in the Ogallala Region, Arthur D. Little, Inc., Cambridge, Massachusetts. March 1982. 182 pages.

- Regional Economic Model Description, Arthur D. Little, Inc., Cambridge, Massachusetts. March 1982. 348 pages.

R. A. Longenbaugh

# COLORADO HIGH PLAINS STUDY

# SUMMARY REPORT

# SIX-STATE HIGH PLAINS STUDY COUNCIL

## COLORADO MEMBERS*

Richard D. Lamm,
Governor
J. Evan Goulding, Commissioner,
Colorado Department of Agriculture
Milton (Bud) Mekelburg, President,
National Association of Conservation Districts
Monte Pascoe, Executive Director,
Colorado Department of Natural Resources

## COLORADO HIGH PLAINS ADVISORY COMMITTEE

Norman Arends, Cheyenne Wells
Don Bishop, Burlington
Bud Bitner, Walsh
Forrest Burns, Lamar
Ken Clark, La Junta
Maryjo Downey, Stratton
David Foy, Otis
Gary Friehauf, Sterling
B.D. "Dale" Hargrove, Seibert
Melba Hastings, Sterling
John Hudler, Burlington
Joanne Jefferies, Sterling
Mickey Kramer, Holyoke
Douglas Melcher, Holly
Doyle Neiman, Sterling
Dale Reimer, Holyoke
Don Self, Springfield
Norman Smith, Walsh
J.A. Spiers, Yuma
Fred Wurtsmith, Yuma
James Weatherill, Yuma
Maynard Yost, Crook

*Morgan Smith, Executive Director of the Colorado Department of Local Affairs, and former Commissioner of the Colorado Department of Agriculture, served on the High Plains Study Council until July 1982. Mr. Goulding joined the Council at that time.

# COLORADO HIGH PLAINS STUDY SUMMARY REPORT

*November 1983*

Copies of this report are available for $3.00 postpaid from:
Resource Analysis Section
Colorado Department of Agriculture
1525 Sherman Street, Room 406
Denver, Colorado 80203

# EXECUTIVE SUMMARY

This report summarizes the Colorado portion of the six-state High Plains-Ogallala Aquifer Study, and includes state-level research results and recommendations for action.

The first five chapters describe the High Plains Study, the Colorado portion of the High Plains region, the Ogallala Aquifer, and five possible future scenarios for the Colorado High Plains region.

The last four chapters discuss four fundamental strategies for action: improve irrigation efficiency, restrict groundwater use, increase water supply, and expand economic development. Specific recommendations, developed by an advisory group of eastern Colorado citizens, are included for each strategy.

## STUDY BACKGROUND

The $6 million High Plains Study, authorized by Congress in 1976 and administered through the U.S. Department of Commerce, was designed to investigate the depletion of the Ogallala Aquifer and develop recommendations for action. The Ogallala covers 156,000 square miles and provides water for more than 20 percent of the nation's irrigated acreage. Six states participated in the study: Colorado, Kansas, Nebraska, New Mexico, Oklahoma, and Texas. Wyoming and South Dakota contain small portions of the Ogallala but did not participate in the study.

The Ogallala is essentially a nonrenewable source of water. Although 95 percent of the water originally accumulated in the aquifer is still there, the water has been exhausted in parts of West Texas and other places where the aquifer layer is thin.

State-level research by Colorado State University (CSU) and three state agencies began in 1979 and was completed in the fall of 1981. An advisory committee of 22 eastern Colorado citizens developed 20 recommendations for action in February 1982 after an extensive public education and participation process. This information is summarized in two newspapers prepared by the Colorado Department of Agriculture. Five full-length technical reports are available through the Colorado Water Resources Institute at CSU. This report summarizes the state-level research and recommendations.

Six-state research results, plus other regional studies, have been compiled by the general contractor, Camp Dresser and McKee, Inc. (CDM), a consulting firm in Austin, Texas. CDM's comprehensive report was released in March 1982. A detailed report on interstate water transport options from the Missouri, Mississippi, and Arkansas-White-Red Rivers to the High Plains has been prepared by the U.S. Army Corps of Engineers.

The High Plains Council, composed of the governors of the six study states, plus three additional members from each state, has prepared its own report. Their report summarizes research results for the six-state region and includes 18 recommendations for action. The Council's report was formally presented to Commerce Secretary Malcolm Baldrige in January 1983.

## RESEARCH RESULTS

Research results for the Colorado portion of the Ogallala region project a 40 percent decline in irrigated acreage over the next 40 years under *baseline* ("business as usual") conditions, with most of the decline occurring in the east central and southeast areas of the aquifer.

These baseline projections are based upon somewhat optimistic assumptions: (1) continued crop yield increases, (2) relatively moderate increases in real energy prices, and (3) increases in the real prices of agricultural commodities. Assumption (3) is inconsistent with recent trends as commodity prices haven't kept pace with inflation. Under less optimistic assumptions, the baseline future shows drastic reductions in irrigated acreage: a decline of 60 percent by 1990 and 90 percent by 2000.

Other scenarios were also developed. *Water conservation* makes a difference: an intense effort to improve irrigation efficiency could cut projected losses in irrigated acreage in half. Additional *restrictions on ground water use* would have little additional effect since most farmers are already using less water per acre than the allowable maximum because of rising energy costs. As for *increasing water supply*, an acre-foot of imported water would provide less than $100 in additional net income to an agricultural producer. The cost of importing water from the Missouri River is $360 an acre-foot in 1981 dollars, excluding distribution costs to deliver water from storage reservoirs to farm headgates.

*Under baseline conditions, crop production for the six-state Ogallala region is projected to increase substantially over the 40-year period.*

The somewhat surprising projection of increased production is chiefly due to the study's assumption that future crop prices will increase faster than inflation. This would give farmers a powerful incentive to keep irrigating until the water is gone, despite higher pumping costs. Since the Ogallala contains about three billion acre-feet--95 percent of the water originally deposited in the aquifer--there is enough water to support increased production for at least 40 years.

## RECOMMENDATIONS FOR ACTION

Steps have already been taken to implement more than half of the 20 recommendations developed by the Colorado High Plains Advisory Committee.

- The Cooperative Extension Service has added an irrigation specialist in the High Plains of Colorado. Through a grant from the Colorado Commission on Higher Education, CSU is evaluating alternate, low-water crops with economic potential for eastern Colorado.
- A Technical Coordinating Committee of local, state, and federal agencies and private organizations is meeting quarterly to improve coordination in research, education, and technical assistance to High Plains irrigators.
- The Colorado office of the Soil Conservation Service has received additional funds to target the Ogallala for special attention.
- A feasibility study of the Trans-County project is underway. This project would direct water from the South Platte River to the Colorado High Plains.
- An 18-county organization, *Colorado Plains, Inc.*, has been formed to promote regional interests, including developing responses to aquifer depletion.

The 18 *six-state recommendations* emphasize the importance of research, education, and technical and financial assistance to promote water and soil conservation, low-water crop development, and economic diversification of the region. However, the recommendations lack specific steps for implementation. The High Plains Study Council also recommends that water importation studies continue and fully involve the states from which the water would be imported.

# COLORADO RECOMMENDATIONS

These 20 recommendations were developed by the Colorado High Plains Advisory Committee, a group of 22 citizens from eastern Colorado. The recommendations were adopted in February 1982 after six public meetings were held in eastern Colorado during the fall of 1981. The recommendations are discussed in more detail in the last four chapters of this report.

## LOCAL ACTION

- **Local Research Foundations.** That local producers form not-for-profit foundations to conduct large-scale agricultural research and demonstration projects.
- **ET Reporting Stations.** That additional ET Reporting Stations be established in the Northern High Plains and that this information be reported daily.
- **Unscheduled Power Interruption.** That utilities determine the impact of unscheduled power interruption on pumping and discontinue this practice if studies show that such programs actually increase water use.
- **Regional Development Board.** That representatives from business and industry, local governments, agricultural and civic organizations, and other interested citizens meet to discuss the need for a regional development and promotion board.

## STATE ACTION

- **Irrigation Specialist.** That the state Cooperative Extension Service assign an additional irrigation specialist to the High Plains region.
- **Model Rate Structure.** That the Public Utilities Commission establish an irrigation rate task force to develop a "model" rate structure acceptable to utilities and irrigators
- **Ground Water Depletion Policy.** That the Colorado Ground Water Commission maintain its policy of no more than 40 percent depletion over 25 years.
- **Supplemental Well Policy.** That the Colorado Ground Water Commission maintain its present policy on supplemental wells.
- **Trans-County Project.** That the State of Colorado assist in funding a detailed feasibility study of the Trans-County Project.
- **Intrastate Water Transfers.** That the State of Colorado investigate the feasibility of diverting water within the state to the High Plains.
- **Railroad District Legislation.** That the Colorado Legislature enact legislation to allow the formation of public railroad districts.

## FEDERAL ACTION

- **SCS Target Assistance.** That the U.S. Soil Conservation Service designate the Ogallala region as a target area for increased technical and financial assistance.
- **Water Conservation.** That Congress place the highest priority on increasing funding to improve water conservation in the Ogallala Aquifer.
- **Interstate Water Transfer.** That Congress continue to investigate the possibility of interstate water transfer projects.
- **Industrial Development Bonds.** That the federal government continue to allow the sale of industrial development bonds.
- **Aquifer Recharge.** That appropriate local, state, and federal agencies determine suitable aquifer recharge sites and carry out demonstration projects.
- **Continue Depletion Analysis.** That state and federal funding be provided to continue monitoring ground water depletion and its projected effects upon the region, state, and nation.

## JOINT ACTION

- **Regional Technical Committee.** That a Colorado High Plains Technical Committee be formed to coordinate irrigation research, demonstration, education, and technical assistance in the region.
- **Agricultural Research.** That funds for additional agricultural research be allocated to improve water use efficiency in the Ogallala region.
- **Alternate Crops.** That state and federal support be increased for research, development, and marketing of alternate crops.

# ACKNOWLEDGMENTS


The research for this report was conducted under contract No. EDA0-78-2550 from the Economic Development Administration of the U.S. Department of Commerce. The statements, findings, conclusions, and other data contained herein are solely those of the authors and do not necessarily reflect the views of the Economic Development Administration or the U.S. Government in general.

This study was conducted under the terms of a contract with Camp Dresser, and McKee, Inc. and the U.S. Department of Commerce by the Colorado Department of Agriculture and its sub-contractors and their associates.

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Additional information for this report was provided by the Soil and Conservation Service, the Cooperative Extension Service, the Agricultural Research Service, the United States Geological Survey, the Colorado State Experiment Station, and the Colorado Water Resources Research Institute.

This report was written and prepared under the supervision of David Carlson and Jim Rubingh, Colorado Department of Agriculture.

# GLOSSARY

**Acre-foot of water** — The amount of water necessary to cover one acre of land to a depth of one foot: 325,851 gallons of water.

**Appropriated water** — Water for which a use permit has been granted by the Colorado Ground Water Commission (C.R.S. 1973, 37-90-107).

**Aquifer** — An underground water-bearing formation, consisting of layers of sand, gravel, clay, and silt.

**Depth to water** — The distance from the surface of the ground to the top of the water table. Ranges from 20 to 400 feet for the Colorado portion of the Ogallala Aquifer.

**Designated ground water** — Ground water which in its natural course would not be available to and required for the fulfillment of decreed surface rights, or ground water in areas not adjacent to a continuously flowing natural stream wherein ground water withdrawals have constituted the principal water usage for at least fifteen years preceding the date of the first hearing on the proposed designation of the basin, and which in both cases is within the geographic boundaries of a designated ground water basin (C.R.S. 1973, 37-90-103 (6)).

**Economically recoverable water** — Defined by High Plains Study researchers to be water in excess of 35 feet of saturated thickness. About two-thirds of the physical stock of water in the Colorado portion of the Ogallala Aquifer is considered economically recoverable for irrigation purposes.

**Hydrograph** — A graph which shows changes in water levels or volumes over time.

**Irrigated land** — Agricultural land supplied with water in excess of natural precipitation.

**Physical stock of water** — The total amount of water in an aquifer. The physical stock of water in the Colorado portion of the Ogallala Aquifer is about 90 million acre-feet.

**Playa lakes** — Depressions in the land surface which temporarily collect rainwater and melting snow. Kit Carson County contains more than 3000 playa lakes.

**Recharge** — The process of adding water to an aquifer through natural precipitation or artificial means. Annual recharge rates for the Northern High Plains of Colorado range from zero to two inches or more and average about three-fourths of an inch throughout the region.

**Saturated thickness** — The portion of an aquifer from which water can be withdrawn by pumping. Ranges from 5 to 350 feet for the Ogallala Aquifer in Colorado.

**Well yield** — The number of gallons of water per minute (gpm) which a well is capable of pumping. A yield of 600-800 gpm is considered necessary to irrigate corn adequately in the Colorado High Plains.

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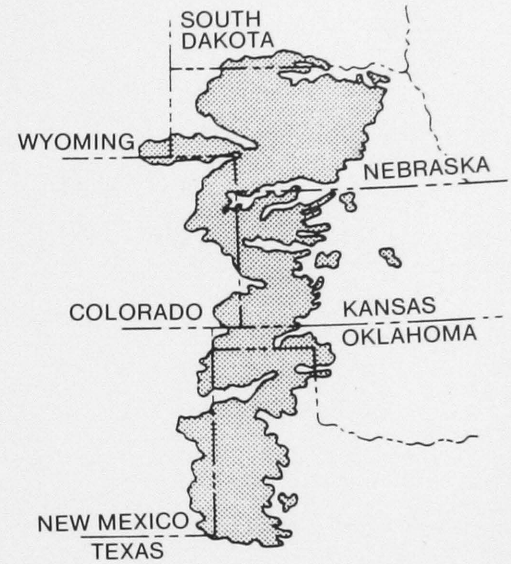
# CHAPTER ONE
# THE HIGH PLAINS STUDY

The Ogallala Aquifer is an underground water-bearing layer of sand, gravel, clay, and silt that lies beneath 156,000 square miles in eight High Plains states (Figure 1.1). The Ogallala contains more than three billion acre-feet of water -- enough to cover the state of Colorado 45 feet deep. About 16 million acres--more than 20 percent of the nation's irrigated land--are watered from the Ogallala Aquifer.

For decades, farmers have tapped this huge underground reservoir for irrigation, transforming wheat and cattle country into a major national producer of corn, cotton, sugar beets, alfalfa, and feedlot cattle. But unlike rivers and streams, which are replenished annually from rain and snowmelt, the Ogallala Aquifer is essentially nonrenewable. No streams or rivers significantly recharge the Ogallala; only a small fraction of the region's scanty precipitation enters the aquifer each year. Annual pumping for irrigation now exceeds recharge rates by ten to fourteen times in many areas. In some places where the water-bearing Ogallala Formation is thin, wells have already gone dry.

The explosive development of irrigation from the Ogallala over the past 20 years has been based upon plentiful supplies of water, cheap energy for irrigation pumps, and the development of the center-pivot sprinkler. Today, rising costs of energy, credit, machinery, and other production expenses are shutting down many wells even where water is plentiful. The net effects of increasing costs and aquifer depletion are the same--fewer irrigated acres, less agricultural production, and less economic activity in this sparsely populated region.

Figure 1.1
**THE OGALLALA AQUIFER**

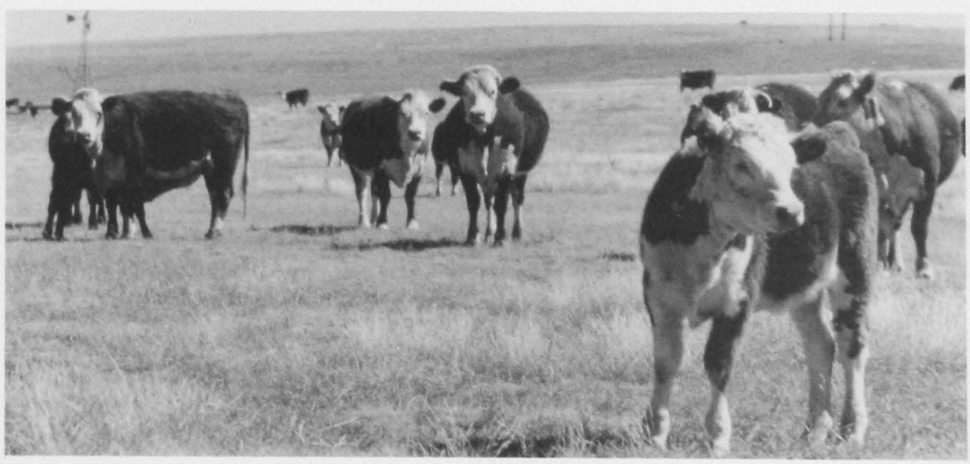



## A DELICATE BALANCE

The current economy of the Colorado High Plains region is based squarely upon irrigation. Irrigation accounted for 60 percent of the value of all crops grown in the region in 1979.

The Colorado High Plains region faces both long-term and short-term problems. *The fundamental long-term problem is how to develop a sustainable level of agricultural production.* If the current depletion rate of one million acre-feet of water per year continues, the Colorado portion of the Ogallala has a useful life of 60 years or so. Of course, subregions where the aquifer layer is thin will run out of water much sooner--and thicker areas much later.

*The short-term problem is how to maintain a viable economy while irrigators face rapidly rising production costs and depressed commodity prices.* If irrigation suddenly stopped throughout the region, school teachers, businessmen and implement dealers--as well as farmers--would be seriously affected.



The value of a non-renewable resource is a major factor in determining its useful life. The greater its value, the sooner the resource gets used up. For the High Plains, higher commodity prices would increase the value of water and result in faster depletion of the Ogallala. If commodity prices fall so low that irrigation is not feasible, the Ogallala wouldn't decline but the region's economy would suffer.

For the past two to three years, the short-term problem has been much more acute than the long-term problem. The economic cost-price squeeze facing many farmers irrigating from the Ogallala is already slowing down irrigation rates. As one irrigator said, "I'm going to run out of money long before the Ogallala runs out of water." Both problems must be solved if the region is to prosper.

## STUDY BACKGROUND

Congress authorized the High Plains Study in 1976 to investigate the extent of ground water depletion of the Ogallala Aquifer and its impacts upon the six-state High Plains region of the United States and to develop recommendations for action. The enabling federal legislation (Public Law 94-587) states the fundamental purpose of the study:

> "Sec. 193. In order to assure an adequate supply of food to the nation and to promote the economic vitality of the High Plains region, the Secretary of Commerce. . .is authorized and directed to study the depletion of the natural resources of those regions presently utilizing the declining water resources of the Ogallala Aquifer, and to develop plans to increase water supplies in the area and to report thereon to Congress. . . In formulating these plans, the Secretary is directed. . .to examine the feasibility of various alternatives to provide adequate water supplies in the area. . . to assure the continued economic growth and vitality of the region. . ."

The Economic Development Administration (EDA) of the U.S. Department of Commerce supervised the project. Colorado, Kansas, Nebraska, New Mexico, Oklahoma and Texas conducted state-level research under the direction of Camp Dresser and McKee, Inc., an Austin, Texas, water engineering and consulting firm. A six-state High Plains Study Council, consisting of an EDA representative and the governor and three additional members from each state, provided overall guidance for the study.

In addition to Governor Richard Lamm, Colorado's members on the High Plains Study Council were: J. Evan Goulding, Commissioner, Colorado Department of Agriculture; Monte Pascoe, Executive Director, Colorado Department of Natural Resources; and Milton (Bud) Mekelburg, Yuma farmer and businessman, and President of the National Association of Soil Conservation Districts. Goulding replaced Morgan Smith on July 1, 1982, when Smith became Executive Director of the Colorado Department of Local Affairs.

State-level research was conducted during 1979-81 by Colorado State University, the Colorado Division of Water Resources, the Colorado Department of Local Affairs, and the Colorado Office of Energy Conservation. The Colorado Department of Agriculture coordinated state-level research and public involvement in the project, and served as liaison among Colorado, the general contractor, and other study states.

The Colorado High Plains Advisory Committee, a group of 22 citizens from eastern Colorado, guided the development of Colorado's recommendations for action. The committee developed 20 specific recommendations after six public meetings in late 1981. These recommendations were integrated with those from the other five states during 1982. In January 1983 the final report of the six-state High Plains Study Council, with recommendations, was presented to Commerce Secretary Malcolm Baldrige. Both sets of recommendations are included in this report.

The U.S. Army Corps of Engineers carried out a reconnaissance-level survey of four possible routes to transfer water from the Missouri River and its tributaries to the High Plains. Energy and economic analyses for the six-state region were prepared by the firms of Black and Veatch of Kansas City and Arthur D. Little, Inc., of Cambridge, Massachusetts. The U.S. Geological Survey is conducting a related study to examine the system of ground water flow within the aquifer and how the aquifer would respond to various water management strategies. The bibliography lists more than 20 regional and state reports related to this study.

The basic research results from the High Plains Study are incorporated in a series of 40-year *scenarios* -- projections of future agricultural production, energy and water use, economic activity, and population changes for the High Plains region under various sets of assumptions. These *scenarios* correspond to basic *strategies* for action: improve irrigation efficiency, restrict water use, or increase the region's water supply.

# THE COST-PRICE SQUEEZE ON A BUSHEL OF IRRIGATED CORN

The cost of producing a bushel of irrigated corn in eastern Colorado has risen much faster than the selling price of that bushel over the past ten years. The costs of credit, machinery, seed, fertilizer, etc. required to produce a bushel of corn are up dramatically (Table 1.1).

In 1971, irrigated corn land sold for approximately $400 an acre and the prevailing interest rate was six percent. Ten years later, the same land sold for nearly $1,200 an acre at 10.5 percent interest. The cost of interest on enough land to raise a bushel of corn has nearly quadrupled in ten years.

Surprisingly, the cost of irrigating a bushel of corn has not risen as fast as the selling price of that bushel over the past ten years. Even though irrigation power costs have risen from $17 an acre to $42 an acre over ten years, higher yields have offset the rise in energy costs per bushel. How can farmers stay in business? The answer hinges on the cost of land. Farmers who own their land pay no interest on land, so their net per bushel is increased by the interest on land figure shown in the table. Such farmers earned a net of 25 cents a bushel in 1971 and seven cents a bushel in 1981. But a farmer who has borrowed money to buy farm-land at today's prices and interest rates is in deep trouble, given today's depressed crop prices.

Table 1.1

**COST-PRICE SQUEEZE ON A BUSHEL OF IRRIGATED CORN**

| | 1971 | 1981 | CHANGE |
|---|---|---|---|
| **COST OF PRODUCTION** | | | |
| Irrigation Power | $0.17 | $0.31 | UP 82% |
| Other Variable Costs | 0.57 | 1.30 | UP 128% |
| Interest on Land | 0.25 | 0.91 | UP 264% |
| Other Fixed Costs | 0.20 | 0.82 | UP 310% |
| COST PER BUSHEL | $1.19 | $3.34 | UP 180% |
| PRICE PER BUSHEL | 1.19 | 2.50 | UP 110% |
| NET PER BUSHEL | $0.00 | −$0.84 | |

# CHAPTER TWO
# COLORADO HIGH PLAINS PROFILE

## GEOGRAPHY

Colorado's High Plains region includes most of the state east of the foothills of the Rocky Mountains, but excludes the valleys of the South Platte and Arkansas rivers. The Colorado High Plains region is part of the larger High Plains region that includes parts of seven other states. Unless stated otherwise, *the term "High Plains region" in this report only refers to the part of the High Plains that lies above the Ogallala Aquifer.* About 12,000 square miles of land, or 11 percent of the state's total area, lie above the Ogallala Aquifer in Colorado (Figure 2.1).

Most of the farmland in the study area lies at elevations between 3,500 and 4,500 feet above sea level. Most of the irrigated areas are nearly level or gently sloping, except for some steeper slopes in the sandhills north of Wray.

The climate of the region is semiarid. The average annual precipitation ranges from 15 to 18 inches, but this varies from year to year, with droughts that sometimes last for several years. Other weather hazards include rapid temperature changes, windstorms severe enough to damage crops and erode soils, and hailstorms severe enough to damage crops on about 10 percent of the planted lands in some years.

Soils vary within the area, ranging from loams to sand. Most of the soils are inherently fertile and produce wheat yields of 25-35 bushels per acre without irrigation in alternate years except under drought conditions. With irrigation these soils can produce corn yields of over 150 bushels per acre. With adequate fertilizer, even the sandhills produce corn, but the sandy areas are especially subject to wind erosion. Almost all land in the region is used for agriculture (Table 2.1).

Figure 2.1
**COLORADO HIGH PLAINS REGION**

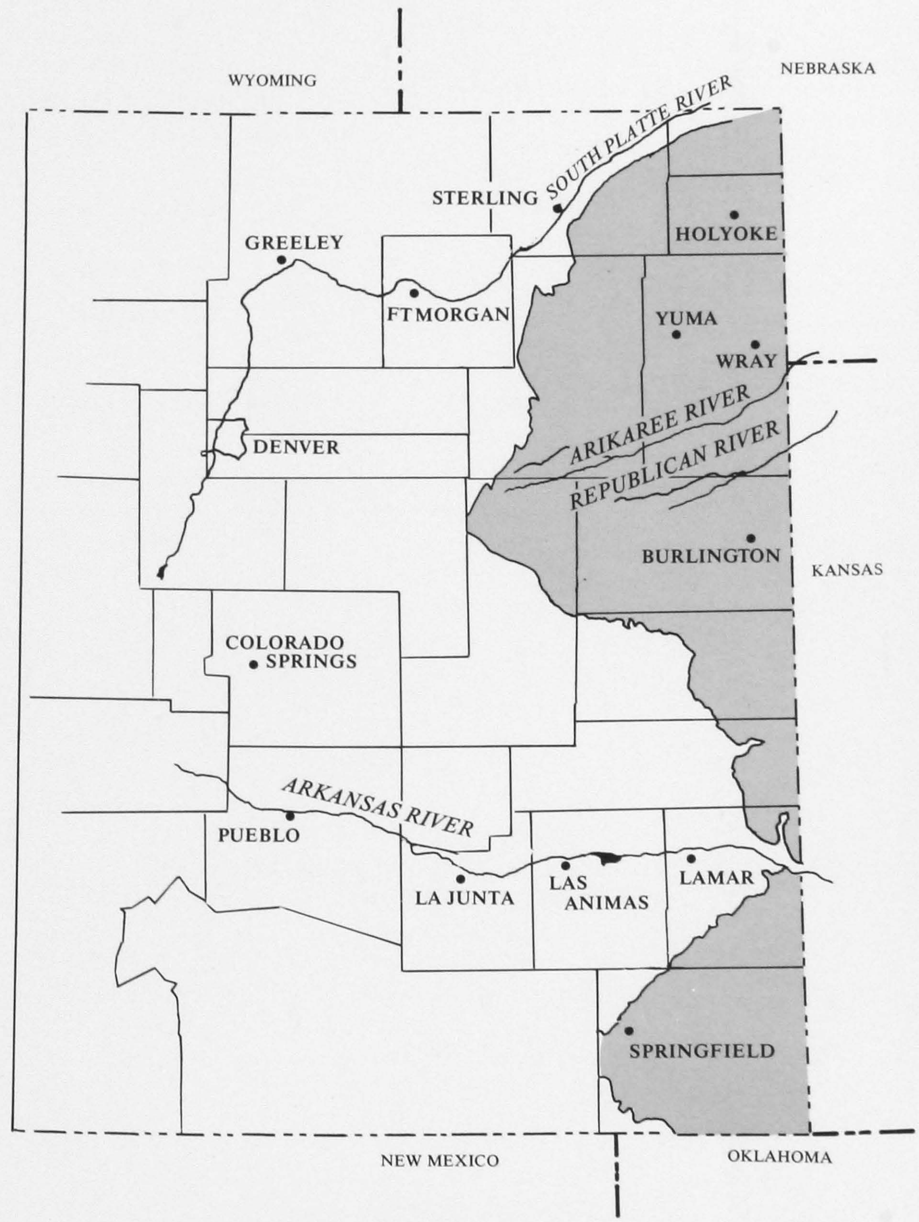



Table 2.1
**LAND USE**
**(Colorado High Plains, 1979)**

| | Area (1000 acres) | Percent of Region | Percent of Colorado's Land in that Use |
|---|---|---|---|
| Irrigated Land | 600 | 8 | 17 |
| Dry Cropland | 3,358 | 44 | 45 |
| Rangeland | 3,172 | 42 | 14 |
| Other Land | 409 | 5 | 1 |
| All Land | 7,539 | 100 | 11 |

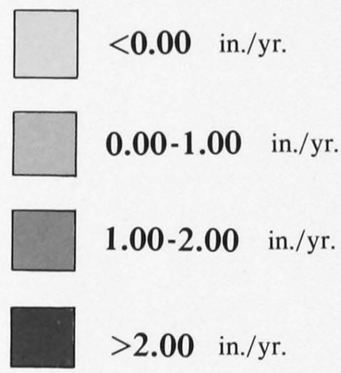
## THE OGALLALA AQUIFER

The *Ogallala Aquifer* consists of water-bearing layers of sand, gravel, silt, and clay. In 1979, the Colorado portion of the aquifer contained about 94 million acre-feet of water, but only two-thirds of this amount is economically recoverable for irrigation.

Saturated thickness and the distance from the land surface to ground water in the aquifer vary widely. *Saturated thickness* is the thickness of the formation from which water can be extracted by pumping. The saturated thickness along the aquifer's western edge in Colorado ranges from 5 to 50 feet, while along the Kansas and Nebraska state lines it ranges from 50 to 350 feet. Irrigation is generally considered economically and technically feasible only where the saturated thickness is more than 35 feet. *Depths to water* range from 20 feet to more than 400 feet as a result of irrigation withdrawals.

Although the Ogallala Aquifier slopes slightly to the east, little water moves in that direction (Figure 2.2). Most of the change in water level is caused by withdrawal through large-capacity irrigation wells. In Colorado no water flows into the Ogallala Aquifer from outside the region. Natural recharge of the aquifer from precipitation varies from zero to more than two inches per year--very small compared to irrigation withdrawals (Figure 2.3).

Figure 2.3
**GROUNDWATER RECHARGE**
**(Colorado Northern High Plains)**



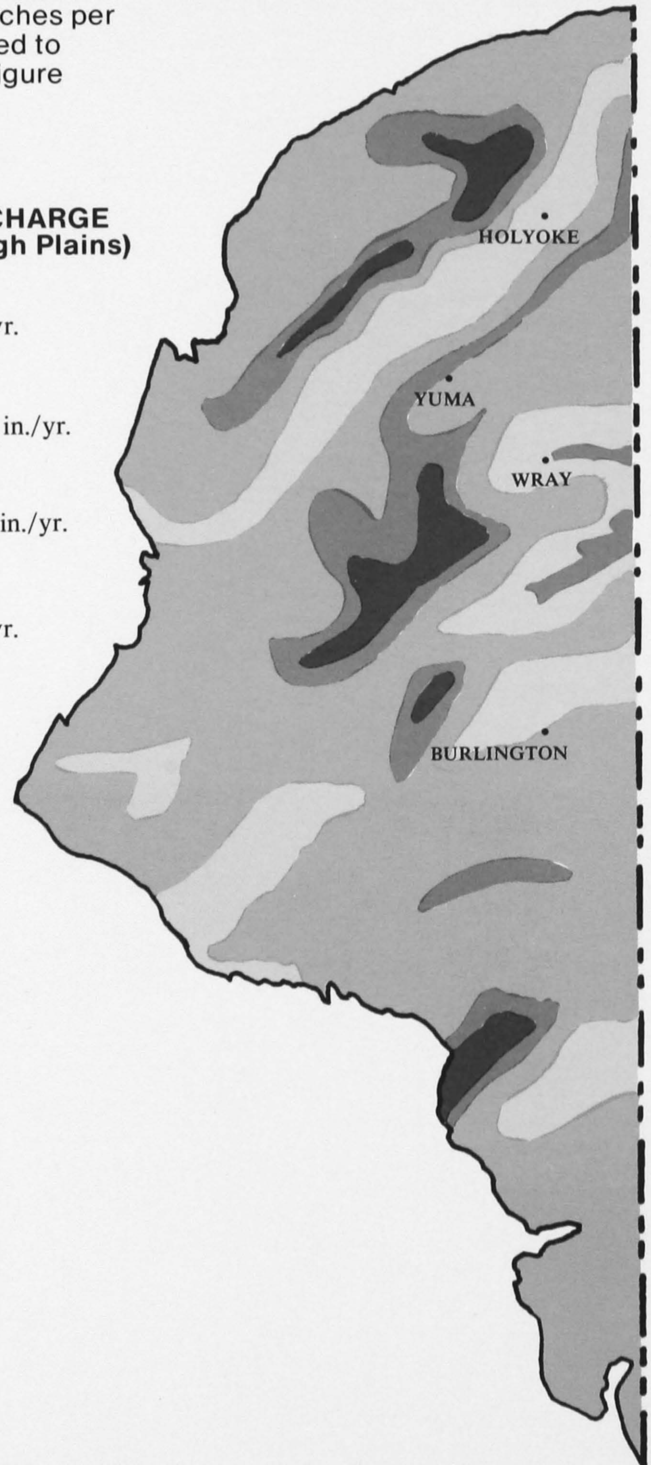
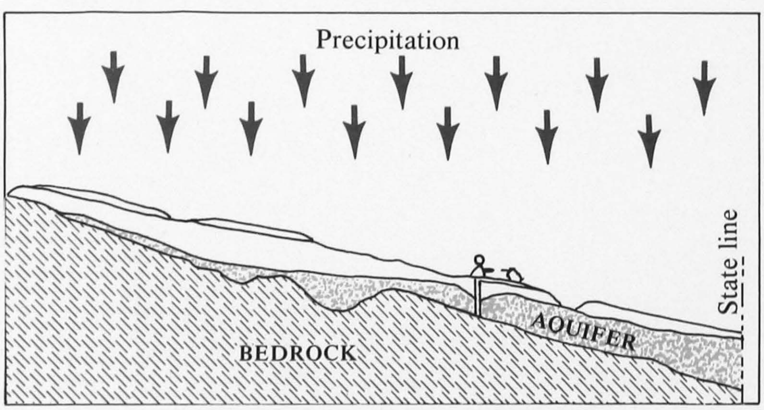




Figure 2.2
**CROSS-SECTION VIEW OF OGALLALA AQUIFER**
**(Colorado High Plains)**



In Baca County in southeastern Colorado, the Dakota and Cheyenne aquifers lie below the Ogallala Aquifer. These aquifers have also been tapped for irrigation, especially in places where the Ogallala Aquifer has been depleted. In several places, these three aquifers are interconnected, which causes difficult technical and administrative problems. The water levels in these aquifers are very deep--in many places more than 400 feet below the surface.

Significant amounts of water from the Ogallala Aquifer were not used for irrigation in the High Plains until the drought years of the 1930s. At that time, farmers in northern Texas started sinking wells to bring water to the surface for irrigation. In 1952 Frank Zybach, of Strasburg, Colorado, developed the first successful center-pivot irrigation system. This system consists of sprinkler heads on a 1200-foot-long boom that pivots around a well. The boom moves slowly, taking several days to irrigate a circular area of about 130 acres in a quarter-section of land. This creates the characteristic green circle pattern seen from the air in the High Plains region in the spring and summer.

Center-pivot systems made full irrigation economical in the High Plains of Colorado. Farmers used cheap natural gas and electricity to pump water from the Ogallala Aquifer. Slowly at first, then more rapidly, irrigated agriculture transformed the High Plains economy. By 1962, 525 wells had been sunk in the northern part of the Ogallala Aquifer in Colorado to irrigate 56,000 acres. By 1980, this had increased to 500,000 acres irrigated by 3800 wells in the Northern High Plains of Colorado. Another 1000 wells irrigate approximately 100,000 acres in the Southern High Plains below the Arkansas River.

The Ogallala Aquifer supplies water for about 17 percent of Colorado's irrigated acreage. The phenomenal increase in irrigated acreage in the High Plains since 1960 has masked losses of irrigated land in other parts of the state, especially the Front Range.

## AGRICULTURAL PROFILE

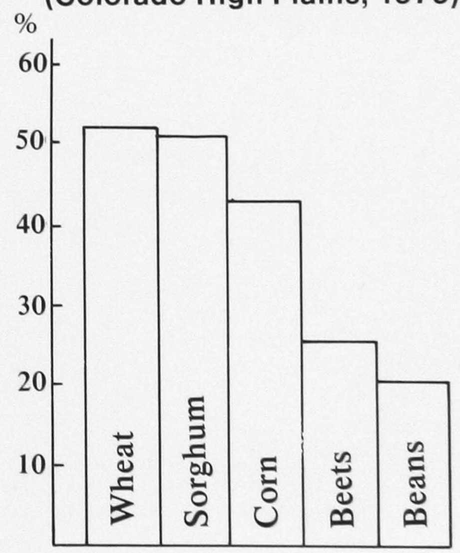
The High Plains region produces an important--and still growing--share of the state's agricultural commodities. In 1979, the region produced $321 million worth of crops, 32 percent of the state total. About half of the state's corn, sorghum, and wheat, and a quarter of Colorado's pinto beans and sugar beets, are produced in the High Plains area (Figure 2.5).

Corn is the chief irrigated crop in the region, while wheat is the principal dryland crop. Although only 15 percent of the region's cropland is irrigated, it produces more than half the region's crop value.

Irrigation supports an intensive corn and cattle-feeding economy in the High Plains region with many small to medium-sized feedlots. But this economy has been based on a plentiful supply of irrigation water, low-priced electricity and natural gas for pumping, and a strong demand for beef. All these factors are changing. Electric power costs are increasing rapidly, natural gas even faster, and ground water is being depleted. At the same time, crop prices and beef prices to farmers have remained stable or even declined slightly.

Farmers in the region are adapting to these changes. In the southern High Plains, farmers have shifted from corn to sorghum, which can be produced with little or no supplemental irrigation water. In the northern part of the region, sugar beet acreage is declining, as beets require large amounts of water. Wheat, which requires less water than corn, is being grown on increasing areas of irrigated land in the region. Less irrigation water is being applied to corn and other crops, even though this reduces yields.

Figure 2.4
**CROP PRODUCTION**
**(Colorado High Plains, 1979)**



## POPULATION

According to the 1980 census, approximately 77,000 people live in the 11-county region containing the Ogallala Aquifer in eastern Colorado--2.7 percent of the state's population (Table 2.2). About 33,000 people live directly above the Ogallala Aquifer. The largest cities in the 11-county region are Sterling and Lamar, each with more than 10,000 people, but neither city lies directly over the Ogallala Aquifer.

Five towns with more than 1500 people lie directly above the Ogallala: Burlington (3100), Yuma (2800), Wray (2100), Holyoke (2100), and Springfield (1700).

The population of the 11-county region has declined by 30 percent since 1930. Exceptions have occurred in Washington County, where oil and gas development in the 1950s brought in new people, and in Yuma and Kit Carson counties, where irrigation development boosted the economy in the 1970s. Counties with little irrigation, such as Cheyenne, Kiowa, Lincoln, and Washington, lost about 15 percent of their population from 1960 to 1980. The population of Baca County, where irrigation is declining, has also dropped.

While the population of the High Plains region has declined during the past several decades, the population of the entire state has doubled since the 1950s. Population is shifting away from rural regions such as the High Plains to metropolitan areas, reducing the proportion of political representation for the High Plains region in the state legislature.

Table 2.2
**COLORADO HIGH PLAINS POPULATION**
**(11-County Region)**

| Year | Population | Percent of State Population |
|---|---|---|
| 1930 | 104,943 | 10.1 |
| 1940 | 86,712 | 7.7 |
| 1950 | 89,318 | 6.7 |
| 1960 | 81,608 | 4.7 |
| 1970 | 76,205 | 3.4 |
| 1980 | 77,434 | 2.7 |

## ECONOMY

The 11-county regional economy totaled $4.3 billion in 1978. Although the region's economy does include some oil and gas production and manufacturing, agriculture is by far the chief economic activity in the region (Table 2.3). Crop and livestock production, farm services, and food processing (chiefly meat packing) account for two-thirds of the region's output and 88 percent of the region's exports to other parts of Colorado, and to the nation and world. These agricultural activities also account for 54 percent of local and county tax revenues and 39 percent of all jobs in the region.

These figures understate the economic importance of agriculture to the region, as most of the region's electricity is generated to operate irrigation pumps, and many government jobs and activities are related to agriculture. Several business enterprises and community services, such as education, are closely related to agriculture as well.

Table 2.3
**COLORADO HIGH PLAINS ECONOMY**
**(11-County Region, 1978)**

| | Output | | Exports | | County & Local Tax Revenue | | Employment | |
|---|---|---|---|---|---|---|---|---|
| | Million $ | % | Million $ | % | Million $ | % | Jobs | % |
| CROP PRODUCTION | $ 360 | 14 | $ 108 | 11 | $10.5 | 24 | 3,300 | 11 |
| LIVESTOCK PRODUCTION | 601 | 24 | 343 | 34 | 11.5 | 27 | 6,500 | 22 |
| FARM SERVICES | 286 | 11 | 58 | 6 | 0.9 | 2 | 800 | 3 |
| FOOD PROCESSING | 386 | 15 | 374 | 37 | 0.5 | 1 | 1,000 | 3 |
| OIL, GAS, ELECTRIC | 162 | 6 | 53 | 5 | 6.5 | 15 | 900 | 3 |
| BUSINESS, MANUFACTURING | 374 | 15 | 78 | 8 | 5.1 | 12 | 10,300 | 34 |
| COMMUNITY SERVICES | 132 | 5 | 0 | 0 | 0.8 | 2 | 5,600 | 19 |
| GOVERNMENT SERVICES | 198 | 8 | 9 | 1 | 7.9 | 18 | 1,700 | 6 |
| HOUSEHOLD a/ | 424 | ---- | ---- | ---- | 5.9 | ---- | ---- | ---- |
| | $2,923 b/ | 100 | $1,023 c/ | 100 | $49.0 d/ | 100 | 30,900 | 100 |

**NOTES**
a/ Wages and salaries.
b/ Does not include imports ($1084 million), transfers ($113 million), and profit, depreciation, and inventory changes ($187 million).
c/ Does not include $154 million in exported imports.
d/ Does not include $9.39 million in local government exports.

# CHAPTER THREE
# GROUND WATER HYDROLOGY AND ADMINISTRATION

This chapter responds to some commonly asked questions about the hydrology and administration of ground water in the High Plains of Colorado.

## GROUND WATER HYDROLOGY

### 1. What is the Ogallala Aquifer?

The *Ogallala Aquifer* consists of layers of gravel, sand, clay and silt lying on a bedrock of Pierre shale. Water is stored in the tiny spaces between the particles of sand, gravel, and rock--similar to the way in which a sponge holds water. Only the fully saturated portion of an aquifer can provide water for withdrawal by wells. The Ogallala underlies 11 counties in eastern Colorado and portions of seven other states.

Other geological formations occur in association with the Ogallala, such as the Brule Formation located in parts of northeastern Colorado and Wyoming. For this reason, estimates of the amount of water stored in the Ogallala Aquifer may vary. Unless otherwise noted, such estimates in this report exclude associated aquifers.

### 2. Are aquifer conditions different in the Northern and Southern High Plains of Colorado?

Geologic conditions are much more complex in the Southern High Plains than in the Northern High Plains. In the southern region, the Ogallala Aquifer overlies much of the area as a thin veneer, with small, localized thicker deposits. Three aquifers underlie the Ogallala in southeastern Colorado: the Dakota, Cheyenne, and Dockum sandstones. Water in these formations was originally *artesian*, or under pressure, which would cause water to rise above the confining shale layer in a well.

In the Southern High Plains, farmers were permitted to drill wells to any depth and most wells were completed in more than one aquifer. As artesian pressures and water levels were lowered in the upper aquifers, farmers deepened their wells to the next lower formation. Farmers benefited for a few years until development reduced the artesian head. This well development practice interconnected the aquifers and allowed water to drain from the upper aquifers to the lower formations, now under reduced pressure.

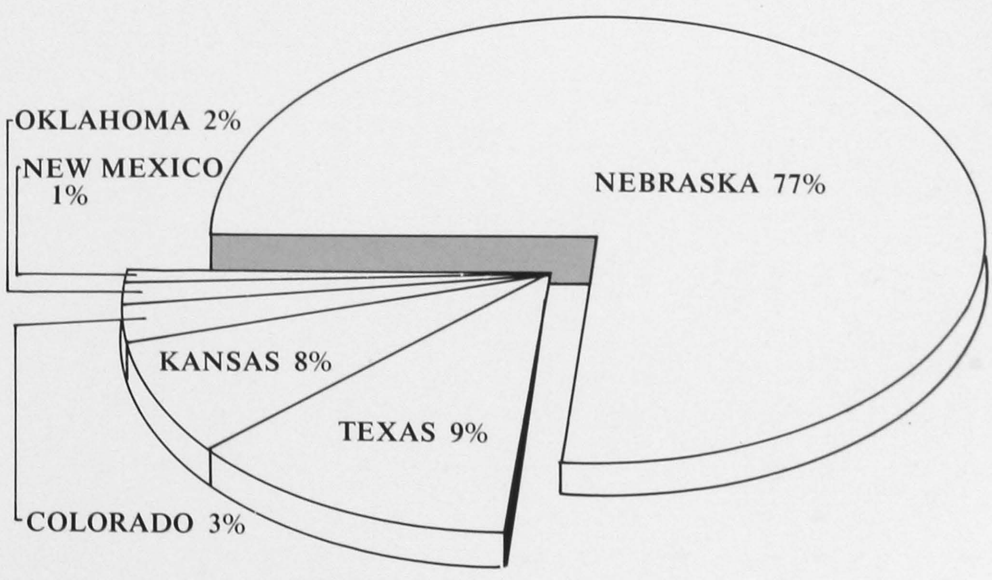
### 3. How much water is in the Ogallala Aquifer?

The Ogallala Aquifer contains slightly more than three billion acre-feet of water, making it the largest underground reservoir of fresh water in the nation. The Ogallala contains enough water to fill Lake Huron.

The distribution of Ogallala water among the six study states is very uneven (Figure 3.1). Nebraska contains more than three-fourths of the Ogallala's water supply. Colorado's 94 million acre-feet is about three percent of the total; the Northern High Plains contains about 75 million acre-feet, and the Southern High Plains 19 million acre-feet. This is enough water to cover the state of Colorado to a depth of 17 inches.

About 95 percent of the water originally contained in the Ogallala Aquifer remains. The fraction remaining for the Colorado portion of the aquifer is about 90 percent.

Figure 3.1
**DISTRIBUTION OF OGALLALA WATER**
**(Six-State Study Area)**



### 4. With so much water in the Ogallala, is there a problem?

Yes, there is a problem. First, only about two-thirds of the Ogallala water in Colorado--about 61 million acre-feet--is *economically recoverable* for irrigation. When the saturated thickness of an aquifer drops below 35 feet, the remaining water is generally not considered economically recoverable. A single well with less than 35 feet of saturated thickness can no longer pump enough water at an adequate rate to irrigate most crops.

Second, outflow and pumping from the Ogallala Aquifer in Colorado exceed recharge *by more than one million acre-feet a year.* (See the FUNDAMENTAL WATER EQUATION box.)

Third, 20 years of pumping have lowered the water table by more than 40 feet in some regions, such as the area around Burlington. Increased pumping lifts and higher energy prices have dramatically increased the cost of irrigation in the High Plains region: the average annual cost of energy to irrigate a 130-acre circle now exceeds $9,000.

Because the region's economy is so closely tied to irrigated agriculture (see Chapter 2), a significant decline in irrigation from any combination of these three factors could affect nearly every citizen in the region.

### 5. Does pumping by other states affect the Ogallala in Colorado?

The rate of ground water outflow from Colorado depends upon the *saturated thickness* of the aquifer and the *slope of the* water table at the state line. Pumping reduces saturated thickness. The effect is similar to shrinking the diameter of a pipe: less outflow. As Colorado, Kansas, and Nebraska continue pumping, outflow across the state will be reduced.

Reducing the saturated thickness, however, also reduces well yields. These effects caused by pumping in adjacent states would be localized near the state line, as the movement of water through the aquifer is quite slow along most of Colorado's eastern border.

Greater pumping by adjacent states also tends to steepen the slope of the water table; by itself, a steeper slope increases ground water outflow. However, *additional pumping east of Colorado* will not increase the slope enough to offset reduced saturated thickness. Therefore, pumping east of Colorado is not likely to have more than localized effects near the state line.

### 6. Can the Ogallala Aquifer sustain irrigation at some reduced level indefinitely?

Yes, but the level of sustainable withdrawals could only be a small fraction of current withdrawals.

To maintain withdrawals at some fixed level indefinitely, annual withdrawals cannot exceed annual recharge minus outflow (see box). Before development, recharge and outflow were identical; sustainability would have required no withdrawals.

As depletion continues, outflows from Colorado will decrease because of reduced saturated thickness. The difference between natural recharge and outflow could become as high as 150,000 to 250,000 acre-feet annually, but changes in well sizes, technology, and locations may be necessary to withdraw such amounts of water and still maintain stability.

With today's water conservation technologies and mix of irrigated crops, 200,000 acre-feet of water is enough to irrigate 100,000 acres of cropland. Several approaches could increase the sustainable level of irrigated acreage, including: improved water conservation methods, expanded markets for low-water crops, artificial recharge, weather modification, and water importation.

Equilibrium will not occur simultaneously or uniformly throughout the region because of different aquifer conditions and levels of pumping. Crop prices and energy costs will also influence water withdrawals and the level and timing of equilibrium. Cheyenne County appears to be approaching equilibrium, while the Burlington area may not reach this point for another 10 years. Yuma and Phillips Counties might not reach equilibrium until after the year 2000.

# THE FUNDAMENTAL WATER EQUATION NORTHERN HIGH PLAINS OF COLORADO

**Current Storage + Recharge − Withdrawals −Outflow =New Storage**

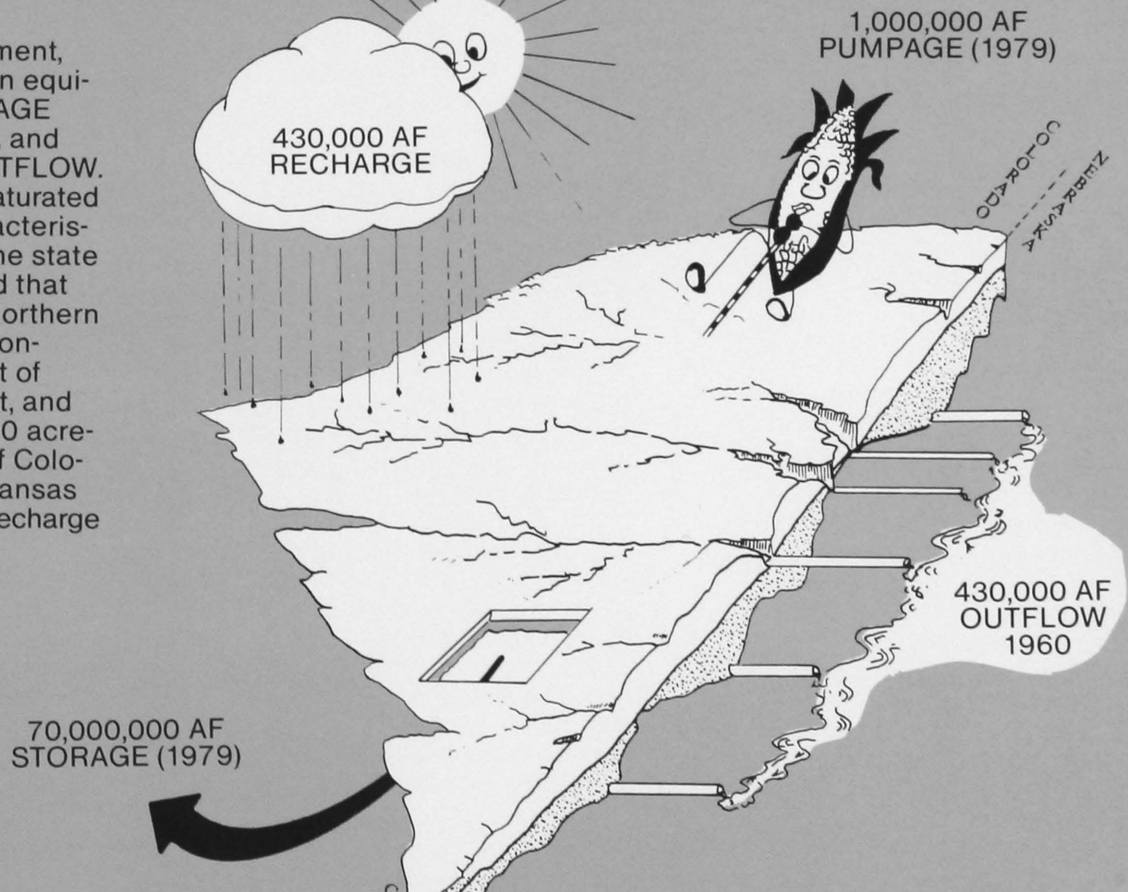
The fundamental water equation is similar to a bank statement for a checking account: current balance + deposits − withdrawals = new balance. CURRENT STORAGE is the amount of water in the aquifer now; RECHARGE is the amount of water added to the aquifer in one year from precipitation and other means; WITHDRAWALS is the amount of water removed from the aquifer in one year for irrigation or other purposes; OUTFLOW is the amount of water that moves across the state line; and NEW STORAGE is the amount of water in the aquifer one year later. (Figure 3.2 illustrates this equation for the Northern High Plains of Colorado.)

Before irrigation development, the Ogallala Aquifer was in equilibrium: CURRENT STORAGE equalled NEW STORAGE, and RECHARGE equalled OUTFLOW. From information on the saturated thickness and other characteristics of the aquifer along the state line, it has been estimated that the aquifer beneath the Northern High Plains of Colorado contained 80 million acre-feet of water before development, and that an average of 430,000 acre-feet of water flowed out of Colorado into Nebraska and Kansas each year. Consequently, recharge from precipitation to the aquifer in this region must also have averaged 430,000 acre-feet of water per year before development.

The average annual recharge from precipitation may change over time, however. Water-conserving agricultural practices such as conservation tillage reduces the amount of water that percolates to the water table; deep chiseling of playa lakes increases recharge.

Under development, WITHDRAWALS in the Northern High Plains of Colorado have increased from zero to approximately one million acre-feet of water per year--almost entirely due to irrigation. OUTFLOWS have been reduced somewhat, because irrigation development in Colorado, Kansas, and Nebraska has reduced the saturated thickness of the aquifer at the state line. The net effect of development has been to reduce the amount of water in storage each year by nearly the amount of water withdrawn annually from the aquifer.

Figure 3.2
**COLORADO NORTHERN HIGH PLAINS**



## GROUND WATER ADMINISTRATION

### 1. How is ground water pumping from the Ogallala Aquifer managed in Colorado?

The Ground Water Management Act of 1965 (C.R.S. 1973, 37-90-101 *et seq.*) provides the framework. This Act allows the state Ground Water Commission, established in 1958, to regulate the use of *designated ground water*. Its precise meaning is complicated (see Glossary).

One of the Commission's first actions was to establish two *designated ground water basins* which include the Colorado portion of the Ogallala Aquifer--the Northern High Plains and Southern High Plains Designated Basins (Figure 3.3). The Commission has jurisdiction for the development, use, and administration of ground water within any designated basin.

Under the 1965 Act, *ground water management districts* can be formed within any designated basin. These management districts are governed by locally-elected boards of directors. They have the authority to adopt rules and regulations that are more restrictive than the policies of the state Ground Water Commission. Districts can also develop water conservation and water supply augmentation programs, and have the power to raise funds through taxation to support such programs.

The Northern High Plains Designated Basin was created in May 1966; the Southern Basin was established 16 months later. Between 1966 and 1977, eight ground water management districts were formed in the Northern Basin. Together these districts include virtually all of the irrigated land within the Northern Basin. A single ground water management district was formed in the Southern High Plains Designated Basin in 1974. This district includes most of the irrigated acreage within the Southern Basin.

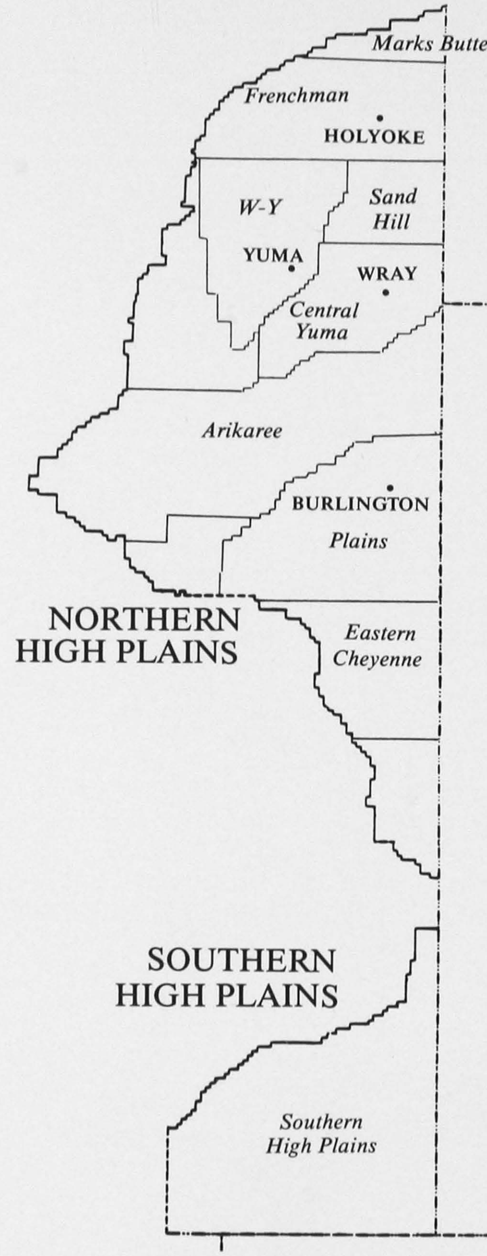
The State Engineer's Office (Division of Water Resources) provides staff support to the Ground Water Commission. The State Engineer issues permits for small capacity wells (less than 50 gallons a minute) for domestic, livestock, and commercial uses within designated basins. Local ground water management districts may, by rules and regulations, further restrict the issuing of permits for small capacity wells. The state Ground Water Commission issues permits for large capacity wells for irrigation and other purposes.

### 2. What are the current policies on ground water pumping from the Ogallala in Colorado?

Three principal policies of the Ground Water Commission govern water withdrawals in the Northern High Plains Designated Basin: *(1) no more than 40 percent depletion of the aquifer in a 25-year period; (2) no more than 2½ acre-feet of water pumped per irrigated acre per year; (3) no less than ½ mile spacing between irrigation wells.* Some wells developed before 1965 have appropriations of more than 2½ acre-feet per acre, and some have less.

In the Southern High Plains, most of the irrigation development preceded the September 1967 date when the area was designated. In this designated basin, the Commission requires at least a half-mile spacing between any new wells and limits annual withdrawals to three acre-feet per acre for any new irrigated lands. Because of rapidly declining water levels and greater pumping lifts in that area and depressed prices for crops grown there, few new irrigation wells have been developed. High pumping costs and reduced well yields have generally controlled annual withdrawals.

Figure 3.3
**GROUND WATER MANAGEMENT DISTRICTS (Colorado High Plains)**



### 3. How were the policies developed?

The policies for the Northern High Plains Designated Basin were developed in 1967 in a joint meeting of the Plains and Sandhills Ground Water Management Districts and four other proposed districts; later, these policies were formally adopted by the Commission for the entire Basin.

The primary policy of no more than 40 percent depletion in 25 years represents a compromise of viewpoints, ranging from virtually no withdrawals to virtually no limit on pumping. Most people felt that this compromise policy could maintain most of the irrigation already established over the initial 25-year period. It was hoped at the time that future technological development--such as improved irrigation practices, more water-efficient crops, improved crop varieties, and artificial recharge--would be developed to enable a significant amount of irrigation to continue for about a century.

### 4. How are requests for new well permits granted or denied in the Northern High Plains?

In order to implement a policy of limiting depletion to 40 percent of the Aquifer over 25 years, the Ground Water Commission adopted a *three mile test* for evaluating requests for new wells.

Under this test, the volume of water is calculated which lies beneath a circle of three-miles radius, centered at the proposed well site. This volume of water depends upon: (1) the amount of water presently in storage; (2) the amount of natural recharge to the circle; and (3) the amount of recharge from irrigation.

Next, the amount of appropriated water from existing wells and from the proposed well within the circle is calculated. (The legal limit in most cases is 2½ acre-feet per irrigated acre per year.) If the amount of water that can legally be withdrawn is 40 percent or less of the water available, the well permit is granted. Otherwise, it is denied.

### 5. How does the actual rate of aquifer depletion compare with the policy of 40 percent depletion in 25 years?

The Northern High Plains' policy is applied each time a well permit is requested, and the 25-year period therefore depends upon the year in which the request is made. Nevertheless, the actual depletion rate for much of the Colorado Northern High Plains is remarkably close to the policy rate applied to each permit request. An extensive network of more than 700 observation wells has been measured annually since development began. These data show that, for much of the irrigated area, the water table has declined about 1.6 percent a year--equivalent to 40 percent depletion of the saturated thickness over 25 years.

In some areas of Kit Carson and Cheyenne Counties, the rate of decline has exceeded the 40 percent in 25 years rate. But in some of the sandhills area in Yuma County, the rate of decline is less.

Changing crop practices, reduced pumping, and higher than normal precipitation have reduced the rate of decline since 1980. It is too early to tell whether this recent trend will continue.

The Southern High Plains Designated Basin has no comparable policy of limiting overall depletions. The intermingling of other aquifers with the Ogallala Formation makes it virtually impossible to measure depletion rates of the Ogallala Aquifer by itself.

### 6. What is the remaining life of the Ogallala Aquifer in Colorado?

Estimates of the remaining life of the Ogallala in Colorado depend directly upon the volume of water currently in storage, and the annual rate of withdrawals from the aquifer. The annual withdrawal rate in turn depends upon two fundamental factors: (1) the economics of irrigation, and (2) ground water policies.

If irrigation remains economically feasible, as is projected under the High Plains Study in all cases except the PESSIMISTIC BASELINE, the current supply of ground water is projected to be reduced to approximately 71 million acre-feet by the year 2020 (See Chapter 4). However, the *economically recoverable water* remaining is projected to be only about 35 million acre-feet in the year 2020. If this pattern is repeated for 40 years thereafter, the supply of Ogallala water could drop to 50 million acre-feet, and economically recoverable water could be virtually gone by the year 2060.

On the other hand, if irrigation rapidly becomes economically infeasible, as under the PESSIMISTIC BASELINE case in Chapter 4, the supply of Ogallala water in Colorado would eventually be restored to pre-development levels. However, rapid phase-out of irrigation could seriously jeopardize the region's economy if crop prices do not keep pace with inflation.

# CHAPTER FOUR
# "A BUSINESS AS USUAL" FUTURE

Thousands of factors shape the future, but our awareness of these factors, our understanding of how they are interrelated, and our ability to express these relationships precisely are limited. This chapter summarizes the combined efforts of several specialists in soil science, agriculture, water, economics, and energy to examine a "business as usual" future of the High Plains region in Colorado, using the best information and analytic methods available. Other future projections, or *scenarios*, are described in the next chapter.

An analysis of the region's future begins with its *soils, climate, and agricultural practices.* Researchers divided the High Plains region into six smaller subregions (Figure 4.1); within each subregion these conditions are similar. Ground water information was developed for each of the 319 townships in the study region. Average depth to water, average saturated thickness, number of wells, and related data were gathered for each township.

Next, assumptions must be made about other factors that will affect irrigation in the future; the primary factors chosen in the High Plains Study were *crop yields, energy prices, and commodity prices.* Also important are assumptions about *water use efficiency, additional water supply, and restrictions on water use.*

This information is combined by computer models to select the mix of crops that gives the greatest economic return to the farmer. Then projections can be made for *resource use, crop production, economic activity, employment, and population* for the region. This is the outline used in the High Plains Study to develop future projections for the High Plains region.

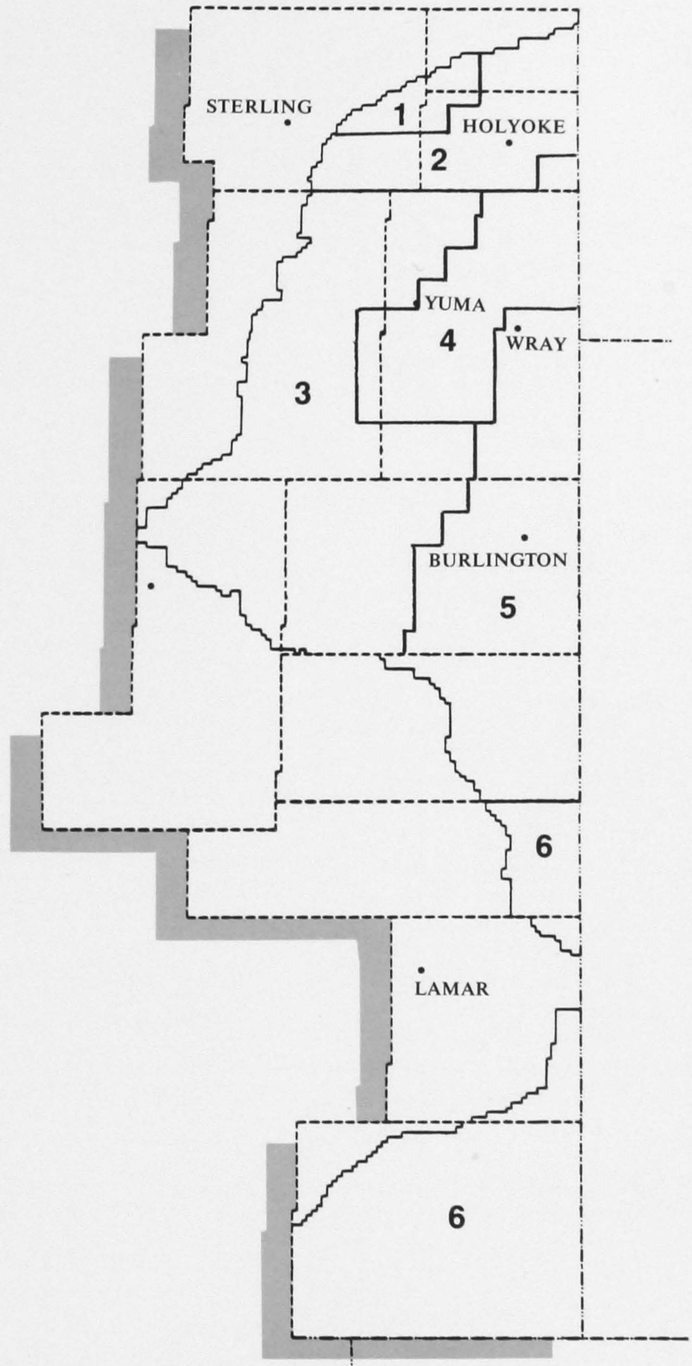



Figure 4.1
**STUDY SUBREGIONS**
**(Colorado High Plains)**

## ASSUMPTIONS

The future described here is called the BASELINE, as it assumes no changes in present public policies on water supply and use. Current trends in farm management are assumed to continue. Under this forecast, there would be no new efforts to increase irrigation efficiency, no new restrictions on water use, and no new water diversion projects.

### Crop Yields

A trend line based on past yields was developed for each of the crops grown in the High Plains. Many plant scientists believe it is unlikely that future increases in yields will be as high as past ones. The BASELINE case assumes that yields will continue to increase at slightly lower rates than before (Table 4.1). Significant yield increases are projected for sunflowers because their genetic potential is only now being seriously investigated.

### Energy Prices

The BASELINE case assumes that energy prices will rise considerably faster than the rate of inflation over the next 40 years. Prices for petroleum-based products such as natural gas and diesel fuel are projected to rise more rapidly than prices for electricity, which is chiefly generated from abundant supplies of coal. Under BASELINE assumptions, electricity doubles in price over 40 years, and natural gas is five times as expensive in 2020 as it was in 1979. Anhydrous ammonia is projected to triple in price over the study period (Table 4.2).

(Note: All prices used in the High Plains Study are in *constant 1979* dollars. Projections of future prices do not include the effects of inflation. Inflated prices would be much greater than prices stated in constant 1979 dollars. For example, if an annual inflation rate of seven percent were used, natural gas would cost $113.26/MCF in 2020 in inflated dollars instead of $7.15/ MCF in 1979 dollars.)

Table 4.1
**IRRIGATED AND DRYLAND CROP YIELD PROJECTIONS (BASELINE SCENARIO) a/**

| CROP | UNIT | 1979 | 1985 | 1990 | 2000 | 2020 |
|---|---|---|---|---|---|---|
| Corn | bu/acre | | | | | |
| Irrigated b/ | | 130.0 | 142.0 | 152.0 | 167.0 | 178.0 |
| Dryland c/ | | 30.0 | 32.0 | 34.0 | 36.5 | 41.5 |
| Grain Sorghum | bu/acre | | | | | |
| Irrigated d/ | | 60.0 | 66.0 | 71.0 | 76.0 | 86.0 |
| Dryland e/ | | 20.0 | 21.5 | 22.7 | 25.2 | 30.2 |
| Wheat | bu/acre | | | | | |
| Irrigated | | 50.0 | 54.0 | 58.0 | 66.0 | 81.0 |
| Dryland f/ | | 32.0 | 35.0 | 37.5 | 41.5 | 46.5 |
| Pinto Beans | cwt/acre | | | | | |
| Irrigated g/ | | 17.0 | 17.1 | 17.2 | 17.5 | 18.0 |
| Dryland | | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 |
| Sunflowers e/ | cwt/acre | | | | | |
| Irrigated | | 18.0 | 21.0 | 24.0 | 27.0 | 33.0 |
| Dryland | | 9.0 | 10.0 | 11.0 | 12.0 | 14.0 |
| Alfalfa | tons/acre | | | | | |
| Irrigated | | 4.5 | 4.7 | 5.0 | 5.5 | 6.0 |
| Grass Hay | tons/acre | | | | | |
| Dryland | | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 |
| Sugar Beets | tons/acre | | | | | |
| Irrigated h/ | | 19.0 | 19.1 | 19.2 | 19.5 | 20.0 |

**NOTES**
a/ Yield projections for irrigated crops assume a full water supply.
b/ Projected yields are 10 bushels per acre less for subarea 6.
c/ Projected yields for subareas 1 and 2. Yields are 10 bushels per acre less for subareas 3, 5, 6.
d/ Projected yields are 15 bushels per acre more for subarea 5 and 30 bushels per acre more for subarea 6.
e/ Projected yields are for subareas 1, 2, 3, 5, 6.
f/ Projected yields are for subareas 1 and 2. Yields are 7 bushels per acre less for subarea 3, 10 bushels per acre less for subareas 4 and 5, and 14 bushels per acre less for subarea 6.
g/ Projected yields are for subarea 2. Yields for subareas 3 and 5 are 1 ton per acre less.
h/ Projected yields are for subarea 2. Projected yields for subareas 3 and 5 are 2 tons per acre less.

Table 4.2
**PROJECTED ENERGY PRICES (BASELINE SCENARIO, 1979 DOLLARS)**

| ITEM | UNIT | 1979 | 1985 | 1990 | 2000 | 2020 |
|---|---|---|---|---|---|---|
| Electricity | $/kWh | 0.05 | 0.06 | 0.07 | 0.09 | 0.10 |
| Natural Gas | $/MCF | 1.70 | 4.42 | 6.45 | 6.80 | 7.15 |
| Diesel Fuel | $/gal | 0.80 | 1.08 | 1.09 | 1.13 | 1.18 |
| Gasoline | $/gal | 0.90 | 1.10 | 1.12 | 1.14 | 1.18 |
| Anhydrous Ammonia | $/lb | 0.09 | 0.18 | 0.25 | 0.26 | 0.27 |
| Other Fertilizer | $/lb | 0.11 | 0.17 | 0.22 | 0.23 | 0.24 |

## Commodity Prices

BASELINE crop prices are projected to increase more rapidly than the rate of inflation over the next 40 years (Table 4.3). These price forecasts were developed from a U.S. Department of Agriculture computer model of national and world factors that affect the supply and demand of agricultural commodities. The model forecasts that demand will grow more rapidly than supply as world population increases and diets are upgraded to include more animal protein. Such a change in supply and demand would necessarily lead to higher prices for agricultural commodities.

Table 4.3
**PROJECTED COMMODITY PRICES (BASELINE SCENARIO, 1979 DOLLARS)**

| CROP | UNIT | 1979 | 1985 | 1990 | 2000 | 2020 |
|---|---|---|---|---|---|---|
| Corn | bu. | $ 2.60 | $ 3.07 | $ 3.11 | $ 3.32 | $ 3.49 |
| Sorghum | bu. | 2.20 | 2.59 | 2.63 | 2.82 | 2.95 |
| Wheat | bu. | 3.50 | 3.26 | 3.29 | 3.36 | 3.66 |
| Pinto Beans | cwt. | 24.00 | 24.40 | 24.70 | 26.00 | 28.00 |
| Sunflowers | cwt. | 10.00 | 11.20 | 10.85 | 11.30 | 12.60 |
| Sugar Beets | ton | 30.00 | 32.45 | 32.85 | 34.55 | 37.20 |
| Alfalfa | ton | 54.00 | 62.50 | 63.00 | 65.40 | 67.20 |

# RESULTS

The results projected under the BASELINE case are quite favorable for Colorado's High Plains region as a whole. Although irrigated acreage drops significantly over the 40-year period, the production and total value of most crops are projected to increase (Table 4.4).

This somewhat surprising result is chiefly due to the BASELINE assumption that future commodity prices will increase faster than inflation. Under such an assumption, farmers will have a powerful incentive to keep irrigating until the water is physically gone, despite higher pumping costs. Since the Colorado portion of the Ogallala still contains about 90 million acre-feet, there is enough water to support irrigation in most areas for at least the next 40 years.

The BASELINE results reported here are not uniform throughout the region. For example, in the *northern High Plains where the aquifer is thickest and less developed, irrigation is projected to expand slightly*. But in the eastern central and southeastern areas of the region, irrigated acreage declines by 57 and 77 percent, respectively, over the 40-year period.

## Resource Use

Irrigated cropland for the entire region drops from 600,000 to 364,000 acres over the next 40 years--a decline of 40 percent. Dry cropland acreage increases by nine percent during this same period.

The amount of irrigation water pumped from the Ogallala Aquifer in Colorado each year drops to about half its current total of 1.1 million acre-feet between 1979 and 2020. Water table declines of one or two feet per year are projected for most of the region.

The number of irrigation wells in the region is projected to decline from about 4800 wells now to about 2800 wells in 2020. Because projected increases in natural gas prices are higher than projections for electricity, the decline is expected to be greater for irrigation pumps that use natural gas. As with electricity, most of the reduction occurs after the year 2000 as aquifer depletion curtails pumping.

While wells in some areas would go out of production because of inadequate recoverable water, new wells would be established in other areas. The Colorado State Engineer's Office estimates that about 200 more wells could be allowed in Yuma County under current regulations. These are included in the projections.

Table 4.4
**BASELINE SCENARIO PROJECTIONS (COLORADO HIGH PLAINS)**

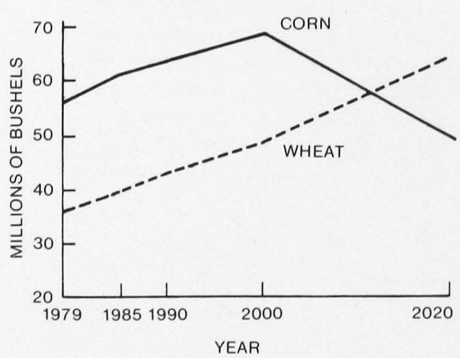
| | 1979 | 1985 | 1990 | 2000 | 2020 |
|---|---|---|---|---|---|
| Irrigated Cropland (thousands of acres) | 600 | 562 | 592 | 501 | 364 |
| Dry Cropland Harvested (thousands of acres) | 1,683 | 1,710 | 1,737 | 1,749 | 1,815 |
| Irrigation Water Pumped (thousands of acre-feet) | 1,148 | 1,076 | 1,005 | 965 | 656 |
| Economically Recoverable Water in Storage (millions of acre-feet) | 61 | 57 | 53 | 46 | 36 |
| Value of Irrigated Crop Production (millions of 1979 dollars) | 189 | 223 | 230 | 255 | 208 |
| Value of Dryland Crop Production (millions of 1979 dollars) | 132 | 148 | 166 | 195 | 256 |
| Net Farm Income (millions of 1979 dollars) | 105 | 110 | 106 | 142 | 188 |
| Employment (11-county region) | 30,090 | 33,495 | 33,884 | 34,857 | 34,982 |
| Population (11-county region) | 79,739 | 88,793 | 89,793 | 92,371 | 92,702 |

## Agricultural Production

Corn remains the dominant irrigated crop throughout the 40-year period. Production peaks in the year 2000 at 20 percent above current levels and then plunges to 18 percent below current levels by 2020 (Figure 4.2). Wheat continues as the major dryland crop and surpasses corn in total bushels by 2020. Wheat production nearly doubles over the 40-year study period.

Sunflowers emerge as the principal water-conserving crop under irrigation, while production of pinto beans and sugar beets declines substantially. These results follow from BASELINE assumptions that future crop prices and yield increases for sunflowers will be better than those for beans and beets. If these assumptions don't materialize, bean and beet production will probably remain near current levels.

Figure 4.2
**CORN AND WHEAT PRODUCTION**
**(Baseline Scenario)**

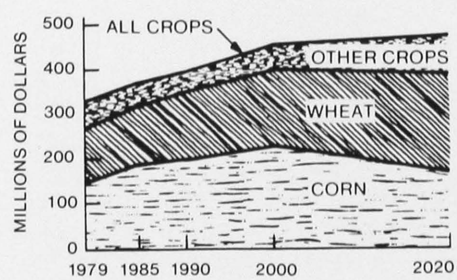



The total value of all crop production rises by nearly 50 percent over the study period, due to assumptions of increased yields and higher commodity prices (Figure 4.3). The value of irrigated crop production peaks in the year 2000 and then declines to slightly above the current levels. The value of dryland crops increases steadily, and surpasses the value of irrigated crops by 2020.

*Net crop income*--returns to land and management--rises steadily over the forecast period, both for irrigated and dryland crops. However, net income rises faster for dryland than for irrigated farming.

Feedlot activity, although not forecast by the model, may follow the upward trend in feed grain production. Corn and sorghum production increases steadily to 20 percent above its present level by 2000, then declines to 18 percent below its present level by 2020. This should add to the total employment in the regional economy at least through 2000, as livestock production would not necessarily decline with feed grain production. Even in 2020, enough feed grain would be produced to support the livestock industry above the 1979 level.

Figure 4.3
**VALUE OF CROP PRODUCTION**
**(Baseline Scenario)**



## Aquifer Status

In 1979, the Colorado portion of the Ogallala Aquifer contained about 94 million acre feet. At projected rates of withdrawal, about 71 million acre- feet would remain after 40 years. Of that amount, only about half is estimated to be *economically recoverable* for irrigation in 2020. Figure 4.4 displays the time periods when irrigation becomes infeasible within the region.

## Socio-Economic Effects

The 11-county Colorado High Plains economy is projected to expand under BASELINE conditions. As explained earlier, BASELINE assumptions that commodity prices will rise faster than inflation mean that the total value of crop production is expected to increase. (Higher crop yields and prices more than offset losses in irrigated land, under these assumptions.) Since the region's economy depends heavily upon agriculture (see Chapter 2), its expansion under BASELINE conditions is no surprise.

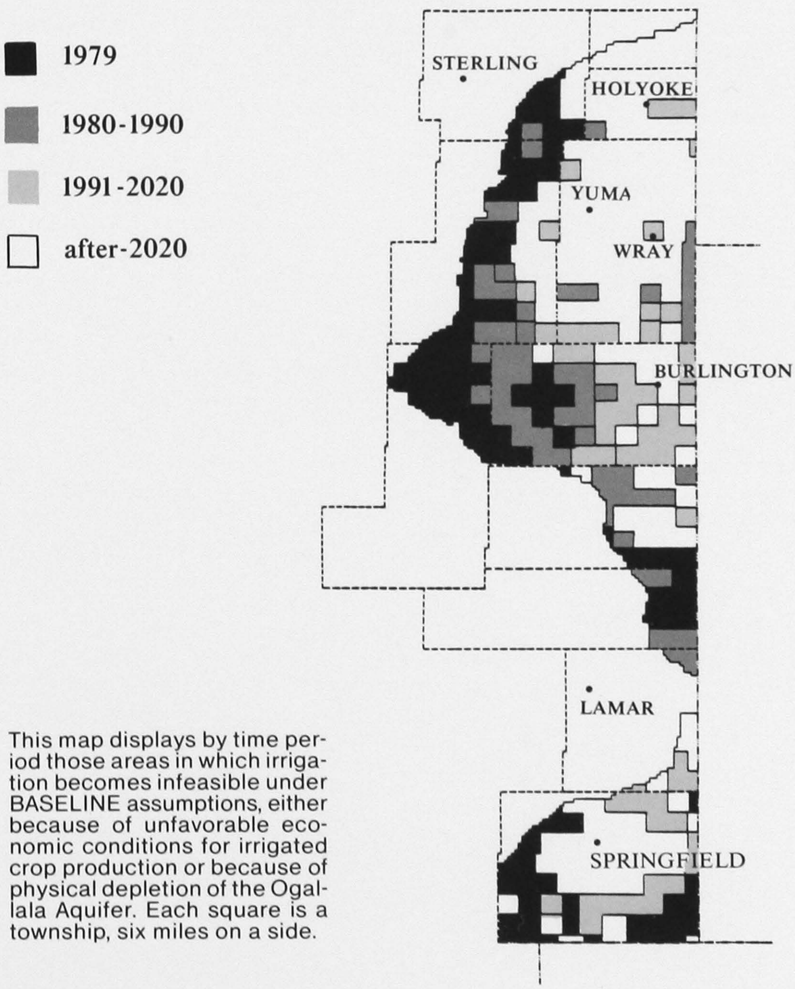
Increases in economic activity will increase the demand for jobs, and population is expected to increase at the same rate. The 11-county region's population is projected to grow from about 80,000 people to nearly 93,000 persons in 2020.

## Environmental Effects

The abandonment of irrigation on 261,000 acres by 2020 would occur mainly on areas with soils suitable for dryland farming. (About 25,000 acres of new irrigated land are projected to come into production in sandhills the area north of Wray during the forecast period. The net loss of irrigated land is 236,000 acres over the period.) The BASELINE case assumes that previously irrigated lands suitable for dryland cultivation will revert to that purpose. The environmental effects of converting such lands are expected to be minimal.

The lands most sensitive to wind erosion are the sandhills. Irrigation in this area is projected to expand, exposing more land to wind erosion. Because water supplies are generally adequate in the sandhills, most of this area would still be irrigated in 2020. When irrigation is discontinued, wind erosion could be serious unless revegetation begins while irrigation systems are still in place.

Figure 4.4
**HOW LONG WILL IRRIGATION LAST?**
**(Baseline Scenario)**




This map displays by time period those areas in which irrigation becomes infeasible under BASELINE assumptions, either because of unfavorable economic conditions for irrigated crop production or because of physical depletion of the Ogallala Aquifer. Each square is a township, six miles on a side.

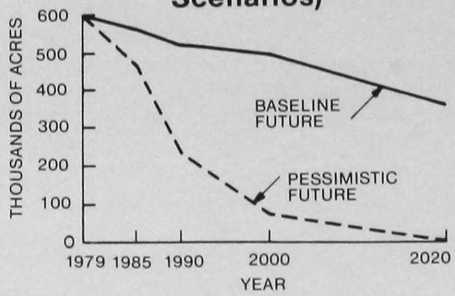
# A PESSIMISTIC BASELINE

The results of the BASELINE case depend squarely upon the assumptions about crop prices and yields, and energy prices.

To illustrate this dependence, researchers prepared an alternate "business as usual" scenario with less optimistic assumptions: *(1) crop prices rise exactly at the rate of inflation, instead of faster than inflation as under the BASELINE; (2) crop yields rise only half as fast as projected under the BASELINE; and (3) energy prices rise twice as fast as projected under the BASELINE.* No changes in public policy regarding water use or supply are assumed, as in the BASELINE case.

The results for the PESSIMISTIC BASELINE are dramatically different from the BASELINE scenario (Table 4.5). Irrigated acreage declines by 60 percent by 1990, by 90 percent in 2000, and irrigation vanishes by 2020 (Figure 4.5). PESSIMISTIC BASELINE assumptions result in widespread *economic failure* -- inability to keep irrigating because of the cost-price squeeze, even though water remains. In contrast, declines in irrigated acreage under the BASELINE are largely due to *hydrologic failure* -- insufficient water.

Figure 4.5
**IRRIGATED CROPLAND (Baseline and Pessimistic Scenarios)**




The PESSIMISTIC BASELINE scenario is excessively gloomy. If the BASELINE seems somewhat over-optimistic, this scenario overstates things in the opposite direction. But it vividly illustrates the direct dependence of research results upon research assumptions.

Table 4.5
**PESSIMISTIC BASELINE PROJECTIONS (COLORADO HIGH PLAINS)**

| | 1979 | 1985 | 1990 | 2000 | 2020 |
|---|---|---|---|---|---|
| Irrigated Cropland (thousands of acres) | 600 | 470 | 235 | 72 | 0 |
| Dry Cropland Harvested (thousands of acres) | 1,683 | 1,750 | 1,828 | 1,887 | 1,918 |
| Irrigated Water Pumped (thousands of acre-feet) | 1,148 | 706 | 202 | 56 | 0 |
| Economically Recoverable Water in Storage (millions of acre-feet) | 61 | 57 | 55 | 56 | 61 |
| Value of Irrigated Crop Production (millions of 1979 dollars) | 189 | 140 | 52 | 19 | 0 |
| Value of Dryland Crop Production (millions of 1979 dollars) | 132 | 146 | 162 | 180 | 206 |
| Net Farm Income (millions of 1979 dollars) | 105 | 39 | 18 | 31 | 60 |
| Employment (11-county region) | 30,090 | 33,426 | 30,744 | 30,565 | 30,691 |
| Population (11-county region) | 74,650 | 80,538 | 81,379 | 80,906 | 81,239 |

# CHAPTER FIVE
# OTHER POSSIBLE FUTURES

The BASELINE analysis presented in Chapter 4 gives a "business as usual" projection of the Colorado High Plains over the next 40 years. This BASELINE projection assumes no changes in water supplies through importation or other means, and no changes in water laws.

This Chapter describes and compares the BASELINE with three other *scenarios*, or possible futures, for the region: (1) an EFFICIENCY scenario in which the current pace of improving irrigation efficiencies is speeded up through increased research, education, and technical assistance; (2) a RESTRICTION scenario, in which ground water withdrawals are limited by policies and regulations beyond those already in place; and (3) a SUPPLY scenario, in which additional water is made available to the region through importation or other means. Changing the assumptions of the BASELINE future changes the estimated extent of future irrigation, agricultural production, energy use, regional employment and population, and the expected life of the Ogallala Aquifer.

## AN "EFFICIENCY" FUTURE: DOES IT MAKE A DIFFERENCE?

*Improving irrigation efficiency* could significantly change the 40-year BASELINE forecast described in Chapter 4. Chapter 6 discusses ways to implement such a strategy.

An EFFICIENCY scenario was developed by High Plains Study researchers to estimate these changes, based upon the following assumptions: *(1) no improvements in efficiency until 1990; (2) electric pump efficiency above BASELINE efficiency by two percent in 1990, nine percent in 2000, and 16 percent in 2020; and (3) water application efficiency above BASELINE efficiency by three percent in 1990, seven percent in 2000, and 12 percent in 2020.* No changes were made in BASELINE assumptions on crop prices and yields, energy prices, and water availability.

The effect of these increased efficiencies is *to reduce the cost of applying an acre-inch of water below BASELINE costs.*

The future of irrigation is brighter under the EFFICIENCY scenario that under the BASELINE, since fewer pumps are abandoned due to high pumping costs. Only about half as much land goes out of irrigation as under BASELINE conditions (Table 5.1).

Table 5.1
**EFFICIENCY SCENARIO PROJECTIONS (COLORADO HIGH PLAINS)**

| | 1979 a/ | 1985 a/ | 1990 | 2000 | 2020 |
|---|---|---|---|---|---|
| Irrigated Cropland (thousands of acres) | 600 | 562 | 567 | 528 | 472 |
| Dry Cropland Harvested (thousands of acres) | 1,683 | 1,710 | 1,712 | 1,735 | 1,764 |
| Irrigated Water Pumped (thousands of acre-feet) | 1,148 | 1,076 | 1,059 | 971 | 783 |
| Economically Recoverable Water in Storage (millions of acre-feet) | 61 | 57 | 53 | 46 | 35 |
| Value of Irrigated Crop Production (millions of 1979 dollars) | 189 | 223 | 245 | 272 | 270 |
| Value of Dryland Crop Production (millions of 1979 dollars) | 132 | 197 | 164 | 194 | 249 |
| Net Farm Income (millions of 1979 dollars) | 105 | 110 | 115 | 163 | 220 |
| Employment (11-county region) | 30,090 | 33,495 | 34,149 | 35,168 | 46,106 |
| Population (11-county region) | 74,650 | 88,661 | 90,392 | 93,090 | 95,575 |

a/ Same as BASELINE scenario.

However, more water is withdrawn from the aquifer under the EFFICIENCY scenario than for the BASELINE case. More land remains in irrigation because of lower pumping costs, and the irrigation water used by this additional land is greater than the combined water savings from greater irrigation efficiencies per acre. Water level declines are also greater under the EFFICIENCY scenario and range from 0.5 to 2.5 feet per year.

Electricity use in the EFFICIENCY case peaks in 1990--10 years earlier than in the BASELINE case--and reflects improved irrigation efficiencies. Although natural gas use for irrigation declines steadily over the 40-year period to about one-third of

present levels, the number of natural gas pumps operating in 2020 is more than double the number projected for the BASELINE.

Corn continues to be the dominant irrigated crop for the EFFICIENCY scenario. The values of total irrigated crop production peaks in the year 2000, and then levels off. Total net crop income is much higher under this scenario than for the BASELINE, because of more irrigated acreage and lower costs of water application.

Since only half as much irrigated land is projected to go out of production for this scenario, environmental impacts from blowing soil are expected to be less than projected BASELINE impacts.

## RESTRICTING IRRIGATION: HOW IS THE FUTURE CHANGED?

A RESTRICTION scenario was developed under the High Plains Study to investigate the effects of limiting ground water availability by changing existing policies. In addition to assuming improved irrigation efficiencies, the RESTRICTION scenario limits pumping levels per acre to 90 percent of current levels in 1985, 80 percent in 1990, and 70 percent in 2000 and beyond. Assumptions on crop yields and energy prices are slightly different from those used in the BASELINE because of differences in agricultural production.

Although irrigated acreage under these assumptions declines more rapidly between 1979 and 2000 than for the BASELINE or EFFICIENCY scenarios, more land remains in irrigation in 2020 under the RESTRICTION scenario (Table 5.2). However, the difference between this scenario and the EFFICIENCY scenario is only about 6,000 acres.

Table 5.2
**RESTRICTION SCENARIO PROJECTIONS (COLORADO HIGH PLAINS)**

| | 1979 | 1985 | 1990 | 2000 | 2020 |
|---|---|---|---|---|---|
| Irrigated Cropland (thousands of acres) | 600 | 557 | 524 | 469 | 478 |
| Dry Cropland Harvested (thousands of acres) | 1,683 | 1,714 | 1,743 | 1,745 | 1,750 |
| Irrigated Water Pumped (thousands of acre-feet) | 1,148 | 968 | 815 | 656 | 584 |
| Economically Recoverable Water in Storage (millions of acre-feet) | 61 | 57 | 53 | 48 | 43 |
| Value of Irrigated Crop Production (millions of 1979 dollars) | 189 | 211 | 205 | 207 | 225 |
| Value of Dryland Crop Production (millions of 1979 dollars) | 132 | 148 | 166 | 195 | 247 |
| Net Farm Income (millions of 1979 dollars) | 105 | 106 | 102 | 134 | 200 |
| Employment (11-county region) | 30,090 | 33,384 | 33,362 | 34,093 | 35,121 |
| Population (11-county region) | 79,650 | 88,367 | 88,309 | 90,244 | 92,965 |

Water use under additional restrictions is dramatically reduced. Pumping in 2020 is about 50 percent of the 1979 level, and about 10 percent below the level predicted by the BASELINE. The water level declines less rapidly than for the other scenarios, ranging from 0.3 to 1.1 feet per year.

With pumping restrictions and increased efficiency, electricity use for irrigation would decline steadily through the 40-year period to about 60 percent of the 1979 level--well below BASELINE and EFFICIENCY projections. Natural gas use for irrigation declines much more rapidly than electricity use, remaining below the level of use in the BASELINE and EFFICIENCY cases.

Net crop income from irrigated production throughout the period is lower than in the EFFICIENCY case, but by 2020, it is 20 percent higher than in the BASELINE, because of the continued availability of water. Changes in total net crop income are similar.

Under this scenario, environmental impacts are greatest between 1979 and 2000, since the greatest decline in irrigated acreage for this period occurs under the RESTRICTION scenario.

The effects of supplying additional water to the High Plains by water importation or other means were examined by researchers in the SUPPLY scenario.

The SUPPLY scenario assumes that additional water would be made available to restore irrigation to lands that went dry under the RESTRICTION scenario. All other assumptions for the RESTRICTION scenario hold for this case. (A similar scenario, restoring lands previously irrigated under the EFFICIENCY scenario, was developed in the High Plains Study but is not discussed here. Differences between these two scenarios are minor.)

Restoring water to this land would require 212,000 acre-feet of water annually by the year 2000 and 175,000 acre-feet by 2020. It is assumed that any additional water would be available on the surface, so additional pumping is needed only to continue using existing sprinklers. It was further assumed that no additional water would be available until 2000, since no major water importation system could be designed, approved, and built in less than 20 years.

The SUPPLY analysis measures the farmer's *ability to pay* for an acre-foot of water. This is defined by economists as: (1) the net irrigated crop return on an acre-foot of water, plus (2) savings in pumping costs for one acre-foot, minus (3) net dryland crop returns displaced by the acre-foot of water.

Under the SUPPLY scenario, the ability of farmers to pay for water in southeast Colorado is $59 an acre-foot in 2000 and $109 per acre-foot in 2020 . The ability of farmers in other parts of Colorado's High Plains region is about $100 an acre-foot in 200 and about $160 an acre-foot in 2020. (These are 1979 dollars, so the effects of inflation are factored out.)

These estimates of ability to pay are higher than the amount the farmers can *afford to pay.* For example, suppose the ability to pay for water is $100 an acre-foot. If a farmer is charged $100 for this acre-foot, he *breaks even:* his profit is zero and he receives no compensation for his time. The ability to pay for water measures the break-even value of water, and treats farm management as a contribution.

As the discussion in Chapter 8 on water importation indicates, *the ability to pay for water is substantially below the estimated cost of importing water into the region.*

The additional water brought into the Colorado High Plains under the SUPPLY scenario would be used to restore irrigation on land where water supplies had been exhausted under the RESTRICTIONS scenario. Additional irrigation development, based on still unused water in the sandhills, would raise the total irrigated area in the Colorado High Plains from 600,000 acres in 1979 to 625,000 acres by 2020 under this scenario (Table 5.3).

More irrigated acreage would mean increases in electric energy use, total crop production, and the value of crop production. Net irrigated crop income cannot be estimated because it depends on the farmer's share of water import costs. If the farmer's cost share is more than his ability to pay, net income will be negative.

Restoration of irrigation would allow annual crop production, without fallow land in alternate years. This would reduce wind erosion. Construction of water storage and distribution systems would expose some soil, but the effect would be minor compared to cultivation. Construction would also temporarily interfere with farming and transportation.

Table 5.3
**SUPPLY SCENARIO PROJECTIONS (COLORADO HIGH PLAINS)**

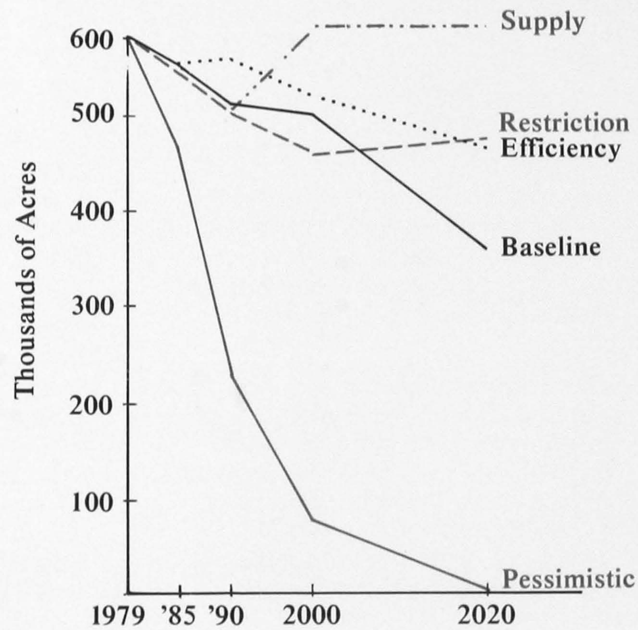
| | 1979 a/ | 1985 a/ | 1990 a/ | 2000 | 2020 |
|---|---|---|---|---|---|
| Irrigated Cropland (thousands of acres) | 600 | 557 | 524 | 625 | 625 |
| Irrigated Water Pumped (thousands of acre-feet) | 1,148 | 968 | 815 | 656 | 584 |
| Economically Recoverable Water in Storage (millions of acre-feet) | 61 | 57 | 53 | 48 | 43 |
| Value of Irrigated Crop Production (millions of 1979 dollars) | 189 | 211 | 205 | 270 | 294 |
| Value of Dryland Crop Production (millions of 1979 dollars) | 132 | 148 | 166 | 189 | 238 |
| Net Farm Income (millions of 1979 dollars) | 105 | 106 | 102 | b/ | b/ |
| Employment (11-county region) | 30,090 | 33,384 | 33,462 | 35,360 | 36,339 |
| Population (11-county region) | 79,650 | 88,367 | 88,309 | 93,333 | 96,189 |

a/ Same as RESTRICTION scenario.
b/ Depends on cost to irrigators of imported water.

## COMPARING POSSIBLE FUTURES

The graphs on these three pages display five different forecasts of future conditions in Colorado's High Plains region lying over the Ogallala Aquifer. These scenarios correspond to strategies available to the region described in Chapters 6 through 9., plus the Pessimistic Scenario discussed in Chapter 4.

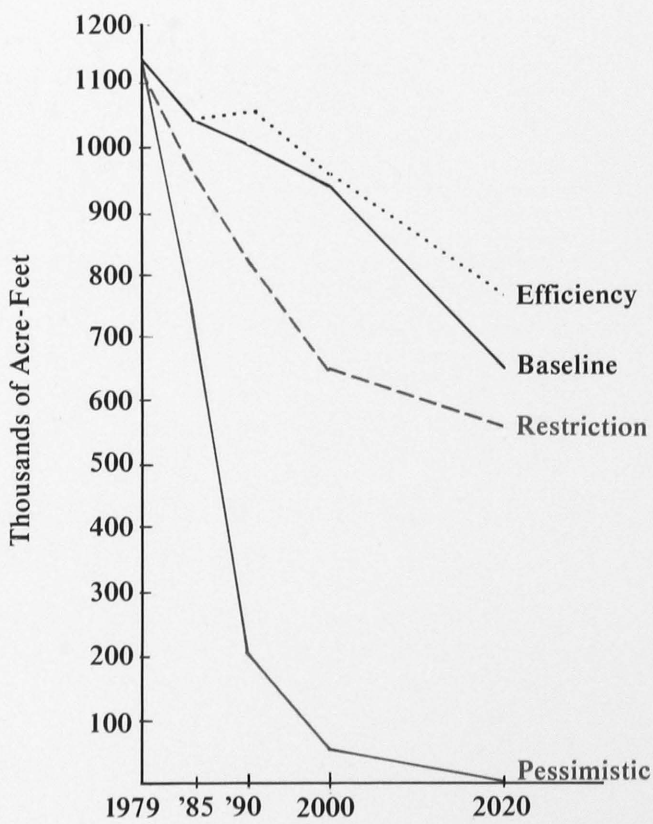
Figure 5.1




### Irrigated Cropland

Under BASELINE assumptions, irrigated cropland declines by 40 percent over the next 40 years. Only half as much land goes out of irrigation under the EFFICIENCY and RESTRICTION scenarios. Improved irrigation efficiencies mean that irrigation remains feasible on more land; restrictions on water use hasten the conversion to less water-consumptive crops and increase the feasibility of irrigation. The SUPPLY scenario assumes that additional water would be brought into the area to restore irrigation to lands that went dry under the RESTRICTION scenario. Projections of additional land being brought under irrigation in the sandhills area boost irrigated cropland under the SUPPLY scenario to 625,000 acres by 2020. The PESSIMISTIC BASELINE shows the other extreme, with irrigated cropland capability disappearing from the region by 2020.

Figure 5.2



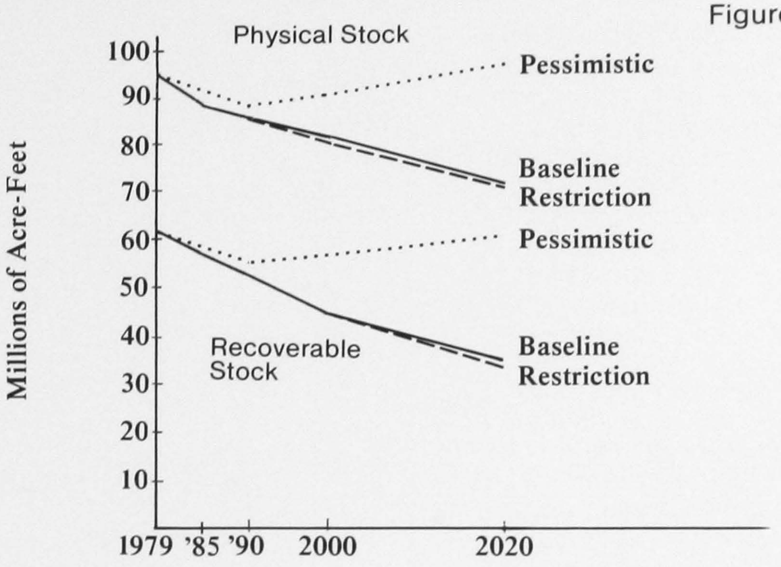

### Irrigation Water Pumped

Average annual withdrawals from the Ogallala Aquifer due to irrigation pumping drop about 40 percent over the 40- year period--the same percentage as the drop in irrigated acreage--under the BASELINE case. The greatest amount of water is pumped under the EFFICIENCY scenario because irrigation efficiencies lower the cost of applying water and farmers irrigate more land. The amount of water needed to irrigate this additional land is greater than the total amount saved by improved irrigation efficiencies per acre. The RESTRICTION scenario assumes both greater irrigation efficiencies and restriction on water use, so irrigation water withdrawn is lowest for this case. Water withdrawn under the SUPPLY case is identical with that for the RESTRICTION case, since additional irrigated lands would use imported surface water. The PESSIMISTIC scenario mirrors the irrigated cropland graph with no water being pumped by 2020.

## Remaining Stock of Water

This graph displays both the physical stock of water remaining in the aquifer at each time period and the portion which is economically recoverable. *Economically recoverable water* is defined as ground water in excess of 35 feet of saturated thickness. (For example, under this definition, portions of the aquifer with 50 feet of saturated thickness contain only 15 feet of economically recoverable water.) The pumping rate of irrigation wells generally begins to decline when remaining saturated thickness falls below 35 feet. As pumping rates decline less land can be irrigated by each well. The remaining stocks of water for the SUPPLY and RESTRICTION scenarios are identical since additional SUPPLY water would be surface water.

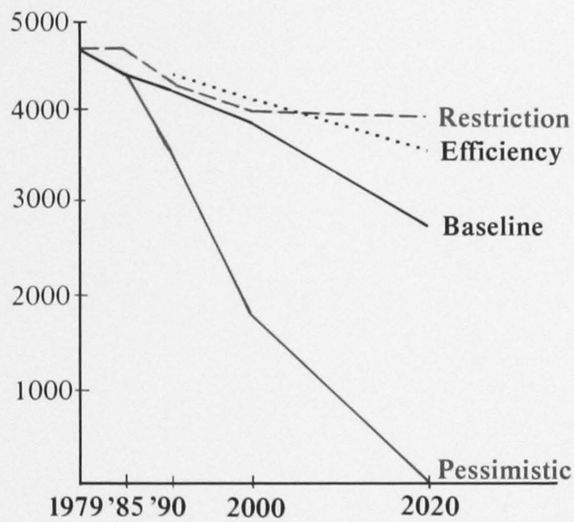
Figure 5.3




## Number of Irrigation Wells

Under each of the scenarios there is a significant decline in the number of irrigation wells. The smallest loss comes under the RESTRICTION scenario, which extends the life of the aquifer because less water is pumped. Under the assumptions of the PESSIMISTIC BASELINE irrigation from wells ceases by 2020.

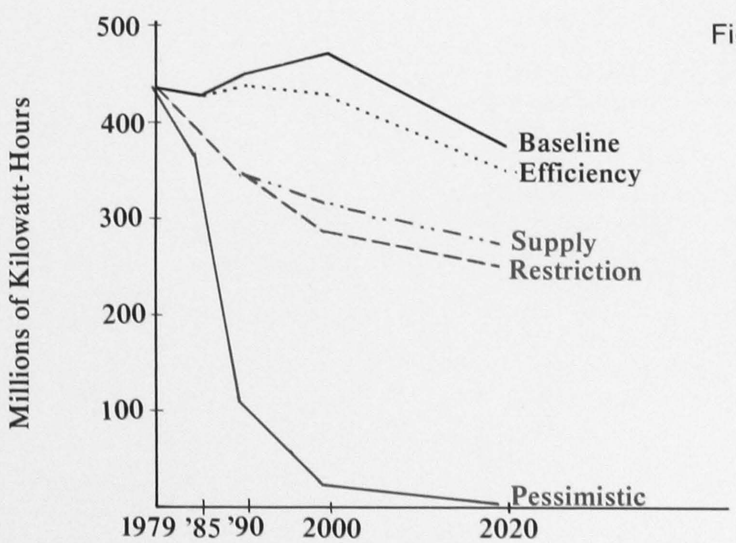
Figure 5.4




## Electric Energy Use

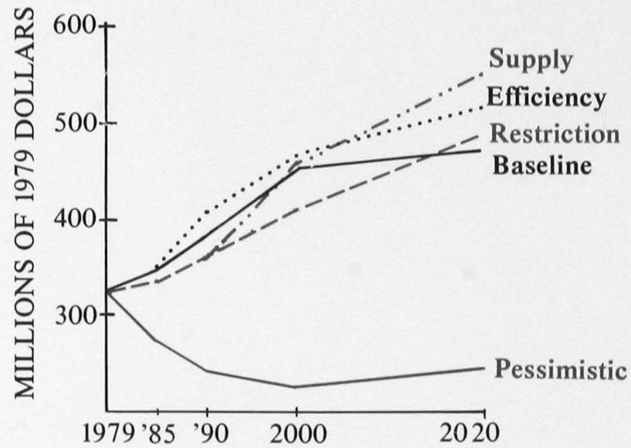
Under the BASELINE scenario, the amount of electricity used for irrigation peaks in the year 2000. Electricity use peaks 10 years earlier under the EFFICIENCY scenario because of increased irrigation efficiencies. Projected shifts from natural gas to electricity for irrigation pumping explain why electricity use is projected to increase under the BASELINE scenario for the next 20 years. Conversion to electricity doesn't offset irrigated acreage declines under the RESTRICTION scenario, so electric energy use drops steadily over the 40-year period. The SUPPLY scenario requires slightly more energy than the RESTRICTION scenario because additional land is under irrigation.

Figure 5.5



## Value of Crop Production

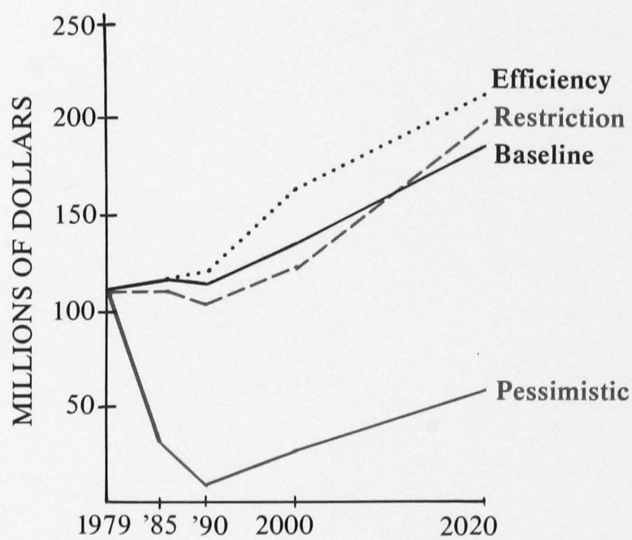
This graph shows that the total value of all crop production--from both irrigated and dry land--is projected to increase under each scenario. The value of crop production increases, despite projected declines in irrigated acreage, for two reasons. First, crop yields per acre are expected to continue increasing, although at slightly lower rates than in the past. Second, commodity price projections developed by USDA for the High Plains Study are expected to increase faster than the rate of inflation over the 40-year period. Greater value per bushel and ton of production and assumed higher yields per acre more than offset projected declines in irrigated acreage.




## Net Crop Income

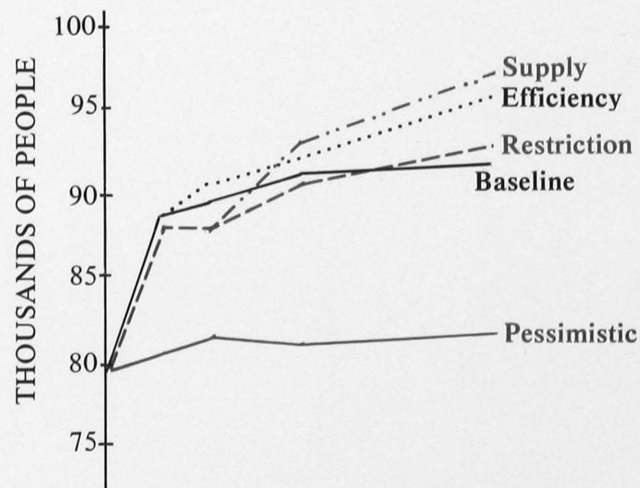
This graph shows the projections of net crop income (i.e., returns to land and management) in the study area. For the BASELINE, EFFICIENCY, and RESTRICTION scenarios there is little change through 1990. Between 1990 and 2020, however, all three scenarios show major increases with the EFFICIENCY scenario showing the highest net crop income.

The PESSIMISTIC BASELINE shows major declines in 1985 through 2000 because of the negative return from irrigated cropland.




## Population

This graph displays population projections for the 11 Colorado counties in which the Ogallala Aquifer occurs. The total population of these counties includes 2½ times as many people as the 33,000 who live in the area that actually lies over the Ogallala Aquifer. In addition to the aquifer area, this region includes parts of the South Platte and Arkansas Valleys, with a larger and more diverse economy, and two large towns--Sterling and Lamar. All scenarios show population increases for this region over the study period.



# CHAPTER SIX
# IMPROVING IRRIGATION EFFICIENCY

Four fundamental strategies could be used to combat aquifer depletion and irrigation decline: (1) *improve irrigation efficiency* to produce more per unit of water and energy; (2) *restrict ground water use* to extend the life of the aquifer; (3) *increase water supply* in the region to offset aquifer decline; and (4) *expand economic development* opportunities to broaden the base of the High Plains economy. Each strategy includes one or more possible options for specific action.

The EFFICIENCY, RESTRICTION, and SUPPLY scenarios discussed in Chapter 5 correspond to the first three strategies. The High Plains Study did not include a scenario that corresponds to the economic development strategy. The BASELINE scenario and its pessimistic variation described in Chapter 4 correspond to a no-action, or "business as usual," strategy, and are not discussed in the remaining chapters. The *scenarios* described in Chapters 4 and 5 indicate what the future might be like; the *strategies* described in Chapters 6 through 9 describe how to get there.

*Improving irrigation efficiency* is the first--and most basic--strategy for maintaining irrigation in the Ogallala region for two reasons. First, most methods for boosting water use efficiency cost only five to ten percent as much per acre-foot as importing water. Second, most methods for conserving water can be implemented within a year or two, while water importation projects generally require decades of planning, authorization, and construction before the first drop of water can be delivered.

This chapter discusses four ways to improve irrigation efficiencies: *research and demonstration*, both for (1) *conventional* and (2) *alternate crops*; (3) *education* and *technical assistance*; and (4) *electricity pricing policies*. Eleven of the 20 recommendations for action developed by the Colorado High Plains Advisory Committee are directed toward improving irrigation efficiency and are listed in this chapter.

## RESEARCH AND DEMONSTRATION: CONVENTIONAL CROPS

Corn, wheat, pinto beans, sorghum, alfalfa, and sugar beets are the principal crops grown in the High Plains region of Colorado. Over several decades, farmers and scientists have determined that these conventional crops are compatible with the region's soils, climate, and water supply, and that there is a market for these crops. The primary thrust of agriculture research and development should be to continue improving the efficient production of these crops.

### 1. Agricultural Research

RECOMMENDATION: THAT FUNDS FOR ADDITIONAL AGRICULTURAL RESEARCH BE ALLOCATED TO IMPROVE WATER USE EFFICIENCY IN THE OGALLALA REGION.

Additional research is needed in several areas to improve irrigation efficiencies in the Ogallala region. These include: (1) crop response to less than full irrigation; (2) genetic research on low-water-use crop varieties; (3) minimum tillage and chemical fallow; (4) irrigation scheduling; and (5) cropping system studies, such as corn-wheat-fallow.

Federal and state spending for agricultural research is not keeping pace with inflation. Federal funding buys 30 percent less research now than it did ten years ago, while state funding buys about 10 percent less research.

Agricultural producers contribute to research through private seed companies when they buy seed.

Some commodities such as wheat have a bushel check-off earmarked for market promotion and agricultural research.

**This recommendation was forwarded to Congress with the six-state recommendations.**

## 2. Local Research Foundations

RECOMMENDATION: THAT LOCAL PRODUCERS FORM NOT-FOR-PROFIT FOUNDATIONS TO CONDUCT LARGE-SCALE AGRICULTURAL RESEARCH AND DEMONSTRATION PROJECTS.

The lack of commercial-scale research and demonstration projects is one of the chief obstacles to adopting more efficient methods of conserving water on High Plains farms. Any change in cropping patterns, cultivation practices, or irrigation methods is usually a major business decision. Because the financial stakes are so high, farmers tend to discount the relevance of research information developed from small plots of land.

In cooperation with Colorado State University, farmers in southeastern Colorado have operated a private research foundation for seven years to promote large-scale field testing of promising ways to conserve water. With the help of a low-interest loan from the Farmers Home Administration, the Plainsman Agri-Search Foundation recently purchased three quarter-sections of land near Walsh after leasing land for several years. An 18-member board makes all major decisions and cooperates closely with state researchers to conduct suitable projects.

A locally-based foundation in the Northern High Plains of Colorado could promote large-scale research and demonstration projects suitable for this section of the region. By providing land and actively cooperating with researchers, such a foundation could speed up the adoption of more efficient practices and methods for conserving water.

**In the fall of 1982 a High Plains Advisory Committee member and a county extension agent from northeastern Colorado met with Board members from the Plainsman Agri-Search Station in Walsh to learn how this private organization was established. Additional meetings with northern High Plains producers will be needed to carry out this recommendation.**

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# RESEARCH AND DEMONSTRATION: ALTERNATE CROPS

Over the past 30 years, crop and livestock patterns in the High Plains region have changed in response to new signals from the marketplace and changes in the availability and price of irrigation water. Growing demand for beef after World War II, the development of the center-pivot irrigation system, and abundant, cheap energy radically changed the "conventional" agricultural enterprises of wheat and cattle grazing to "alternate enterprises" of corn, sugar beets, alfalfa, and cattle feedlots.

Today different signals are coming from the marketplace, and water is scarcer and more expensive. Crop and livestock patterns are already changing. Sugar beet acreage in the High Plains has declined drastically over the past 5 years in response to low beet prices and rising costs of supplying water to this thirsty crop. High interest rates and declining per capita demand for beef are reducing the number of cattle on feed in Colorado. Production of pinto beans, well-suited to High Plains soils and sunshine, has increased over the same period; beans require about 12 inches of supplemental water--two-thirds the requirement of corn.

As conditions change, it will be important to supplement the current crop and livestock options with alternate crops that require less water. Some possible alternate crops include *sunflowers*, which require about half as much water as corn; *grain amaranth*, whose seeds yield a high quality protein and oil; and the *Jerusalem* *artichoke*, a starchy tuber suitable for human consumption or fuel alcohol use.

Within 30 years, the High Plains could possibly produce crops and other plants for the chemical industry, which by then will likely have to look for other feedstocks besides petroleum.

### 3. Alternate Crops

RECOMMENDATION: THAT STATE AND FEDERAL FINANCIAL SUPPORT BE INCREASED FOR RESEARCH, DEVELOPMENT, AND MARKETING OF ALTERNATE CROPS.

A systematic inventory and analysis of alternate crops with economic potential is urgently needed--not only for the High Plains but other areas of the state as well. In addition to determining whether such crops can be raised in the state, such studies must investigate problems and opportunities in processing and marketing alternate crops. Such exploratory research and development should be done in addition to--not in place of--research on conventional crops.

If low-water crops could be grown commercially on one-third of the region's current irrigated land, annual aquifer withdrawals could be reduced by as much as 200,000 acre-feet--the amount of water that has been proposed for importation.

Identifying, producing, processing, and marketing new commodities is a lengthy, complex process. It commonly takes 10 to 15 years for research results to move from the laboratory to commercial use.

As with Edison's search among thousands of substances for a suitable light bulb filament, there will be many failures. But the payoffs in terms of expanded agricultural options and related economic activity in the region could be significant.

**The Colorado Commission on Higher Education awarded a grant to the CSU Department of Agronomy in March 1982 to prepare an analysis of promising crop alternatives for eastern Colorado. A report will be available by the fall of 1983.**

## EDUCATION AND TECHNICAL ASSISTANCE

Research and development results have little value unless they reach potential users. The Colorado Cooperative Extension Service, a network of 165 extension agents in county offices and 60 specialists at Colorado State University, has primary state responsibility for disseminating information about irrigation efficiency to farmers. The U.S. Soil Conservation Service has primary federal responsibility for providing technical assistance to farmers who wish to apply that knowledge. Education and technical assistance are also available to farmers through private publications, equipment, seed, and fertilizer companies, and private agricultural consultants.

## 4. Irrigation Specialist

RECOMMENDATION: THAT THE STATE COOPERATIVE EXTENSION SERVICE ASSIGN AN ADDITIONAL IRRIGATION SPECIALIST TO THE HIGH PLAINS REGION.

The Extension Service employed a full-time irrigation specialist to work exclusively with irrigators in the High Plains region, but the position has been vacant since early 1980 due to Extension Service budget cuts. (There is now one full-time irrigation extension specialist for eastern Colorado and a quarter-time specialist for the Western Slope.)

As pumping costs increase and water supplies decrease, it will become more and more important to provide up-to-date, practical information at the farm level on methods to improve water use efficiency.

**The Cooperative Extension Service has assigned an additional irrigation specialist to the High Plains region. This specialist is located at the ARS-USDA Central Great Plains Field Station in Akron.**

## 5. Evapotranspiration (ET) Reporting Stations

RECOMMENDATION: THAT ADDITIONAL ET REPORTING STATIONS BE ESTABLISHED IN THE NORTHERN HIGH PLAINS AND THAT THIS INFORMATION BE REPORTED DAILY.

Daily information on crop evapotranspiration (ET) rates could significantly reduce irrigation pumping. Farmers can use accurate estimates of the daily water requirement of each crop to determine when and how much irrigation water to apply.

With the help of local newspapers and radio stations, the Cooperative Extension Service in Logan County has been reporting ET information daily for the past two years. Because rainfall and climatic conditions vary from place to place, this service chiefly benefits those within 30-50 miles of the reporting station.

Each additional ET reporting station would require a one-time cost of approximately $3,000 for equipment plus modest labor and telephone costs for five months each year to read and transmit the ET information to cooperating newspapers and radio stations. Expenses could be cut if local organizations helped to operate these ET stations.

An expanded ET reporting network would be particularly useful in the Northern High Plains, where climatic and aquifer conditions allow irrigators to make maximum use of such information.

**The Cooperative Extension Service established an ET reporting station in Akron in the fall of 1982. The Extension Service plans to establish stations in both Yuma and Walsh as funds become available.**

## 6. SCS Target Assistance

RECOMMENDATION: THAT THE U.S. SOIL CONSERVATION SERVICE DESIGNATE THE OGALLALA REGION AS A TARGET AREA FOR INCREASED TECHNICAL AND FINANCIAL ASSISTANCE.

The State Conservationists from the U.S. Soil Conservation Service (SCS) in the six-state Ogallala region have requested that this region be targeted for increased technical and financial assistance to improve water and soil conservation practices. This assistance will be particularly important as thousands of acres in this region go from irrigation back to dryland production and rangeland. Additional personnel are also needed to help conduct on-farm irrigation efficiency tests and promote effective seasonal water management practices.

The Colorado SCS office estimates that an additional 20 employees would be needed in the High Plains of Colorado to carry out such programs. These employees should represent a net increase rather than a transfer of personnel from other regions in the state.

**An additional $125,000 has been allocated to the Colorado office of the Soil Conservation Service for increased technical assistance to the Colorado High Plains region for the 1983 fiscal year. Similar additional amounts can reasonably be expected for the next five years.**

### 7. Regional Technical Committee

RECOMMENDATION: THAT A COLORADO HIGH PLAINS TECHNICAL COMMITTEE BE FORMED TO COORDINATE IRRIGATION RESEARCH, DEMONSTRATION, EDUCATION, AND TECHNICAL ASSISTANCE IN THE REGION.

Several local, state, federal, and private agencies and organizations are conducting irrigation research, demonstration, education, and technical assistance programs in the High Plains of Colorado. As program costs continue to rise, it will be important for agencies and organizations to avoid unnecessary duplication of effort.

A High Plains Coordinating Committee composed of these agencies and organizations could serve as a clearinghouse for information and provide a forum for coordinating irrigation research, education, and technical services in the High Plains region. Soil conservation districts, ground water management districts, and other local organizations should be heavily involved.

A similar coordinating committee has been formed in the Grand Valley to reduce salinity in the Colorado River. This committee has speeded up the transfer of research information to irrigators through extension and technical assistance, and researchers have obtained first-hand knowledge of problems in applying theory to practice.

**In March 1982, the Colorado High Plains Technical Coordinating Committee was formed. The Committee consists of more than 30 local, state, and federal officials, plus representatives from private organizations. Meetings are held quarterly to initiate and coordinate research, education, and technical assistance on water conservation and related topics in the Colorado High Plains region.**

### 8. Continue Depletion Analysis

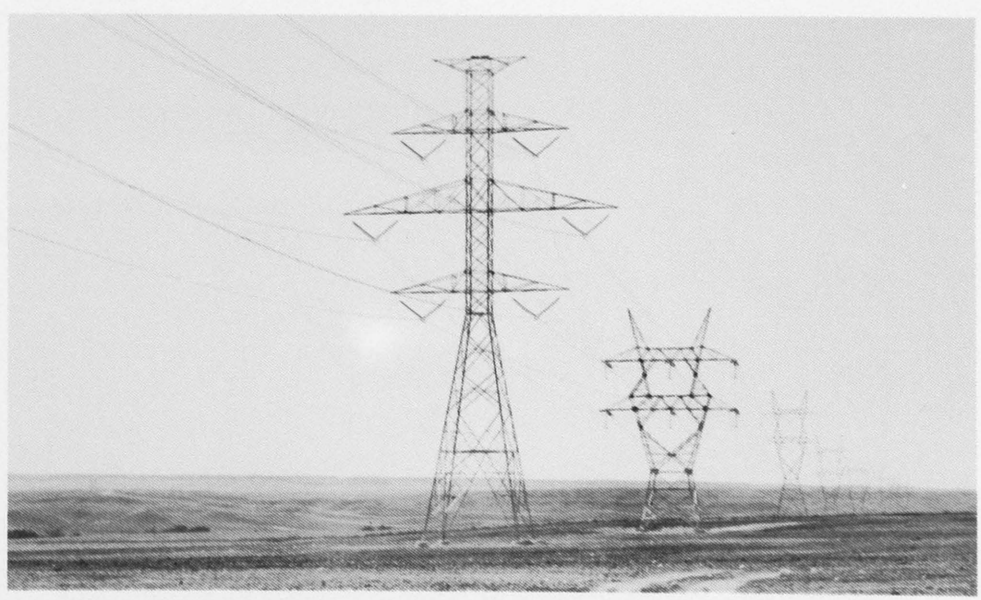
RECOMMENDATION: THAT STATE AND FEDERAL FUNDING BE PROVIDED TO CONTINUE MONITORING GROUND WATER DEPLETION AND ITS PROJECTED EFFECTS UPON THE REGION, STATE, AND NATION.

The detailed analysis of the Ogallala Aquifer prepared through the High Plains Study should be refined and updated at regular intervals. Representatives from the eight states which lie above the Ogallala Aquifer and appropriate federal agencies should meet periodically after the High Plains Study is complete to share information on aquifer depletion and activities to combat it.

Funding should be provided for Colorado State University and appropriate state agencies to continue the Colorado analysis and disseminate information to the High Plains region, the state legislature, and other groups in the state. The Colorado High Plains Advisory Committee or some other regional group should serve as a formal link to the region in conducting these studies and information programs.

**This recommendation was forwarded to Congress with the six-state recommendations.**

## ELECTRICITY PRICING POLICIES



In addition to ground water policies, commodity prices, and interest rates, natural gas and electricity prices are among the most important factors affecting the future of irrigation in the High Plains. These two sources of energy are used in 98 percent of all High Plains irrigation. Because of substantial price increases forecast for natural gas, and because electric motors are generally easier to maintain and repair than natural gas engines, electricity is expected to be used for most irrigation in the future.

Current pricing policies for electricity and natural gas provide limited incentives for irrigators to conserve energy and water. Under declining block rate policies, the last unit of energy costs less than the first, so the last acre-inch of water applied costs much less than the first. Under a flat rate structure with hook-up charges, reductions in energy use may not result in comparable reductions in the energy bill.

The utility companies developed these pricing policies to insure sufficient revenue to construct, operate, and maintain power plants and electric transmission systems. Unfortunately for irrigators, if total energy use in the region declines, utilities will have to increase their charges to cover fixed costs. *The "reward" for saving energy could be a rate increase, regardless of the rate structure.*

The pricing policies of electric utilities--local REA cooperatives--have an important effect on energy and water use efficiency and on the life of the Ogallala Aquifer. It will be difficult to balance the interests of all parties involved. Irrigators want cheaper energy so they can continue to irrigate. Utilities need sufficient revenue to supply electricity. And all citizens of the region have a stake in sustaining the economic life of the aquifer.

### 9. Model Rate Structure

RECOMMENDATION: THAT THE PUBLIC UTILITIES COMMISSION ESTABLISH AN IRRIGATION RATE TASK FORCE TO DEVELOP A "MODEL" RATE STRUCTURE ACCEPTABLE TO UTILITIES AND IRRIGATORS.

Dr. Robert Young and Richard Gardner of Colorado State University recently completed a study on the impact of rate structure changes upon pumping rates, cropping patterns, net income to irrigators, and utility revenues. They found that rate structures can affect water and energy use under low commodity price levels (e.g., 1982 conditions).

A task force representing irrigators, REA cooperatives, natural gas companies, and other citizens should be established to: (1) review the results of the CSU study on rate structures, (2) conduct public meetings and obtain public comments on this issue, and (3) develop and recommend to the Public Utilities Commission a model rate structure that promotes energy and water conservation while providing sufficient revenues to utilties.

**Young and Gardner presented their findings to representatives from REAs and the PUC during the spring of 1983.**

### 10. Unscheduled Power Interruption

RECOMMENDATION: THAT UTILITIES DETERMINE THE IMPACT OF UNSCHEDULED POWER INTERRUPTION ON PUMPING AND DISCONTINUE THIS PRACTICE IF STUDIES SHOW THAT SUCH PROGRAMS ACTUALLY INCREASE WATER USE.

Several local REAs have voluntary power interruption programs that reduce peak energy loads on their systems. A cooperating irrigator allows the REA to shut off one or more of his pumps through a radio control unit at any time. In exchange, the irrigator receives a discount on his power bill.

However, this system may be increasing the amount of water applied per acre. Since irrigators do not know when their pumps will be shut off, they tend to overirrigate in case this happens at a critical time. Studies should be conducted to determine if this is true, since this load management program may speed up the depletion of the aquifer.

**This recommendation has been forwarded to the Highline Electric Association--the only High Plains REA that has an unscheduled power interruption program.**

The final recommendation in this chapter is related to each of the four lines of action:

### 11. Water Conservation

RECOMMENDATION: THAT CONGRESS PLACE THE HIGHEST PRIORITY ON INCREASING FUNDING TO IMPROVE WATER CONSERVATION IN THE OGALLALA AQUIFER.

High Plains Study research shows that improved irrigation efficiency would: (1) maintain more irrigated acres, (2) raise the total value of agricultural production, and (3) increase returns to land and management all above BASELINE conditions. The public costs for providing incentives for greater irrigation efficiencies are estimated to be only slightly above projected BASELINE expenditures.

**This recommendation has been partially implemented through recommendations 1, 3, 6, and 8. This recommendation was forwarded to Congress with the six-state recommendations.**

# CHAPTER SEVEN
# RESTRICTING GROUND WATER USE

The term "water conservation" has two related but different meanings for High Plains irrigation. First, it can refer to improved efficiency: producing more crops per acre-foot of water, or reducing the number of acre-feet of water used per bushel or ton of crop production. Minimum tillage, irrigation scheduling, crop rotation, and boosting crop yields are some important ways water can be conserved in this "efficiency" sense.

Water conservation in the High Plains can also refer to prolonging the life of the Ogallala Aquifer by slowing the rate of water withdrawal. For more than 15 years, Colorado High Plains irrigators have operated within policies set by ground water management districts which limit water withdrawals (see Chapter 3). The goal in prolonging the aquifer is to place reasonable limits on the total number of acre-feet withdrawn from the aquifer each year.

*The first two strategies--improving irrigation efficiency and restricting ground water use--reflect these two meanings of water conservation for High Plains irrigation.-*

These two aspects of "water conservation" aren't always compatible. It's possible for the total volume of water pumped per year to increase as irrigation becomes more efficient. Improved irrigation efficiencies can reduce the cost of irrigation, so more irrigated land remains in production. If the water savings per acre are offset by the water pumped to irrigate these additional acres, the total amount of water withdrawn each year could increase. This is exactly what happens in the EFFICIENCY scenario, discussed in Chapter 5.

There are other important differences between these two views of water conservation. The "efficiency" point of view revolves around farm management decisions, such as changing irrigation practices, cropping systems, pumping plants, etc. These decisions are primarily *individual, technical and economic*: How can water be used more efficiently? Will it be cost-effective? Decisions are made by individual producers, in consultation with their bankers, in light of information provided through research and demonstration, technical assistance, and extension activities conducted by state and federal agencies and private firms.

In contrast, the issue of extending the life of the Ogallala Aquifer is primarily *public, regulatory and political*: What rate of decline in this nonrenewable resource is desirable or acceptable to the region, to Colorado, and the nation? How shall the need for water for this generation of farmers be balanced with the need of succeeding generations? The issue is *public* because the future of the entire region --not only the individual irrigators-- will be shaped by the answer. The issue is *regulatory and political* because answers to these questions are closely tied to the policies, rules, and regulations of the Colorado Ground Water Commission and local ground water management districts--each a political entity.

Any serious attempt to conserve water and energy in the High Plains must include both strategies. But we must recognize that these strategies will often be at odds with each other; the primary farm management goal is to maximize net income, which so far has been done by increasing rates of water withdrawals.

## 12. Ground Water Depletion Policy

RECOMMENDATION: THAT THE COLORADO GROUND WATER COMMISSION MAINTAIN ITS POLICY OF NO MORE THAN 40 PERCENT DEPLETION OVER 25 YEARS.

Three principal policies of the Ground Water Commission govern water withdrawals in the Northern High Plains Designated Basin: (1) no more than 40 percent depletion of the aquifer in a 25-year period; (2) no more than 2½ acre-feet of water pumped per irrigated acre per year; (3) no less than ½ mile spacing between new irrigation wells. Water level decline in much of the Northern High Plains is approaching the policy guideline of 40 percent depletion over 25 years.

Except for some regions of the sandhills north of Wray, the aquifer is nearly 100 percent appropriated. Thus, revising the spacing policy would have virtually no impact on aquifer depletion rates. To continue historic crop rotation practices, including crops such as sugar beets and alfalfa that need a lot of water, irrigators must be allowed to pump up to 30 acre-inches of water per acre per year. Most irrigators feel that rising energy costs and declining ground water levels will be more effective in reducing pumping than additional government regulation.

**The Ground Water Commission is maintaining its policy of no more than 40 percent depletion over 25 years.**

## 13. Supplemental Well Policy

RECOMMENDATION: THAT THE COLORADO GROUND WATER COMMISSION MAINTAIN ITS PRESENT POLICY OF SUPPLEMENTAL WELLS.

Existing state law (C.R.S. 1973, 37-90-111 (2)) states that no supplemental well should be allowed if the proposed well or wells would in combination deplete the aquifer in excess of the rate prescribed by the Ground Water Commission or by the rules and regulations of local ground water management districts. This statute and these policies, rules, and regulations have helped to extend the life of the Ogallala Aquifer and should be maintained.

**The Ground Water Commission is maintaining this policy.**

# CHAPTER EIGHT
# INCREASING WATER SUPPLY

## INTERSTATE WATER TRANSFERS

For decades, people have thought about importing water to the High Plains region served by the Ogallala Aquifer. The Missouri River and its tributaries are closest to the High Plains, but the possibility has also been discussed of bringing water from the Columbia River in Washington and Oregon, the Yukon River in Alaska, and the MacKenzie River in Canada.

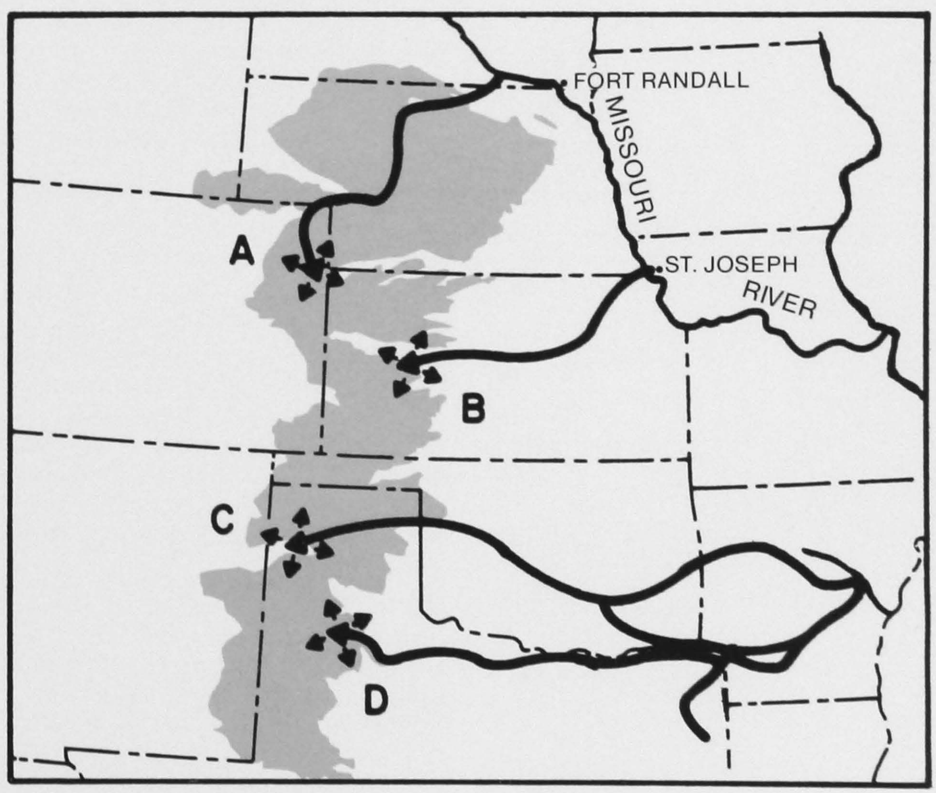
As part of the High Plains Study, the U.S. Army Corps of Engineers examined the technical feasibility and costs of importing water from the Missouri River and its tributaries. The four routes studied by the Corps are displayed in Figure 8.1. Proposed structures were sized to import sufficient water to restore and maintain irrigated lands projected to go out of production during the next 40 years, even if voluntary water conservation measures are undertaken. Where possible, routes were located along ridgelines to minimize environmental impacts.

Route A could most conveniently provide water to Colorado and Nebraska. Route A would use a 620-mile open concrete canal, up to 280 feet wide, diverting water from Fort Randall, South Dakota, and delivering it to six terminal storage points in Nebraska and one in Colorado--Bonny Reservoir, 30 miles north of Burlington. Eighteen pump stations would be needed to lift the water 2400 feet along the route.

Researchers project that about 2.0 million acre-feet of water per year would be needed by 2020 to restore previously irrigated land in Colorado and Nebraska, even with voluntary water conservation measures in effect (about 250,000 acre-feet annually for Colorado and 1,780,000 acre-feet for Nebraska).

Not all of the routes could be built. Withdrawals through route A, for example, would reduce the amount of water available for other routes.

Figure 8.1
**INTERSTATE WATER IMPORTATION ROUTES**



Several billion dollars would be needed to build any one of the four routes. For route A, the first cost estimates are $5.4 billion to deliver 1.91 million acre-feet annually, and $8.9 billion to deliver 3.40 million acre-feet annually. (The lower figures serves demands of Nebraska and one-half of Colorado; the upper figure serves demands of Nebraska, Colorado, Kansas, Oklahoma, and one-third of Texas.) First costs include construction costs over a 15-year period, plus interest at the annual federal rate of 7-3/8 percent amortized over 100 years. The estimated cost to deliver an acre-foot of water to terminal storage by Route A is approximately $291 per acre-foot per year. This does not include costs to construct and maintain local distribution systems to deliver water from terminal storage to farm headgates. (All figures are in 1977 dollars.) As discussed in Chapter 5, *the cost per acre-foot of imported water exceeds agriculture's ability to pay for this water by three to five times.*

The purpose of the Corps' study was to provide cost estimates for transporting water from specific sources to specific terminal points. Their report does not evaluate such possible features as: (1) using the system to control flooding; (2) using open canals as a transportation system; and (3) possible exchanges of water to use natural elevation to avoid pumping. Such options should be considered in any detailed studies.

### 14. Interstate Water Transfer

RECOMMENDATION: THAT CONGRESS CONTINUE TO INVESTIGATE THE POSSIBILITY OF INTERSTATE WATER TRANSFER PROJECTS.

Although the costs for interstate transfers of water to the Ogallala region are greater than agriculture's ability to pay, water importation studies should continue. As world population grows and the global need for food increases, agricultural production in the six-state region will be more and more important.

Several decades are usually required to study, plan, authorize, and construct major water projects. It is sensible to continue exploring all feasible solutions to the region's water problems,including interstate water transfers.

**This recommendation was forwarded to Congress with the six-state recommendations.**

## INTRASTATE WATER TRANSFERS

The South Platte River is the only significant source of water within the state that could conceivably provide additional water to the High Plains regions of Eastern Colorado. (The Arkansas River is over-appropriated, and all available water is being put to beneficial use.)

In 1975 the Trans-County Project (formerly known as the Tri-County Project) was formally proposed to divert excess flood flows from the South Platte to Washington, Yuma, Sedgwick, and Phillips counties in northeastern Colorado. Under this proposal, approximately 200,000 acre-feet of water could be delivered annually to these High Plains counties for irrigation, domestic, municipal, industrial, and recreational purposes. The project would provide supplemental irrigation water for approximately 250,000 acres of cropland.

The Trans-County Project is designed to be constructed whether or not a downstream mainstream reservoir-- such as Narrows--is built. In the "upper unit" of the proposed project, excess water from the South Platte would be conveyed to the proposed Fremont Butte Reservoir through two intermediate storage reservoirs--Morgan-Beaver and Beaver Creek. The Fremont Butte Reservoir would be located just north of the basin divide which separates the High Plains region from the South Platte River basin. From Fremont Butte, water would be transferred to three proposed reservoirs in the High Plains area.

The "lower unit" would divert water from the South Platte River at Sedgwick and pump it up over the basin divide to three proposed reservoirs in Sedgwick and Phillips counties. From these proposed High Plains reservoirs in both units, water would be distributed via canals and ditches to High Plains irrigators and other users.

The first cost estimate for building the upper and lower units of the project is $137 million. The unit cost for delivering an acre-foot of water from the South Platte to terminal storage in the High Plains is estimated at between $61 and $68 per acre-foot per year (1981 dollars). This estimate includes amortization of construction costs, pumping and maintenance costs, and assumes a six percent interest rate over a 100-year period.

15. **Trans-County Project**

RECOMMENDATION: THAT THE STATE OF COLORADO ASSIST IN FUNDING A DETAILED FEASIBILITY STUDY OF THE TRANS-COUNTY PROJECT.

Supporters of the Trans-County Project recently attempted to form a water conservancy district but were denied the opportunity to put the matter to a vote of citizens in the project area. The Division I water court judge ruled that existing studies hadn't established the feasibility of the Trans-County Project, and therefore, it would be premature to form such a district. Project supporters have raised over $40,000 to help pay for a detailed feasibility study. At least $150,000 more is needed. The State of Colorado could assist by providing additional study funds through the Colorado Water Conservation Board or the Colorado Water Resources and Power Development Authority.

**The Colorado Water Conservation Board has agreed to loan $50,000 to Trans County Water, Inc. to begin a reconnaissance-level study provided this group can raise matching funds. In April 1983 the water court judge ruled that project supporters had not shown due diligence, and thus their water right was cancelled. This decision may be appealed to the State Supreme Court.**

16. **Intrastate Water Transfers**

RECOMMENDATION: THAT THE STATE OF COLORADO INVESTIGATE THE FEASIBILITY OF DIVERTING WATER WITHIN THE STATE TO THE HIGH PLAINS.

Two plans for importing water to the High Plains region have been studied: (1) the Trans-County project, to import 200,000 acre-feet from the South Platte River, and (2) the Corps of Engineers' analysis through the High Plains Study on importing 200,000 acre-feet or more from the Missouri River. Other possible sources of water within the state for the High Plains region should be identified and appropriate studies conducted.

**This recommendation was forwarded to the Colorado Water Conservation Board in 1982.**

## AQUIFER RECHARGE

Increasing the rate of aquifer recharge from natural precipitation is another way to increase the region's water supply. Common techniques for artificially recharging an aquifer include spreading basins, recharge ponds, and recharge wells. *Spreading basins* are best suited for areas with inexpensive land, soils with high infiltration rates, and impervious layers between the land surface and water table. *Recharge ponds and pits* are more suitable if land is expensive and if construction of the pond or pit would remove such impervious layers. *Recharge wells* are normally used where one or more impervious layers separate the land surface and the water table. Since the early 1960s several artificial recharge projects have been conducted in the Northern High Plains. However, no systematic survey of potential aquifer recharge sites in the region has been prepared.

Another method of aquifer recharge involves *playa, or wet weather lakes*. Such lakes are depressions which collect water after rainfall or periods of snowmelt. Water could be pumped directly to supply crop needs or used to artificially recharge the aquifer for later withdrawal. Heavy clay soils could be broken up and the lake bottom regraded for maximum recharge.

Several playa lakes are located on the High Plains of Colorado. Kit Carson County alone has more than 3000 of them, ranging in size from one to 20 acres each.

17. **Aquifer Recharge**

RECOMMENDATION: THAT APPROPRIATE LOCAL, STATE, AND FEDERAL AGENCIES DETERMINE SUITABLE AQUIFER RECHARGE SITES AND CARRY OUT DEMONSTRATION PROJECTS.

A cooperative effort involving the U.S. Geological Survey, U.S. Soil Conservation Service, State Engineer's Office, and local ground water management districts is needed to: (1) identify the most promising aquifer recharge sites, and (2) design and carry out beneficial projects.

**A subcommittee of the Colorado High Plains Technical Coordinating Committee (see recommendation #7) is preparing a report on aquifer recharge potential in the High Plains region. Federal legislation (H.R. 71) was introduced early in 1983 to establish 12 High Plains aquifer recharge demonstration projects.**

# CHAPTER NINE
# EXPANDING ECONOMIC DEVELOPMENT


All previous strategies assume that agricultural production will continue to be the chief activity supporting the region's economy. A strategy of economic development does not challenge this assumption, but seeks to complement it.

Such a strategy is important for several reasons as the supply of water declines. First, economic development diversifies the region's economy, making it less dependent on a single activity. Second, it can create jobs and help reverse the population decline in the region. Third, and perhaps most important, economic development can generate more dollars in the region's economy for each acre-foot of Ogallala water consumed than irrigated agriculture can. It simply takes much more water to produce a dollar's worth or irrigated corn than a dollar's worth of machinery, haircuts, or health care.

It will not be easy to expand opportunities for economic development in the High Plains region of Colorado. The region is sparsely populated, so commercial markets and labor supply are scattered. As a result, High Plains residents purchase many goods and services outside the region. Limited markets and labor concentrations also contribute to the lack of industrial development in the region.

Perhaps the most realistic prospects for manufacturing and industry are those which build upon the considerable agricultural activity of the region. The High Plains region is the heart of Colorado's developing alcohol fuels industry, which uses grain and other agricultural commodities as feedstocks. Farmers are growing sunflowers in small, but increasing, acreages, and the possibility of building a processing plant in the region is being seriously discussed. Small manufacturing plants for farm machinery and other equipment have been started by farmers and bankers in several small towns in western Kansas, so small population shouldn't automatically rule out manufacturing as a possibility.

Recent studies by the Colorado Division of Commerce and Development indicate that some High Plains communities could profitably expand their commercial and public services. The Division offers assistance in systematically identifying local needs and preferences. Each dollar generated locally turns over more often before leaving the region if local services are available, expanding the local economy.

A systematic evaluation of the region's potential for expanding economic activity is outside the scope of the High Plains Study. Furthermore, several organizations in the region are already involved in studies and promotion. Many Chamber of Commerce groups in the region have active industrial development committees. The three regional councils of governments, which together cover the entire region, have each developed an extensive list of goals and strategies for increasing economic activity in the High Plains.

## 18. Regional Development Board

RECOMMENDATION: THAT REPRESENTATIVES FROM BUSINESS AND INDUSTRY, LOCAL GOVERNMENTS, AGRICULTURAL AND CIVIC ORGANIZATIONS, AND OTHER INTERESTED CITIZENS MEET TO DISCUSS THE NEED FOR A REGIONAL DEVELOPMENT AND PROMOTION BOARD.

Local groups in the High Plains are related by several common concerns--aquifer depletion among them--but there is no single group to give these issues a regional focus. As population elsewhere in the state continues to expand, the High Plains region will have less political representation at state and national levels. A regional group to promote measures to maintain the region's economy could help counteract the effects of aquifer depletion and diminished political representation.

A similar organization on the Western Slope--Club 20--has been very effective in working for that region's transportation, natural resource, tourism, and economic needs.

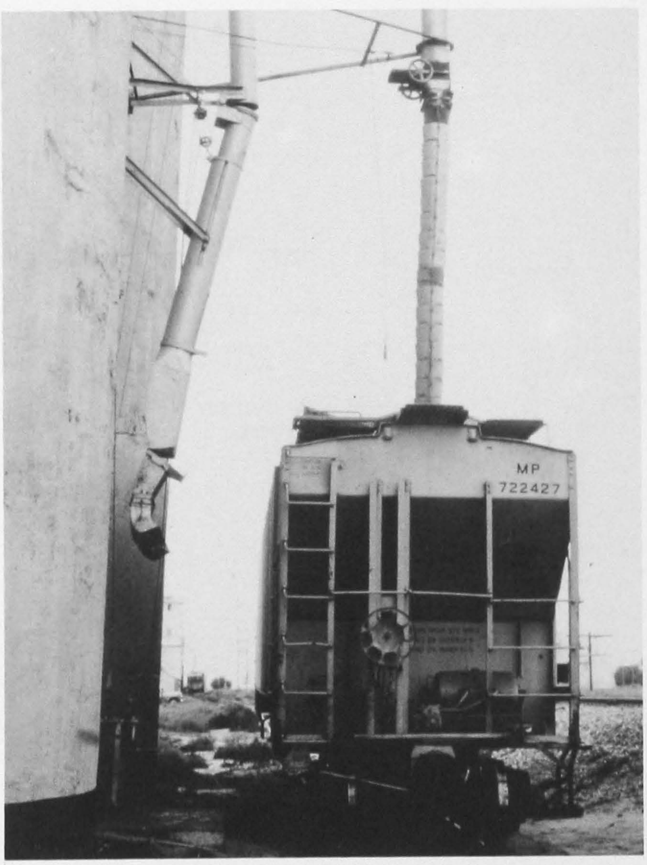
A Regional Development Board could help promote industrial and commercial development, rail service, sunflower processing, water importation, and other activities of importance to the region.

**An eastern Colorado organization called Colorado Plains, Inc. was established in the spring of 1983 to promote regional interests in economic development, agriculture, water, and related issues. Members include counties, towns, organizations, and individuals.**

## 19. Industrial Development Bonds

RECOMMENDATION: THAT THE FEDERAL GOVERNMENT CONTINUE TO ALLOW THE SALE OF INDUSTRIAL DEVELOPMENT BONDS.

Tax-exempt industrial development bonds have provided an important source of funds to local governments for stimulating industrial and commercial growth. Congress is considering legislation to prohibit the sale of such bonds because some communities have used industrial development bonds to attract large, well-established firms that have ready access to other sources of capital.




As ground water levels decline, it will be important for High Plains communities to diversify their economic base. Congress could assist the High Plains region by continuing to allow the sale of industrial development bonds but tightening up the conditions under which bonds can be sold.

**At the present time, the federal government still allows industrial development bonds to be used by local and state governments to stimulate economic activity.**

## 20. Railroad District Legislation

THAT THE COLORADO LEGISLATURE ENACT LEGISLATION TO ALLOW THE FORMATION OF PUBLIC RAILROAD DISTRICTS.

Adequate rail service is essential if the High Plains region is to expand--or even maintain--its current level of economic activity. Rail is generally the cheapest way to ship grain out of the region and to import raw materials.

In March 1980, the Rock Island Railroad stopped rail service between Colorado Springs and the Kansas line because of financial difficulties. Temporary service was resumed on part of this line six months later, but continued service is uncertain.

One solution to keep rail service in this region is to form a public railroad district. Upon a vote of approval by local residents, a public corporation could be created and funded to purchase and maintain the track and right of way. The corporation itself could provide rail service to the area or could contract with a railroad for this service. But before voters could decide whether to form such a district, enabling legislation must be passed by the Colorado legislature.

**Enabling legislation was passed by the state legislature in 1982. Regional lenders are exploring additional options to resolve this issue.**

# APPENDIX

# APPENDIX

## SIX-STATE RECOMMENDATIONS

These 18 recommendations were developed by the six-state High Plains Study Council and presented to Mr. Malcolm Baldrige, Secretary of the U.S. Department of Commerce, in January 1983. Additional details are contained in the Council's report, referenced in the bibliography.

### A. WATER CONSERVATION RESEARCH AND DEMONSTRATION

1. Increase the level of both public and private funding for research to increase water-use efficiencies, decrease erosion losses and improve agricultural productivity for both irrigated and dryland farms throughout the High Plains region.
2. Expand programs to demonstrate the use of water-efficient irrigation techniques and practices, and soil/water conservation management systems.
3. Increase public and private funding for research, demonstration and market development for more water-efficient crops adapted to High Plains growing conditions.

### B. PUBLIC INFORMATION, EDUCATION, EXTENSION AND TECHNICAL ASSISTANCE

1. Expand public and privately sponsored programs to publicize the need for water and soil conservation improvements in High Plains agriculture and to disseminate widely the more effective research results and management information needed for farming operations in the High Plains region.
2. Conduct short courses and field tours in order to demonstrate on a farm basis the use of proven and cost-effective management methods for both irrigated and dryland farming conditions throughout the High Plains.
3. Initiate a program for informing domestic, municipal, commercial and industrial water users in the High Plains Region of effective methods, practices and devices for improved water-use efficiencies and conservation.

### C. WATER SUPPLY

1. Expand research, planning, development and use of technology and programs to increase the quantity and protect the quality of water resources available within the High Plains Region.
2. Continue regional interstate water transfer feasibility and planning studies, with appropriate consideration for the water needs and concerns of basins and states of origin of potential export waters.
3. Provide state and federal funding to continue monitoring ground water quantity and quality and the projected effects of continued ground water depletion on the region and nation.

## D. AGRICULTURAL ENERGY ALTERNATIVES

1. Demonstrate the use of on-farm energy use efficiency and auditing methods and devices to increase energy efficiencies for agricultural purposes.
2. Increase research and demonstration programs and projects for the development and use of alternative energy sources for agricultural uses.

## E. LEGAL AND INSTITUTIONAL

1. Establish Technical Advisory Committees in each High Plains state to provide ongoing guidance and coordination for research, demonstration, education and technical assistance programs for water and energy use efficiency and conservation programs.
2. Provide financial incentives to encourage improved methods for conserving soil, water, and energy.
3. Individual states should evaluate existing state laws and institutions for water management and, where appropriate, suggest needed changes for state action to provide improved state or local management capabilities and more efficient use of waters in each state.

## F. ENVIRONMENTAL MAINTENANCE AND PROTECTION

1. Select and manage cropping systems, irrigation and farm management practices, and irrigated, dryland and rangeland vegetation to conserve soil and water resources and wildlife habitats.
2. Provide technical and financial assistance for re-establishing permanent vegetative cover on all lands going out of cultivation in order to control erosion and to restore habitat.
3. Include provisions for management and protection of fish, wildlife, and related environmental resources in all soil and water conservation or water supply development projects and plans.

## G. ECONOMIC DEVELOPMENT OPPORTNITIES

1. Assist ongoing programs to help diversify the economy of the High Plains region, to develop less water-intensive enterprises, and to improve the economic viability of dryland farming, ranching and non agricultural opportunities.

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