ENERGY PRODUCTION AND USE IN COLORADO'S HIGH PLAINS REGION

by

Emm McBroom

February 1982

COLORADO WATER RESOURCES
RESEARCH INSTITUTE

Colorado State University
Fort Collins, Colorado

Technical Report No. 30

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Colorado Office of Energy Conservation
1525 Sherman St.
Denver, Colorado 80203

February 1982

This report was prepared in partial fulfillment of the Colorado portion of a six-state study of the Ogallala Aquifer. Funding was provided by the U. S. Economic Development Administration through the firm of Camp Dresser and McKee, Inc.

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Norman A. Evans, Director

PREFACE

This publication is one of six technical reports prepared by Colorado State University, the Colorado Office of Energy Conservation, the Colorado Division of Water Resources, and the Colorado Department of Local Affairs as part of the six-state High Plains-Ogallala Aquifer Study. The study was authorized by Congress in 1976 under Public Law 92-587 to investigate the extent of groundwater depletion of the Ogallala Aquifer to project its future depletion to 2020 A.D. and the associated economic impacts upon the High Plains region of the United States and to develop recommendations for action to minimize economic disruption in the region.

The six technical reports listed below make up the Colorado portion of this study:

Technical Report No. 29. McKean, John, et al. An Economic Input-Output Study of the High Plains Region of Eastern Colorado.

Technical Report No. 30. McBroom, Emm. Energy Production and Use in Colorado's High Plains Region.

Technical Report No. 31. Burns, Robert. Community and Socio-Economic Analysis of Colorado's High Plains Region.

Technical Report No. 32. Longenbaugh, Robert. Hydrologic and Pumping Data for Colorado's Ogallala Aquifer Region, 1979.

Technical Report No. 33. McKean, John. Projected Population, Employment, and Economic Output in Colorado's Eastern Plains, 1979-2020.

Technical Report No. 34. Young, Robert, et al. Energy and Water Scarcity and the Irrigated Agricultural Economy of the Colorado High Plains: Direct Economic-Hydrologic Impact Analysis.

Copies of the Colorado technical reports may be purchased at $7.00 each from: Colorado Water Resources Research Institute, Bulletin Room, 171 Aylesworth Hall SW, Colorado State University, Fort Collins, Colorado, 80523 (Telephone: 303/491-6198). Prepayment requested for orders under $25.00. An abstract of any of the reports will be sent upon request.

In addition to these technical reports, a 12-page newspaper published in November 1982 summarizes research results for the Colorado portion of the study and describes possible options for action. Copies are available at no cost upon request from: Resource Analysis Section, Colorado Department of Agriculture, 1525 Sherman Street, Denver, Colorado, 80203, telephone (303) 866-3219.

The studies on which these reports are based were financed in part by the Economic Development Administration of the U. S. Department of Commerce under Contract No. EDA-78-2550 with the State of Colorado. The statements, findings, conclusions, recommendations, and other data contained therein 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.

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I. EXECUTIVE SUMMARY

INTRODUCTION

Energy is as important to the High Plains region as the water contained in the Ogallala Aquifer. Its production provides a source of income to the region and its consumption is necessary to irrigated agriculture. In Colorado, its importance is not a function of production, but of consumption. The Ogallala region in Colorado produces relatively insignificant and decreasing amounts of energy resources. However, the price of energy consumed to pump water in the Aquifer is a critical factor in determining the future of the study area. Without affordable energy, irrigation in Eastern Colorado will decline.

Purpose and Scope

The legislation authorizing this study (P.L. 94-587) describes the fundamental purpose of the study as follows:

> "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 the Congress....In formulating these plans, the Secretary is directed....to examine the feasibility of various alternatives to provide adequate water supplies to the area....to assure the continued economic growth and vitality of the region...."

The High Plains-Ogallala Aquifer Study is a project funded by the United States Department of Commerce and administered by the Economic Development Administration. The management organization of the six-state High Plains Study consists of the Water Resources Division of Camp, Dresser & McKee, Inc. (water analysis) in association with Black & Veatch (energy

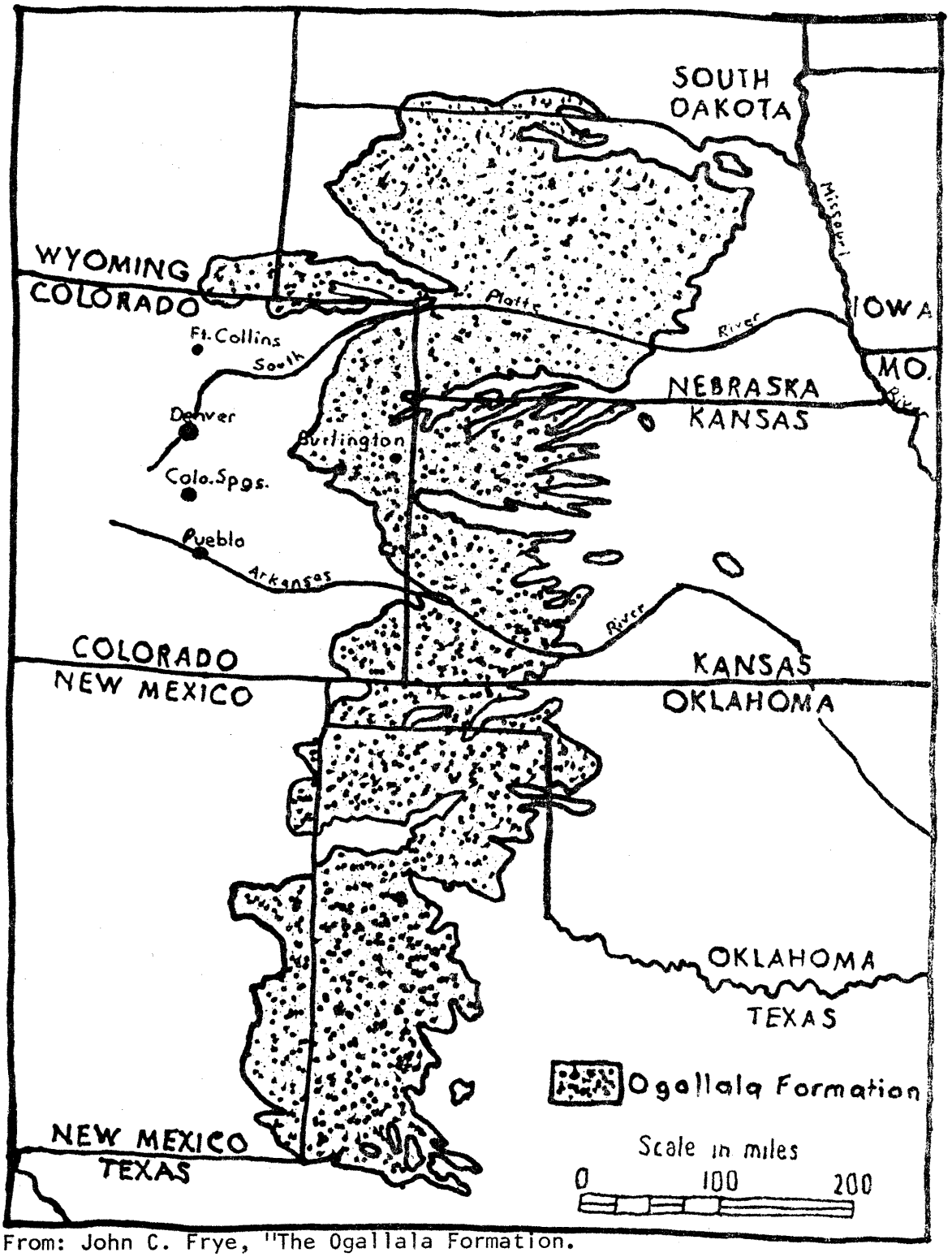
analysis) as joint venturer and Arthur D. Little, Inc. (agricultural and socioeconomic analysis) as subcontractor. These firms are responsible for coordinating research among the individual states and conducting the six-state regional analyses. In addition to these analyses, the U.S. Corps of Engineers is examining alternatives for importing water into the region, through the High Plains Study.

The six states involved in the project are Colorado, Nebraska, Kansas, Oklahoma, New Mexico, and Texas (Figure I-1). In Colorado the study area encompasses parts of eleven eastern counties and includes some 6.9 million acres (Figure I-2).

Figure I-3 describes the High Plains Study organization. There are ten study elements to be completed for the entire six-state region and three study elements to be completed by each state. The Colorado A-2 Energy element, which is the subject of this report, was completed with inputs from other Colorado research elements and the Regional B-8 Energy Price and Technology Assessment element. Information from the A-2 Energy element is to be used in Regional elements B-4 (Environmental Impact Assessment), B-10 (Nonagricultural Development Potential Assessment), and B-11 (Assessments of Alternative Regional Development Strategies).

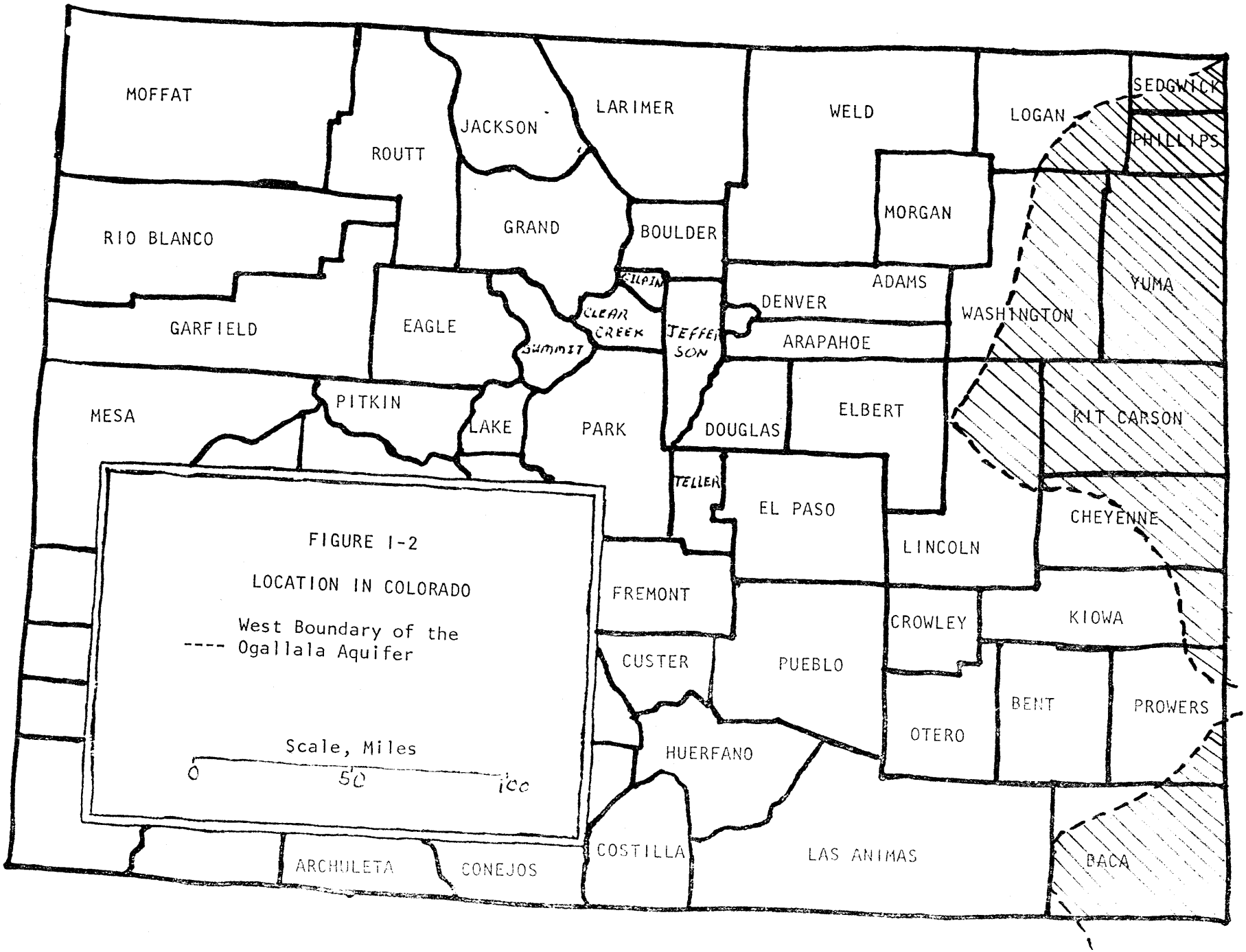
Energy Element Structure and Methodology

The Colorado A-2 Energy Element Report is divided into two parts: (1) Executive Summary and (2) Working Papers on: (a) Energy Production, (b) Energy Production Impacts on Employment and Income, (c) Energy Production Impacts on Water for Energy Production, (d) Energy Production Impacts on Royalty Payments, and (e) Irrigation and Energy. The Executive Summary



From: John C. Frye, "The Ogallala Formation. A Review." 1970 Ogallala Aquifer Symposium, Texas Tech University

Figure I-1
LOCATION OF THE OGALLALA AQUIFER


MOFFAT
ROUTT
JACKSON
LARIMER
WELD
LOGAN
SEDGWICK
PHILLIPS
RIO BLANCO
GRAND
BOULDER
MORGAN
GARFIELD
EAGLE
SUMMIT
CLEAR CREEK
GILPIN
JEFFERSON
DENVER
ADAMS
ARAPAHOE
WASHINGTON
YUMA
MESA
PITKIN
LAKE
PARK
DOUGLAS
ELBERT
KIT CARSON
TELLER
EL PASO
CHEYENNE
LINCOLN
FREMONT
CROWLEY
KIOWA
CUSTER
PUEBLO
BENT
PROWERS
OTERO
HUERFANO
COSTILLA
LAS ANIMAS
BACA
ARCHULETA
CONEJOS
FIGURE I-2
LOCATION IN COLORADO
West Boundary of the
Ogallala Aquifer
Scale, Miles
0
50
100

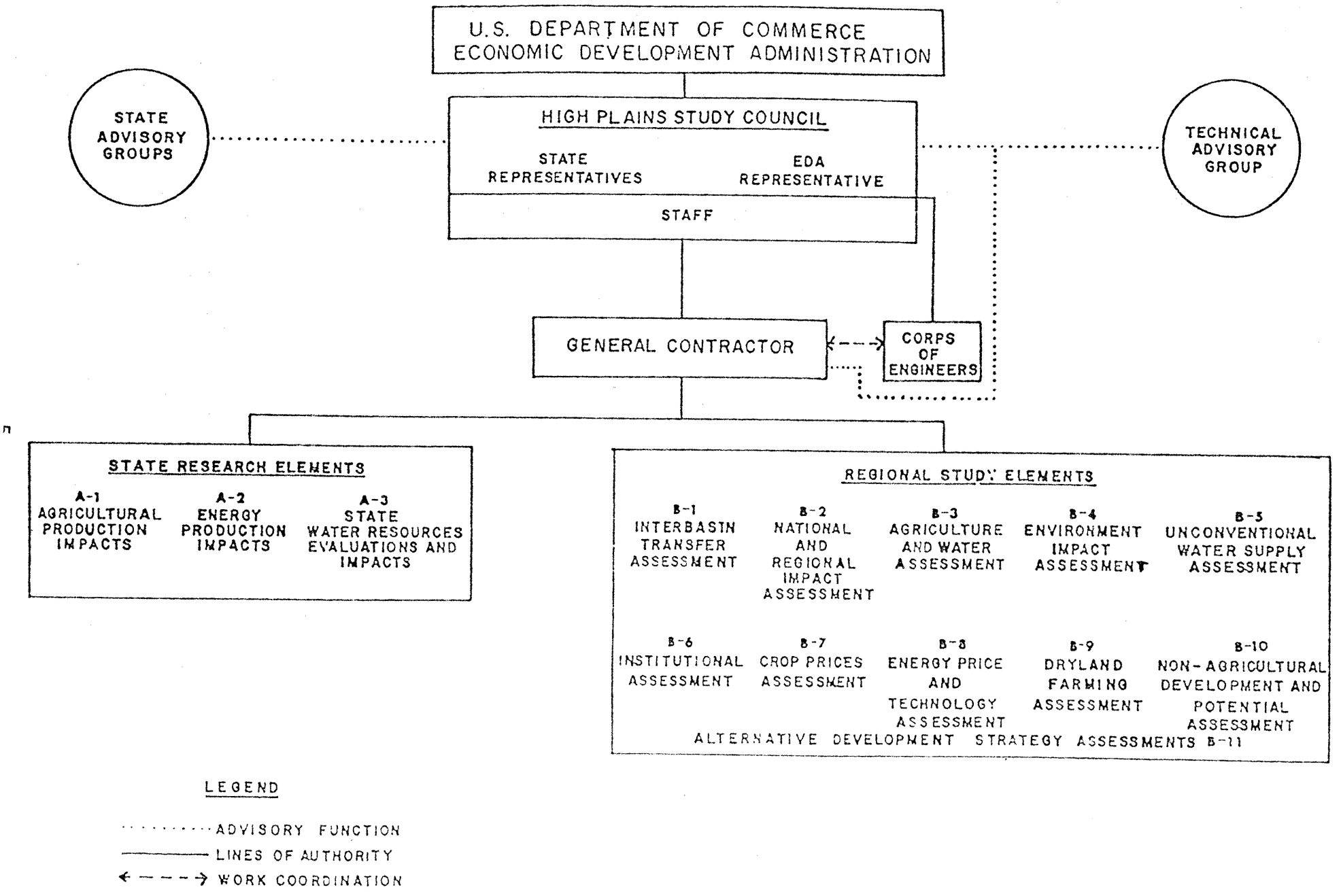


FIGURE I-3 - HIGH PLAINS STUDY ORGANIZATION

explains the purpose and interrelationship of the energy element with other study elements and describes the historical baseline data and projections. The Working Papers detail data sources, assumptions, and projection methodology.

The energy component of the High Plains Study includes historical baseline data and projections of (1) energy production and its associated impacts and (2) irrigation energy demand. The historical baseline for projections was the ten year period from 1969 to 1978. Projections were made for five specific years: 1980, 1985, 1990, 2000, and 2020. A "most likely", "low", and "high" projection was made for each of the above years. In this chapter, only the "most likely" projection is discussed; the other projections are found in the Working Papers.

The Colorado Office of Energy Conservation was responsible for collecting all of the historical baseline data, for making some projections, and for coordinating other projections included in the A-2 Energy element report.

Historical baseline data were gathered primarily from State of Colorado agency sources and from electric and natural gas utilities and oil and gas industry sources as detailed in the Working Papers.

Although various projection techniques were used, most were based on the collected historical data. Consequently, a major assumption of this study is that the factors which were historically, and are currently, important in influencing each factor will continue to be important in the future.

Energy Prices

The energy price projections of the B-8 regional study element calculated by Black and Veatch are an integral part of this study. The prices are

incorporated in most of the projections of this part of the study. Table I-1 summarizes both the historical baseline and projected prices of end-use energy commodities and of primary energy commodities in constant 1977 dollars by price per common measure and by dollars per million BTU. Figure I-4 graphically describes the historical and projected energy prices. The prices of primary energy commodities (crude petroleum and natural gas at the wellhead) fluctuated during the historical baseline period but in the lat 1970's began to increase steadily so that by the end of the period the prices had more than doubled for natural gas and had increased by about sixty percent for crude oil. This rapid increase is projected to continue through 1990, at which time the prices are expected to grow at a slower rate. Past and projected wellhead price increases are more rapid for natural gas than for crude oil; between 1969 and 1990 the price of crude oil is projected to increase about four times while the price of natural gas is projected to increase more than seventeen times. Generally, prices of end-use energy commodities parallel those of the primary commodities. However, gasoline and diesel show a less drastic increase in price from 1980 to 1990.

Electricity is the one end-use commodity that does not follow the general trend. As it becomes more expensive by the year 2020 it is projected to be about twice as expensive as gasoline and diesel and more than four times as expensive as natural gas.

Energy Production

The Colorado study area does not contain significant resources of either coal or uranium. Consequently, this study is only concerned with crude oil, natural gas, and electrical energy production. The projection of energy

FIGURE 1-4

COLORADO HIGH PLAINS – OGALLALA AQUIFER AREA STUDY

ENERGY PRICES (CONSTANT 1977 DOLLARS)

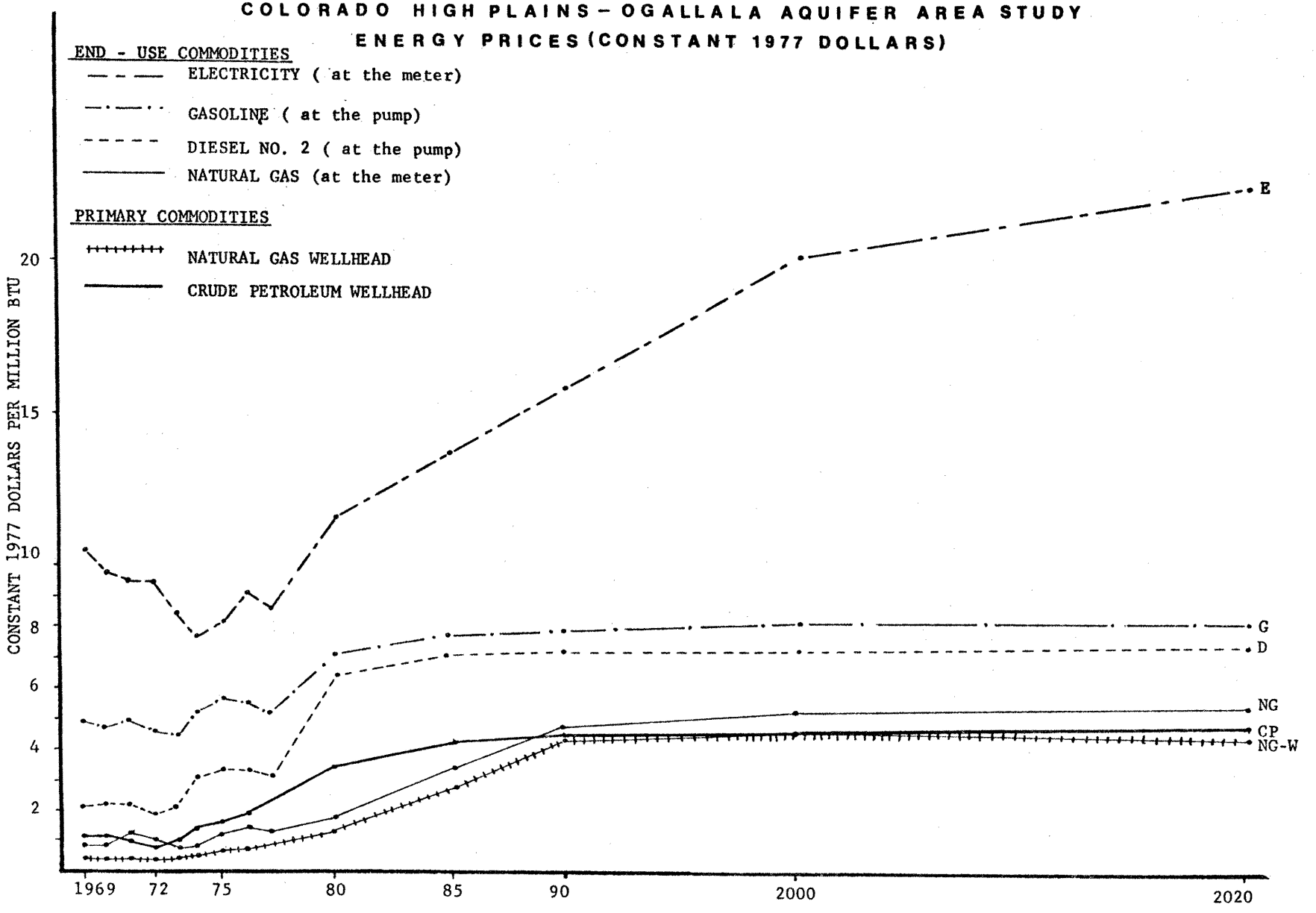


TABLE I-1

COLORADO HIGH PLAINS-OGALLALA AQUIFER AREA STUDY
RESEARCH ELEMENT A-2: REGIONAL ENERGY PRICES (1977)

	End-Use Energy Commodities									
	Diesel (No. 2) Oil (at pump)*		Gasoline (at pump)*		Natural Gas (Commercial class)**		Natural Gas Liquid (at plant)		Electricity (small commercial)**	
	$/gal	$/MBTU	$/gal	$/MBTU	$/mcf	$/MBTU	$/bbl	$/MBTU	mills/kwh	$/MBTU
1. HISTORICAL										
1969	0.16	1.17	0.61	4.84	0.99	0.97	6.45	1.60	35.70	10.46
1970	0.17	1.22	0.60	4.75	0.99	0.97	9.92	2.46	33.89	9.93
1971	0.18	1.28	0.62	4.97	1.23	1.21	10.16	2.52	33.07	9.69
1972	0.17	1.21	0.57	4.58	1.03	1.01	10.12	2.51	32.39	9.49
1973	0.20	1.42	0.56	4.48	0.97	0.95	9.07	2.25	28.70	8.41
1974	0.35	2.50	0.52	4.18	0.99	0.97	11.74	2.91	26.31	7.71
1975	0.37	2.70	0.58	4.66	1.19	1.17	13.47	3.34	27.85	8.16
1976	0.39	2.84	0.61	4.90	1.47	1.44	15.73	3.90	31.37	9.19
1977	0.42	3.03	0.64	5.13	1.39	1.36	14.80	3.67	29.56	8.66
1978										
2. PROJECTED										
LOW										
1980	0.86	6.18	0.89	7.11	1.73	1.69	6.81	1.69	39.50	11.60
1985	0.92	6.60	0.94	7.50	3.05	2.99	12.10	2.99	42.30	12.40
1990	0.92	6.60	0.94	7.50	4.38	4.29	17.30	4.29	45.10	13.20
2000	0.92	6.60	0.94	7.50	4.38	4.29	17.30	4.29	50.50	14.80
2020	0.92	6.60	0.94	7.50	4.38	4.29	17.30	4.29	57.70	16.90
MOST LIKELY										
1980	0.86	6.18	0.89	7.11	1.73	1.69	6.81	1.69	39.50	11.60
1985	0.97	7.01	0.99	7.89	3.31	3.24	13.10	3.24	46.80	13.70
1990	0.98	7.10	1.00	7.97	4.89	4.79	19.30	4.79	54.30	15.90
2000	1.01	7.27	1.02	8.13	5.06	4.96	20.00	4.96	68.60	20.10
2020	1.06	7.65	1.06	8.49	5.45	5.34	21.50	5.34	76.50	22.40
HIGH										
1980	0.90	6.52	0.93	7.43	1.85	1.81	7.30	1.81	47.40	13.90
1985	1.09	7.85	1.08	8.67	3.81	3.73	15.00	3.73	56.30	16.50
1990	1.10	7.96	1.10	8.78	5.77	5.65	22.80	5.65	64.90	19.00
2000	1.13	8.16	1.12	8.96	5.97	5.85	23.60	5.85	82.60	24.20
2020	1.20	8.62	1.17	9.39	6.44	6.31	25.40	6.31	91.50	26.80

* includes federal and state excise taxes.

** at the meter.

TABLE I-1 (continued)

COLORADO HIGH PLAINS-OGALLALA AQUIFER AREA STUDY
RESEARCH ELEMENT A-2: REGIONAL ENERGY PRICES (1977)

	Primary Energy Commodities				
	Crude Oil (wellhead price)		Natural Gas (wellhead price)		
	$/BBL	$/MBTU	$/mcf	$/MBTU	
1. HISTORICAL					
1969	5.81	1.00	0.2536	0.2484	
1970	5.73	0.98	0.2553	0.2500	
1971	5.90	1.01	0.2709	0.2653	
1972	5.66	0.96	0.2675	0.2620	
1973	5.74	0.99	0.2896	0.2836	
1974	8.54	1.47	0.3580	0.3506	
1975	8.76	1.51	0.4983	0.4880	
1976	9.26	1.59	0.6815	0.6675	
1977	9.49	1.64	0.8100	0.7933	
1978	9.21	1.58	0.7792	0.7632	
2. PROJECTED					
LOW					
1980	19.60	3.38	1.23	1.20	
1985	22.00	3.79	2.55	2.50	
1990	22.00	3.79	3.88	3.80	
2000	22.00	3.79	3.88	3.80	
2020	22.00	3.79	3.88	3.80	
MOST LIKELY					
1980	19.60	3.38	1.23	1.20	
1985	24.40	4.21	2.55	2.50	
1990	24.90	4.29	4.39	4.30	
2000	25.90	4.47	4.56	4.47	
2020	28.60	4.84	4.95	4.85	
HIGH					
1980	21.60	3.72	1.35	1.32	
1985	29.30	5.05	3.31	3.24	
1990	29.90	5.16	5.27	5.16	
2000	31.10	5.36	5.47	5.36	
2020	33.80	5.83	5.94	5.82	

production is the most essential part of this study. Projections for most impacts are based on energy production projections and depend upon the accuracy of those projections.

Crude Oil and Natural Gas

Historical baseline data on production and sales of crude oil and natural gas were derived from the records of the Colorado Oil and Gas Conservation Commission. All projections of production were based upon an analysis of the ten-year historical baseline and the estimated reserves of the study area. Several analytical methodologies were examined and tested for both technical and subjective accuracy. The examination resulted in the use of an exponential decline function to project crude oil production and in the use of a harmonic decline (constant rate decline) to project natural gas production.

Assumptions which color the projections are: (1) there will be no new big finds of either oil or natural gas in the study area; (2) the world price of oil and gas will continue to rise; (3) no new technologies will radically influence supply and demand for energy in the study area; and (4) the price increase in primary energy commodities will make it attractive for small producers to replace major producers who leave the area and to extract energy resources until they are depleted.

Figure I-5 and Table I-2 describe the historical and projected production of crude oil and natural gas for both the Eleven-County Area and the Ogallala Aquifer Area. The study are does not contribute significantly to overall state production--in 1978, the Eleven-County Area produced approximately ten percent of Colorado's production of crude oil, and about five percent of its production of natural gas.

FIGURE I-5

COLORADO HIGH PLAINS – OGALLALA AREA STUDY

PETROLEUM PRODUCTION

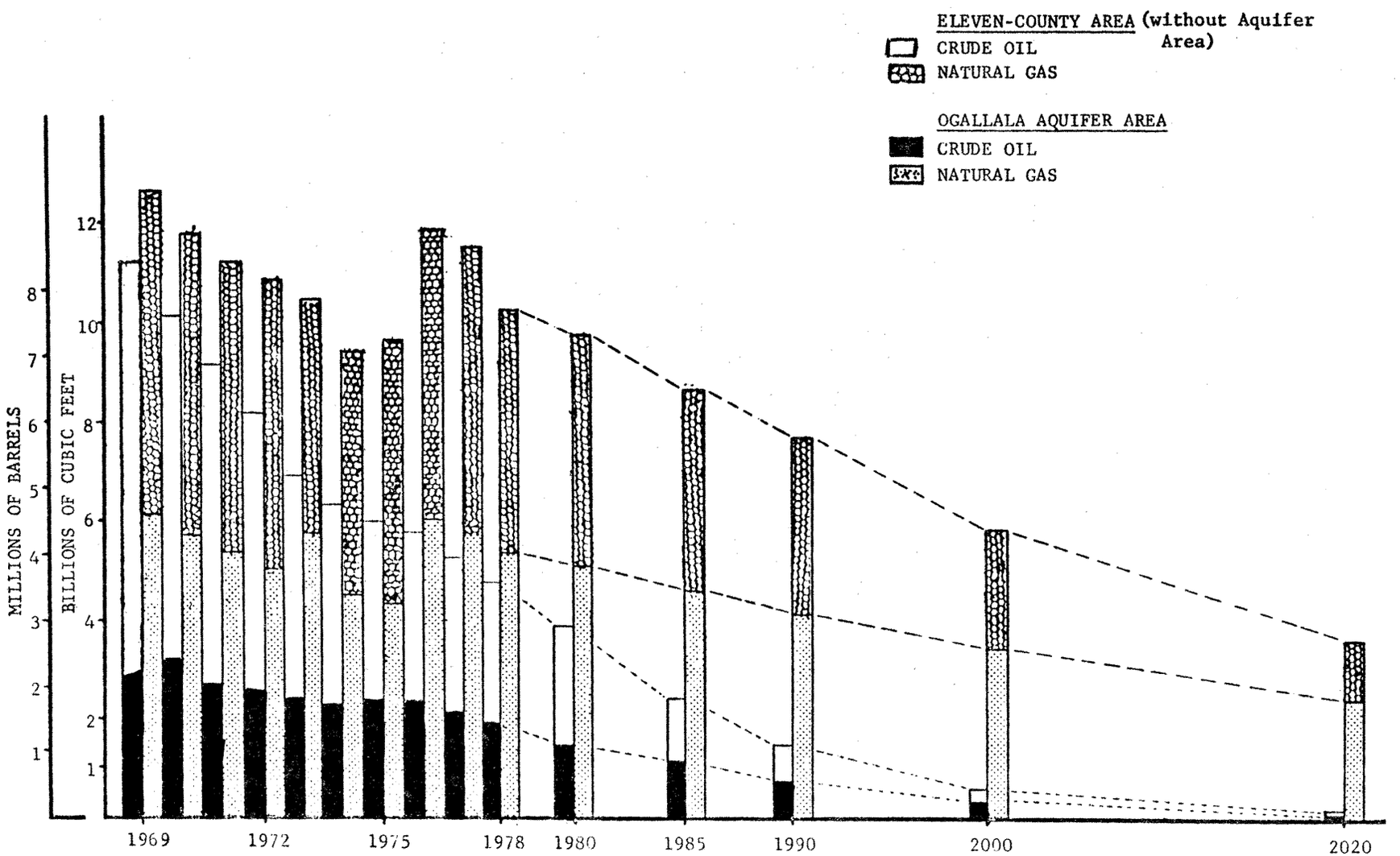


TABLE I-2

COLORADO HIGH PLAINS-OGALLALA AQUIFER AREA STUDY
RESEARCH ELEMENT A-2: ENERGY PRODUCTION

	Eleven-County Area				Ogallala Aquifer Area			
	Petroleun		Electricity		Petroleum		Electricity	
	Crude Oil (Mils. of BBLS)	Natural Gas (Bils of CU Ft)	Generating Capacity (MW)	Production (Mils of kwh)	Crude Oil (Mils of BBLS)	Natural Gas (Bils of CU Ft)	Generating Capacity (MW)	Production (Mils of kwh)
1. HISTORICAL								
1969	8.382	12.661	32.22	82.94	2.190	6.143	32.22	82.94
1970	7.632	11.753	32.22	92.23	2.322	5.667	32.22	92.23
1971	6.799	11.128	32.22	96.32	2.059	5.293	32.22	96.32
1972	6.103	10.857	56.02	104.09	1.937	5.036	56.02	104 .09
1973	5.262	10.539	56.02	107.96	1.784	5.695	56.02	107.96
1974	4.748	9.392	56.02	115.38	1.684	4.427	56.02	115.38
1975	4.523	9.621	249.02	179.79	1.745	4.307	249.02	179.79
1976	4.327	11.899	249.02	187.98	1.733	6.005	249.02	187.98
1977	3.925	11.400	349.02	143.41	1.573	5.889	349.02	143.41
1978	3.599	10.262	349.02	140.43	1.422	5.268	349.02	140.43
2. PROJECTED								
LOW								
1980	2.687	8.971	330.50	165.29	1.086	4.647	330.50	165.29
1985	1.600	6.411	320.50	193.40	0.683	3.423	320.50	193.40
1990	0.951	4.581	320.50	216.62	0.428	2.520	320.50	216.62
2000	0.336	2.339	125.50	178.66	0.167	1.361	125.50	178.66
2020	0.047	0.610	0.70	0.00	0.025	0.394	0.70	0.00
MOST LIKELY								
1980	2.889	9,755	344.40	196.06	1.167	5.053	344.40	196.06
1985	1.805	8.595	338.35	237.46	0.771	4.590	338.35	237.46
1990	1.127	7.573	335.50	261.71	0.507	4.165	335.50	261.71
2000	0.440	5.879	325.50	332.27	0.218	3.422	325.50	332.27
2020	0.067	3,543	24.80	206.39	0.039	2.289	24.80	206.39
HIGH								
1980	3.105	10.037	349.02	263.54	1.254	5.199	349.02	263.54
1985	2.036	9.497	349.02	334.15	0.869	5.071	349.02	334.15
1990	1.336	8.986	349.02	399.84	0.601	4.942	349.02	399.84
2000	0.557	8.045	349.02	538.20	0.236	4.682	349.02	538.20
2020	0.107	6.449	349.02	661.52	0.063	4.063	349.02	661.52

Source: Colorado Office of Energy Conservation Projections--See A-2 Working Paper

Historically during the base period, crude oil production in the Eleven-County Area exhibited a rapid decline from 8.4 million barrels in 1969 to only 3.5 million barrels in 1978, or a decline to 43 percent of the 1969 production level. The Aquifer Area showed a less drastic decline because wells were not as old. Nevertheless, production of crude oil was only 65 percent of that produced at the beginning of the period. The projections for the Eleven-County Area show that production will continue to decline through 2020 when it is estimated that the production of only 39,000 barrels will come mostly from the Aquifer Area and will be only 3 percent of the 1978 level.

Natural gas productionin the Eleven-County Area during the base period also showed a decline until it was revived in the late 1970's due to increased price incentives for exploration and production. Despite the increased activity after the mid 1970's, the Eleven-County Area production level in 1978 was only 84 percent of that of 1969. Once again, the Aquifer Area increasingly contributed a higher proportion of the Eleven-County Area Area total--from 48 percent in 1969 to 51 percent in 1978. The future of conventional natural gas production is somewhat brighter than that of crude oil due to non-associated natural gas. Nevertheless the 1978 production level for the Eleven-County Area of 5.268 billion cubic feet is projected to decline to 2.289 billion cubic feet in 2020, or a loss of nearly 57 percent. An increasing proportion of future production will come from the Aquifer Area--65 percent in 2020 versus 51 percent in 1978.

Although never a major economic factor in the region relative to other economic sectors, crude oil and natural gas production will become even less significant in the future. The declining production may be significant for the marginal agricultural enterprise which depends upon royalty payments and/or seasonal employment to make farming "pay its way".

Electric Energy

Historical baseline data for electric energy requirements, electric generating capacity, and electric energy production were obtained primarily from the Colorado Public Utilities Commission and the individual electric utilities serving the study area. Because the only electric generation facilities in the Eleven-County Area were also within the Aquifer Area, it was only necessary to examine one areal unit, namely, the Eleven-County Area.

Table I-2 shows historical and projected generating capacity and electric energy production and Figure I-6 describes historical and projected electric energy requirements and production.

Figure I-6 indicates that the electric energy required in the Eleven-County Area increased from 305 to 893 million kilowatt hours, or almost a three-fold increase during the ten year period 1969 to 1978. During the same period, a ten-fold increase in generating capacity, from 32 to 349 mega-watts, occurred. However, electric energy produced increased only from 83 million kilowatt hours to 140 million kilowatt hours, or only by about 70 percent. This discrepancy between increased generating capacity and electric energy produced is explained by the fact that generation added by the City of Lamar was to replace existing capacity and generation added by Tri-State Electric was high operating cost, peak load generating capacity. Consequently, the gap between the electric energy required and electric energy produced increased throughout the period with an increasingly larger proportion of electric energy (73 percent in 1969 and 84 percent in 1978) being imported from outside the area.

Projections of future generation capacity within the area was based upon interviews with personnel of utilities serving the area. Then, electric energy

production projections were made using a modified annual aggregate capacity factor in conjunction with those projections of future generation capacity. Projection of future energy requirements was based on Colorado Public Utilities Commission projections through 1988 as dampened and extended to the year 2020. Because of an estimated four-fold increase in requirements, the absence of any plans to build any new generating facilities in the area, and the possible retirement of some existing generating facilities, the gap between requirements and production will continue to increase (by 2020 the area may produce only 6 percent of its electric energy requirement) and an even larger proportion of the electric energy needed will have to be imported unless demand, technological, or capital and fuel cost factors intervene to change the situation.

ENERGY PRODUCTION IMPACTS

Again it must be pointed out that in relative terms because of the low level of energy production activity, the impacts of energy production are small; however, they may be of significance to selected individuals residing in the study area. This section describes the impacts of energy production on employment and income, water consumption, and royalty payments to resident landowners of the area.

Employment and Income

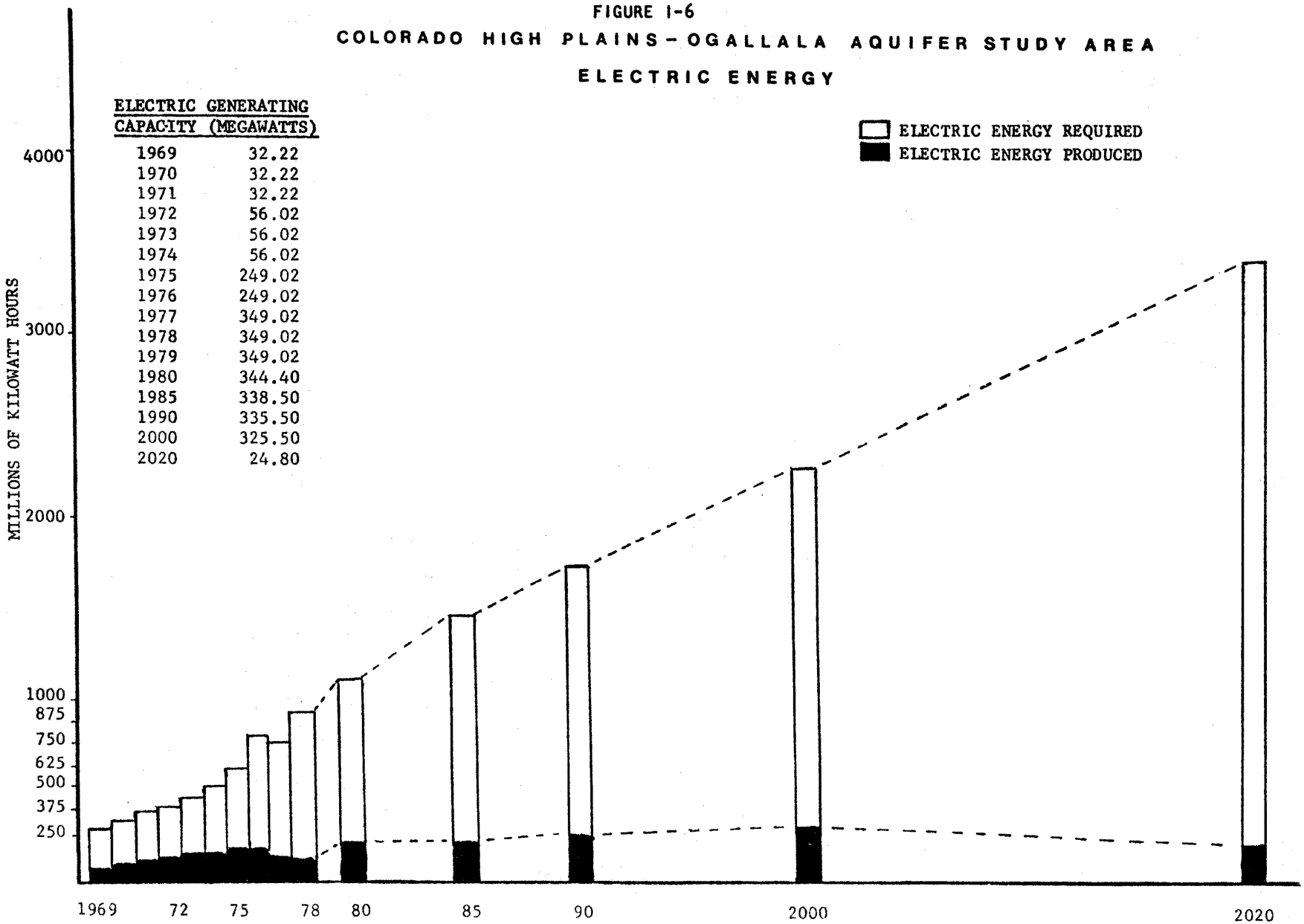
The historical baseline data for the number of persons employed in the oil and gas production, electrical energy production, and energy transportation sectors as well as income from wages and salaries were derived from information provided by the Colorado Division of Employment and individual

FIGURE I-6

COLORADO HIGH PLAINS - OGALLALA AQUIFER STUDY AREA

ELECTRIC ENERGY

ELECTRIC GENERATING CAPACITY	(MEGAWATTS)
1969	32.22
1970	32.22
1971	32.22
1972	56.02
1973	56.02
1974	56.02
1975	249.02
1976	249.02
1977	349.02
1978	349.02
1979	349.02
1980	344.40
1985	338.50
1990	335.50
2000	325.50
2020	24.80



electric and natural gas utility companies serving the Eleven-County Area. There was no employment in the study area for coal or uranium production and processing, oil refining, oil products manufacturing, or oil and gas production equipment manufacturing. Oil and gas proprietor's income was estimated from salary and wage income and royalty income was estimated from crude oil and natural gass wellhead sales. The results are summarized in Table I-3 and Figure I-7.

Persons employed in oil and gas production, electric energy production, and energy transportation increased from 541 persons in 1972 to 650 persons in 1978, or an increase of 30%. Employment fluctuated primarily with changes in oil and gas development and production which generally included about one-half to two-thirds of the persons employed in energy enterprises. At its ten year peak (1978), energy enterprise employment involved only about two percent of the total workforce of the Eleven-County Area.

Wages and salaries increased about 11% from 8.0 million dollars in 1972 to 9.4 million dollars in 1978. However, regional income from energy production grew about 28% from 10 to 13 million dollars over the same period due to a more rapid increase in oil and gas proprietor's income and royalty income brought on by rapidly escalating prices of crude oil and natural gas.

Projections for employment and salary and wage income for the five specified years are currently being developed by the economic research team at Colorado State University in conjunction with their input-output model.

Water Consumption for Energy Production

Electric energy generation in the study area consumes almost no water because of closed systems for evaporative cooling and because of discharge

FIGURE 1-7

COLORADO HIGH PLAINS–OGALLALA AQUIFER AREA STUDY

EMPLOYMENT AND INCOME FROM ENERGY PRODUCTION

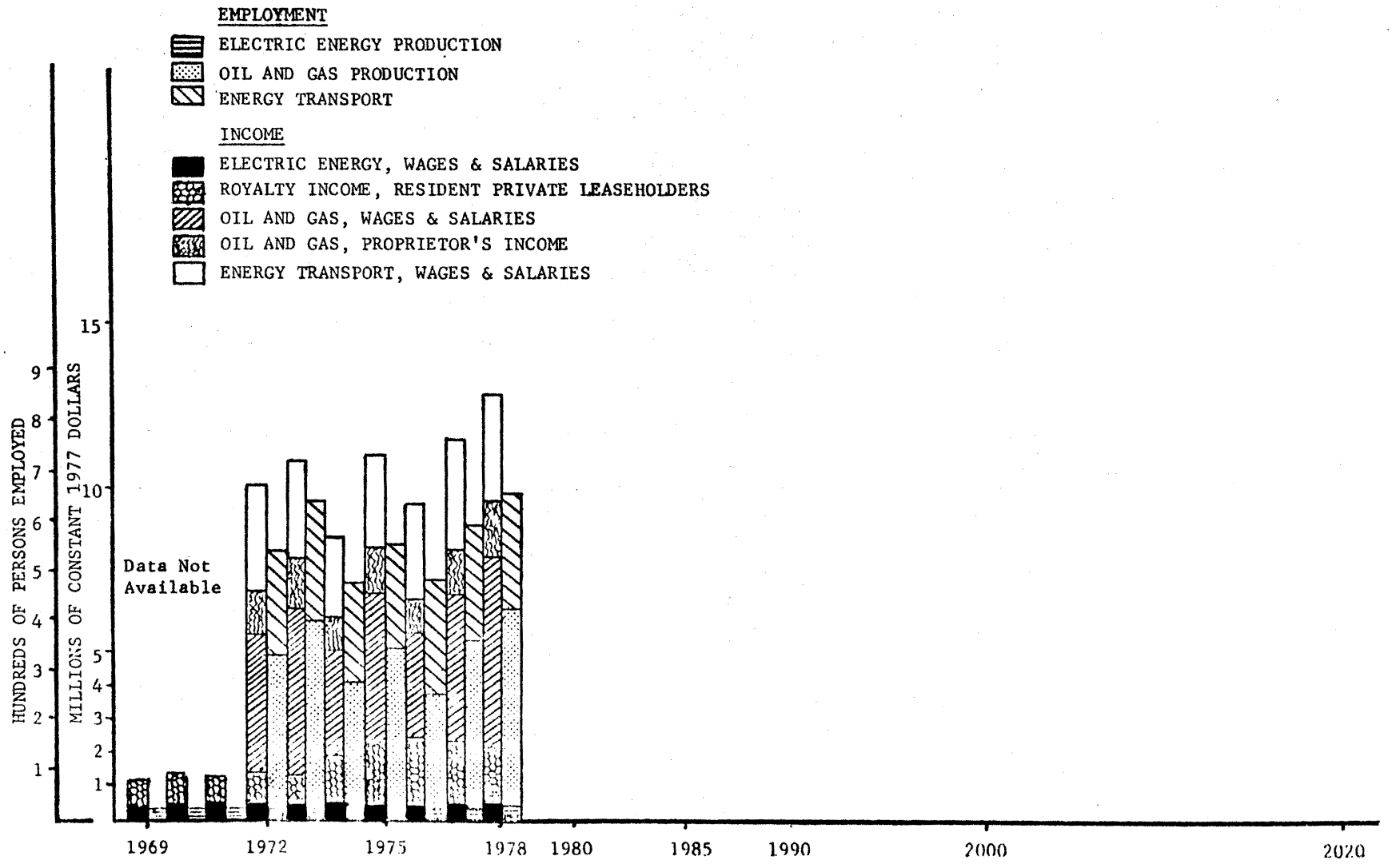


TABLE I-3

COLORADO HIGH PLAINS-OGALLALA AQUIFER AREA STUDY
RESEARCH ELEMENT A-2: ENERGY PRODUCTION IMPACTS--1. EMPLOYMENT AND INCOME

	Employment (Number of Persons)*			Income (Millions of Constant 1977 Dollars)*				
	Oil & Gas Production	Electric Energy Production	Energy Transport	Oil & Gas, Wages & Salaries	Electric Energy, Wages & Salaries	Energy Transport, Wages & Salaries	Oil & Gas, Proprietors Income	Royalty Income, Resident Private Leaseholders
1. HISTORICAL								
1969	---	29	---	-----	0.354	-----	-----	0.749
1970	---	29	---	-----	0.389	-----	-----	0.798
1971	---	29	---	-----	0.422	-----	-----	0.761
1972	298	29	214	4.349	0.432	3.182	1.305	0.803
1973	371	29	239	5.068	0.389	3.017	1.520	0.826
1974	234	29	209	3.222	0.405	2.460	0.967	1.422
1975	293	36	216	4.689	0.451	2.734	1.407	1.730
1976	218	32	221	3.240	0.408	2.962	0.972	1.951
1977	316	33	235	4.480	0.432	3.386	1.344	1.862
1978	380	36	234	5,719	0.445	3.266	1.716	1.738
2. PROJECTED								
LOW								
1980								
1985								
1990								
2000								
2020								
MOST LIKELY								
1980								
1985								
1990								
2000								
2020								
HIGH								
1980								
1985								
1990								
2000								
2020								

* Eleven-County Area

into irrigation canals. Direct historical information about water consumption for crude oil and natural gas production was not available. Consequently, estimates of water used for well drilling and development activity were calculated by applying average per well conversion factors to annual drilling activity. The derived annual figures were then added to actual figures from the Colorado Oil and Gas Conservation Commission regarding water injected into wells to enhance recovery to provide total annual water consumed for energy production activity. The results are summarized in Table I-4 and Figure I-8.

Since more than four-fifths of the water consumed in the Eleven-County Area is for injection to enhance recovery, water consumption parallels petroleum production trends but with some variation in timing due to exploration and development activity. Water consumption for energy production in the Eleven-County Area, as might be expected, exhibited a decline with a slight increase predating the post-1975 production increases. From a high of about 3.3 thousand acre feet in 1971 water consumption decreased to about 2 thousand acre feet in 1978. As the level of energy production declines in the future, so will the amount of water required for energy production; consequently, by the year 2020 only about 163 acre feet will be required. Because there has been more well drilling and development activity in the Aquifer Area, water consumption in that area (although never more than 10% of the eleven-county area total) showed a 15% increase from 1969 to 1978 and is projected to continue to increase into the early 1980's before decreasing.

Although of highly local and generally temporary importance, water consumption for energy production is insignificant when compared to the total water consumed by other uses within the study areas.

FIGURE I-8

COLORADO HIGH PLAINS-OGALLALA AREA STUDY

WATER CONSUMPTION FOR ENERGY PRODUCTION

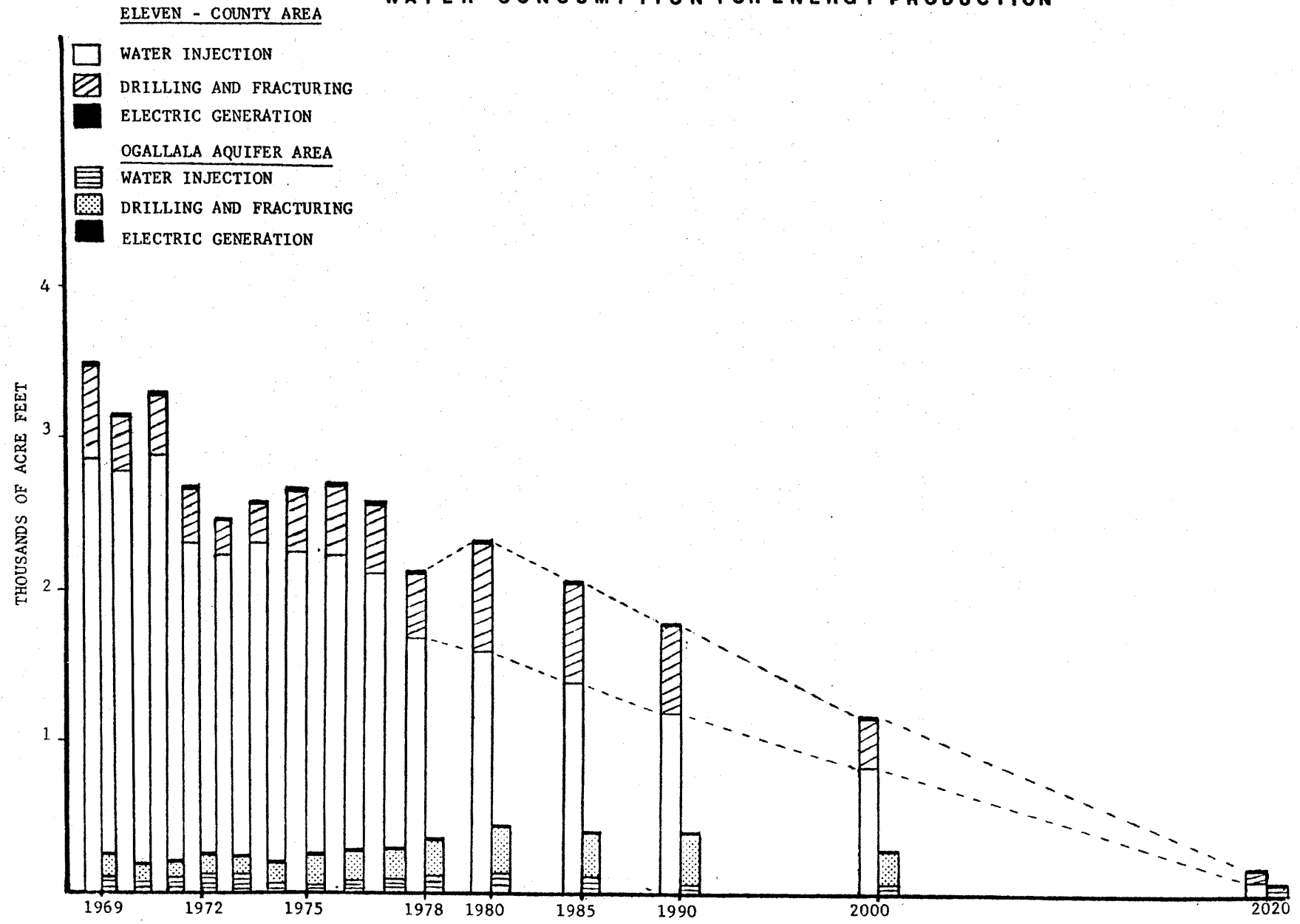


TABLE I-4

COLORADO HIGH PLAINS-OGALLALA AQUIFER AREA STUDY
RESEARCH ELEMENT A-2: ENERGY PRODUCTION IMPACTS--2. WATER CONSUMPTION

	Eleven-County Area			Ogallala Aquifer Area		
	Petroleum Production		Electric Energy Generation (Ths. of Ac. Ft.)	Petroleum Production		Electric Energy Generation (Ths. of Ac. Ft.)
	Conventional--Drilling & Fracturing (Ths of Ac. Ft.)	Secondary Water Injection (Ths. of Ac. Ft.)		Conventional--Drilling & Fracturing (Ths. of Ac. Ft.)	Secondary Water Injection (Ths. of Ac. Ft.)	
1. HISTORICAL						
1969	0.6217	2.8640	------	0.1872	0.0669	------
1970	0.3646	2.7830	------	0.1116	0.0611	------
1971	0.3840	2.9006	------	0.1210	0.0852	------
1972	0.3744	2.2781	------	0.1224	0.0924	------
1973	0.3261	2.1307	------	0.1102	0.0707	------
1974	0.3183	2.2769	------	0.1148	0.0449	------
1975	0.4511	2.2418	0.0037	0.1666	0.0464	0.0037
1976	0.4212	2.3215	0.0046	0.1681	0.0729	0.0046
1977	0.4586	2.1327	0.0030	0.1948	0.0805	0.0030
1978	0.4678	1.6755	0.0027	0.2031	0.0883	0.0027
2. PROJECTED						
LOW						
1980	0.6688	1.5783	0.0096	0.2970	0.0881	0.0096
1985	0.5413	1.3354	0.0113	0.2610	0.0583	0.0113
1990	0.4063	1.0924	0.0125	0.2111	0.0379	0.0125
2000	0.1482	0.6070	0.0104	0.0806	0.0195	0.0104
2020	0.0204	0.0000	0.0000	0.0125	0.0029	0.0000
MOST LIKELY						
1980	0.7206	1.5984	0.0114	0.3200	0.0947	0.0114
1985	0.6926	1.4057	0.0139	0.3357	0.0703	0.0139
1990	0.6438	1.2131	0.0153	0.3400	0.0482	0.0153
2000	0.3438	0.8277	0.0194	0.1913	0.0299	0.0194
2020	0.1165	0.0570	0.0120	0.0745	0.0058	0.0120
HIGH						
1980	0.8466	1.6185	0.0154	0.3751	0.1080	0.0154
1985	0.9564	1.4761	0.0195	0.4647	0.0887	0.0195
1990	0.9167	1.3337	0.0198	0.4842	0.0649	0.0198
2000	0.5519	1.0489	0.0314	0.2965	0.0389	0.0314
2020	0.2515	0.4792	0.0386	0.1576	0.0113	0.0386

Royalty Payments to Energy Production

Historical baseline royalties were estimated from the interaction of common royalty factors, wellhead prices, and production figures provided by the Colorado Oil and Gas Conservation Commission in combination with actual dollar amounts from specific government leases indicated by Colorado State Land Board records. Projections also were derived from the interaction of projected wellhead prices, productoin estimates and common royalty factors. Figure I-8 and Table I-5 summarize the resulting estimates and projections for both the Eleven-County and Aquifer Areas.

Although historically most royalty income in the Eleven-County Area was from curde oil production, the proportion has been decreasing with the increase in the wellhead price of natural gas and the decline in crude oil production, so that by 1978 only 80 percent of the 5.14 million dollars, as compared to 93 percent of 6.4 million dollars in 1969, was from crude oil. By the year 2020 it is estimated that less than 10 percent of the approximately 2.3 million dollars in royalty income will be from crude oil production. Due to these factors and increased natural gas production, the Aquifer AREa has had an increasing share of the Eleven-County Area royalty payments. This trend is projected to continue into the future so that by 2020 Aquifer Area lands will produce about 65 percent of the royalty income for the Eleven-County Area (this compares with about 27 percent in 1969 and about 42 percent in 1978). It should be noted that royalty payments to government landowners have never been more than 6 percent of total royalty income in the Eleven-County Area and are projected to decline as a percentage of total royalty income.

FIGURE I-9

COLORADO HIGH PLAINS-OGALLALA AQUIFER AREA STUDY

ROYALTY PAYMENTS

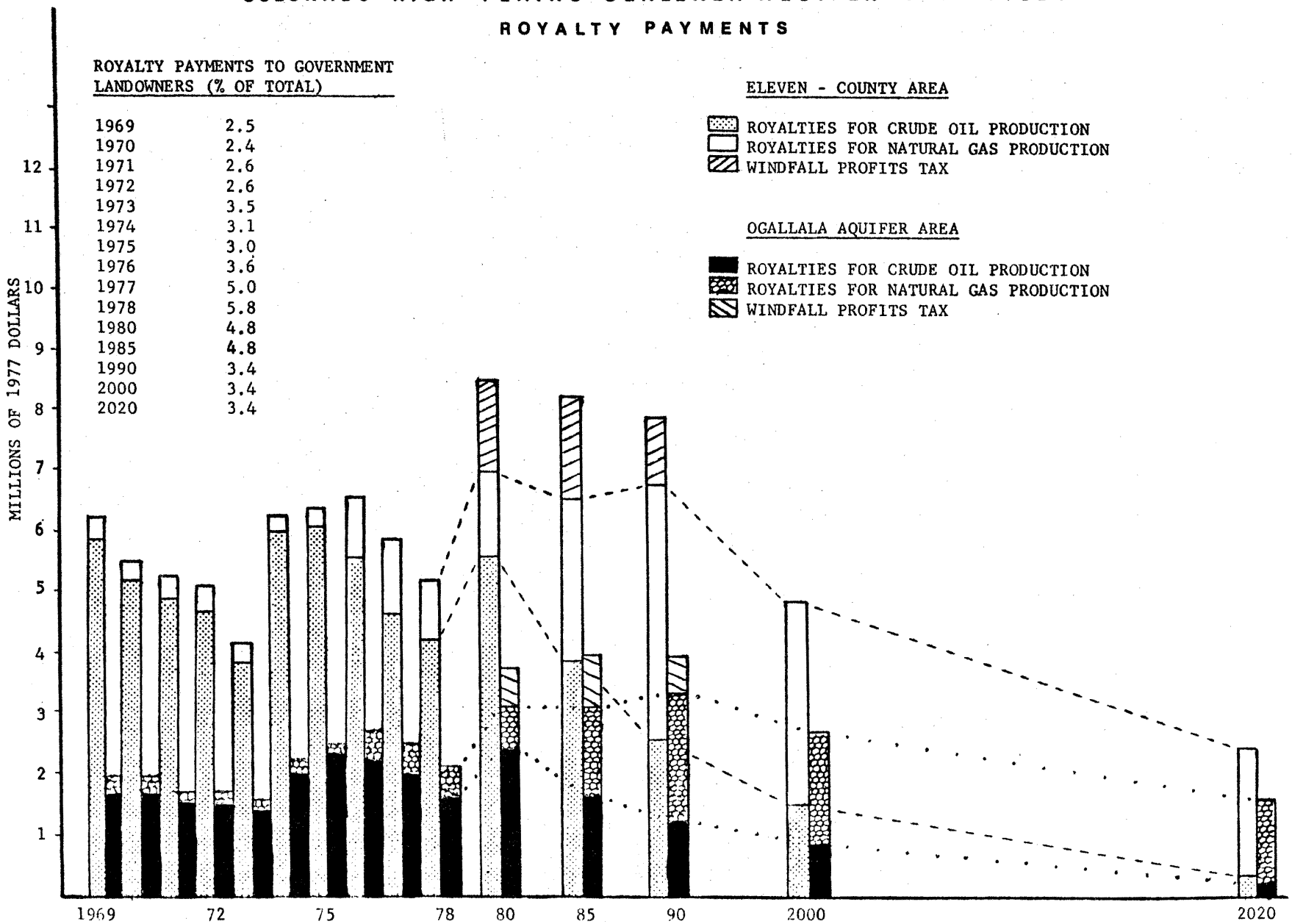


TABLE I-5

COLORADO HIGH PLAINS-OGALLALA AQUIFER AREA STUDY
RESEARCH ELEMENT A-2: ENERGY PRODUCTION IMPACTS--3. ROYALTY PAYMENTS

	Eleven-County Area				Ogallala Aquifer Area			
	Royalty Payments for Crude Oil (M 1977 $)	Royalty Payments for Natural Gas (M 1977 $)	Royalty & Excess Profits Tax Payments to Govt. (M 1977 $)	Royalty Payments to Private Landowners (M 1977 $)	Royalty Payments for Crude Oil (M 1977 $)	Royalty Payments for Natural Gas (M 1977 $)	Royalty & Excess Profits Tax Payments to Govt. (M 1977 $)	Royalty Payments to Private Landowners (M 1977 $)
1. HISTORICAL								
1969	5.965	0.432	0.160	6.237	1.558	0.194	0.044	1.708
1970	5.342	0.380	0.140	5.585	1.625	0.174	0.044	1.755
1971	4.995	0.332	0.139	5.188	1.513	0.150	0.043	1.620
1972	4.791	0.365	0.134	5.023	1.520	0.162	0.044	1.638
1973	4.027	0.341	0.153	4.216	1.366	0.177	0.055	1.488
1974	5.907	0.285	0.192	6.000	2.095	0.131	0.068	2.158
1975	6.024	0.347	0.191	6.180	2.324	0.152	0.075	2.401
1976	5.540	0.947	0.234	6.253	2.219	0.467	0.097	2.589
1977	4.656	1.154	0.291	5.520	1.865	0.585	0.122	2.328
1978	4.140	1.000	0.298	4.842	1.636	0.504	0.124	2.016
2. PROJECTED								
LOW								
1980	5.142	1.379	1.823	6.139	2.078	0.714	0.745	2.630
1985	3.227	2.044	1.482	4.962	1.375	1.091	0.642	2.324
1990	1.983	2.222	0.797	4.040	0.893	1.222	0.366	2.033
2000	0.924	1.134	0.070	1.988	0.459	0.660	0.038	1.081
2020	0.129	0.296	0.014	0.411	0.069	0.191	0.008	0.251
MOST LIKELY								
1980	5.528	1.500	1.962	6.616	2.234	0.777	0.800	2.837
1985	3.880	2.740	2.021	6.217	1.658	1.463	0.877	2.938
1990	2.525	4.156	1.243	6.421	1.136	2.286	0.574	3.290
2000	1.426	3.351	0.163	4.614	0.706	1.951	0.090	2.567
2020	0.235	2.192	0.083	2.344	0.137	1.416	0.053	1.500
HIGH								
1980	6.309	1.694	2.558	7.520	2.548	0.877	1.043	3.220
1985	4.901	3.929	3.103	8.283	2.092	2.098	1.345	3.936
1990	3.401	5.920	1.963	8.950	1.530	3.256	0.903	4.599
2000	2.165	5.500	0.261	7.404	0.917	3.201	0.140	3.978
2020	0.452	4.788	0.178	5.062	0.266	3.017	0.112	3.171

IRRIGATION AND ENERGY

Baseline information on the number and energy use by electric and natural gas pumps was derived from the records of natural gas and electric utility companies within the study area. Data on the number and energy use by gasoline, diesel, and LP pumps were not examined because of difficulty in obtaining information and because of their relatively insignificant role in irrigation within the study area. Projections were derived from the Colorado A-1 study element. The results are shown in Figure I-10 and Table I-6.

Pump Power Sources

While the number of wells which used natural gas as an energy source increased from approximately 922 wells in 1969 to 1532 wells in 1978 (a 66% increase), those using electricity increased from 860 wells in 1969 to 3784 wells in 1978 (a 340% increase). It is believed that the growth in the number of both types of pumps has peaked and that in the future both will decline, so that by the year 2020 there will be only 465 wells using natural gas as a power source and 2365 wells using electric powered pumps. This represents a 70% decrease in the number of natural gas pumps but only a 40% decrease in the number of electric pumps.

BTU Energy Requirements

Energy requirements for pumping show a similar but more erratic trend because of other factors such as weather. While natural gas consumption for pumping shows a 38% increase from 1969-1978, electricity consumption for pumping grew by 670% during the same period. The demand for electricity for irrigation is projected to continue to grow until the year 2000 despite a

FIGURE I-10

COLORADO HIGH PLAINS-OGALLALA AQUIFER AREA STUDY

ENERGY FOR IRRIGATION

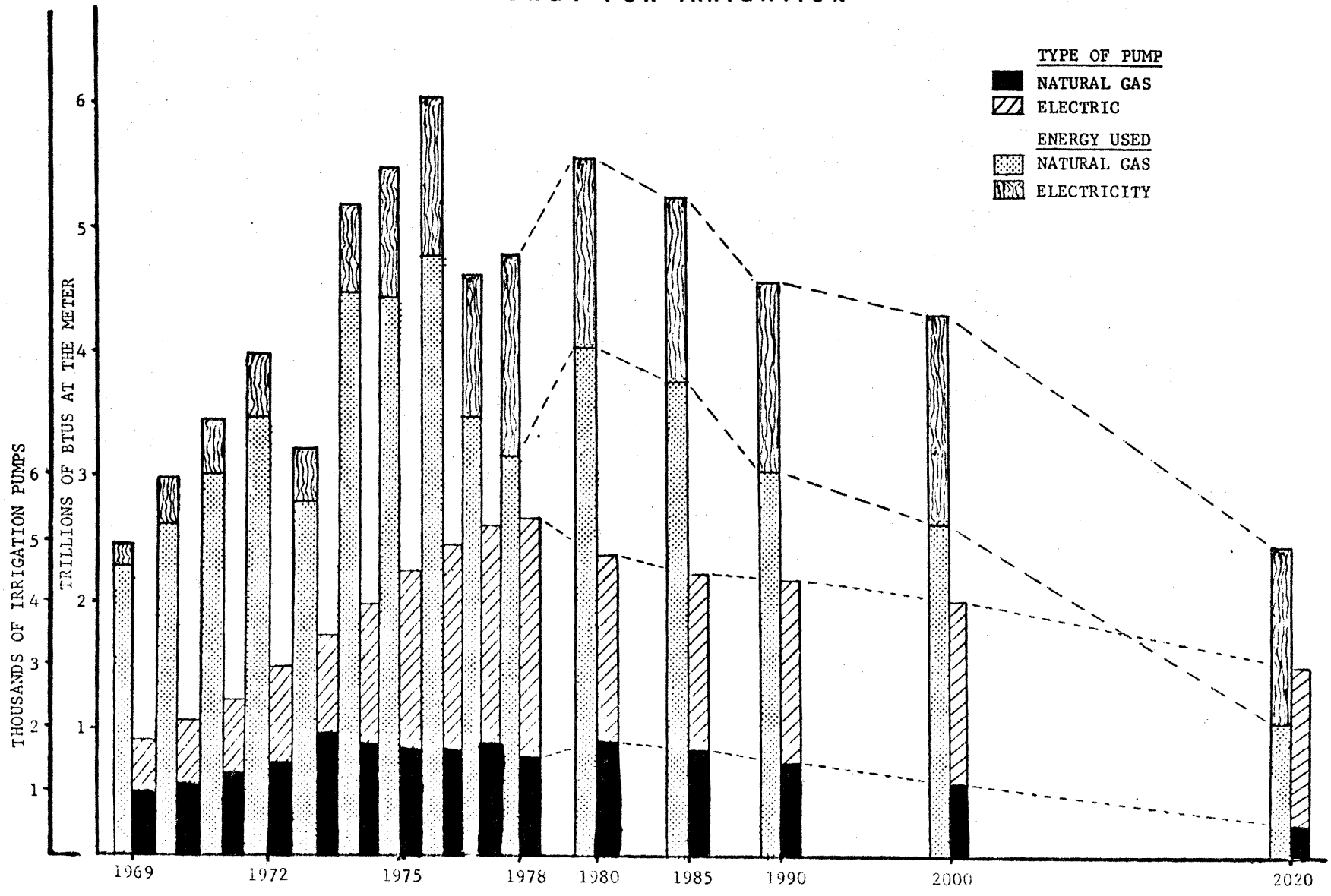


TABLE I-6

COLORADO HIGH PLAINS-OGALLALA AQUIFER AREA STUDY
RESEARCH ELEMENT A-2: ENERGY FOR IRRIGATION

	Ogallala Aquifer Area				
	Number of Irrigation Pumps by Power Source		Energy Used for Irrigation Pumping (Billions of BTU at the Meter)		
	Natural Gas	Electric	Natural Gas	Electric	Total
1. HISTORICAL					
1969	922	860	2,278.78	191.93	2,470.71
1970	1081	1025	2,652.62	269.74	2,922.36
1971	1265	1217	3,050.51	320.37	3,370.87
1972	1483	1463	3,512.56	366.44	3,879.00
1973	1764	1736	2,798.91	423.61	3,222.52
1974	1756	2144	4,481.24	705.45	5,186.69
1975	1692	2733	4,445.00	946.55	5,391.54
1976	1619	3204	4,744.77	1,328.86	6,073.45
1977	1585	3555	3,470.13	1,159.60	4.629.73
1978	1532	3784	3,162.77	1,480.16	4,642.93
2. PROJECTED					
LOW					
1980	1289	2286	3,050	1,129	4,179
1985	1205	2137	2,848	1,106	3,954
1990	1100	2134	2,312	1,145	3,457
2000	809	2140	2,001	1,216	3,217
2020	349	1774	828	996	1,824
MOST LIKELY					
1980	1719	3048	4,066	1,505	5,571
1985	1606	2849	3,797	1,474	5,268
1990	1466	2845	3,082	1,526	4,608
2000	1078	2853	2,668	1,621	4,289
2020	465	2365	1,104	1,328	2,432
HIGH					
1980	2149	3810	5,083	1,881	6,964
1985	2008	3561	4,746	1,843	6,589
1990	1833	3556	3,853	1,908	5,761
2000	1348	3566	3,335	2,026	5,361
2020	581	2956	1,380	1,660	3,040

decrease in the number of electric irrigation pumps because pumping will be from greater depths and will, therefore, require more energy. In contrast the demand for natural gas is projected to decline after 1985. By 2020 natural gas energy required for irrigation will have declined by 65 percent to a level below all baseline demand years and electric energy required for irrigation will have declined by about 10 percent to a level below all baseline years except 1978.

CONCLUSIONS

Compared to other activity within the study area and to energy production activity within Colorado or the six-state region, the production of energy in the Eleven-County and Aquifer Area is not significant in the amounts produced, persons employed, wages and salaries paid, royalty received, or in the amount of water consumed.

However, energy and its impacts are significant in at least two ways. First, energy production has significant individual and local impacts on incomes and water consumption. Secondly, the rapidly increasing cost of energy has and will have a great impact on the irrigated agriculture sector within the study area.

II. WORKING PAPER

ENERGY PRODUCTION

INTRODUCTION

The purpose of this working paper is to project time profiles of energy production in the Colorado High Plains Study Area. Initial investigation revealed that there was no production or significant resource potential for either surface or deep minable coal[1] or for uranium[2]. Consequently, this chapter focuses on crude oil and natural gas production and electric energy requirements and production.

Total projected and historical crude oil and natural gas production is illustrated in Figure II-1 and Figure II-3 for the "Eleven-County Area" and in Figure II-2 and Figure II-4 for the "Aquifer Area". Table II-1 and Table II-2 summarize the projected and historical crude oil production for the "Eleven-County Area" and the "Aquifer Area". Table II-3 and Table II-4 summarize the projected and historical natural gas production for the "Eleven-County Area" and the "Aquifer Area" respectively.

Electric energy requirements and production information for the "Eleven-County Area" are illustrated in Figures II-5, II-6, and II-7: Figure II-5

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[1] State of Colorado. Department of Natural Resources. Geological Survey. "Coal Resources and Development Map of Colorado" (Map Series 9), by David C. Jones, Janet Schultz, and D. Keith Murray, 1978; State of Colorado. Department of Natural Resources. Geological Survey. "Map of Licensed Coal Mines in Colorado as of July 1, 1979 (Map Series 12), by Nirbhao Singh Reade and Charles R. Campbell.

[2] State of Colorado. Department of Natural Resources. Geological Survey. "Radioactive Mineral Occurrences of Colorado". (Bulletin No. 40), by James L. Nelson-Moore, Donna Bishop Collins, and A. L. Hornbaker, 1978; United States Department of Energy. Assistant Secretary for Resource Applications. Grand Junction Office. "National Uranium Resource Evaluation, Interim Report," June 1979.

shows electric energy requirements, Figure II-6 electric energy generating capacity, and Figure II-7 electric energy produced. The Tables which correspond to the aforementioned Figures are Tables II-5, II-6, and II-7, respectively.

METHODOLOGY

Crude Oil and Natural Gas

Baseline Data. The historical baseline data for crude oil and natural gas production and sales were derived from the records of the Colorado Oil and Gas Conservation Commission. Oil and gas fields identified as being in the "Eleven-County Area" were located by section and township to further identify the fields within the "Aquifer Area". Data were collected on a field-by-field basis from the Commission's Annual Reports from 1969 to 1978 and aggregated to provide "Aquifer Area" and "County Totals" for each county. These results were then aggregated into "Aquifer Area" and "Eleven-County Area" totals.

As has been mentioned above, both crude oil production and natural gas production and sales data were collected for two separate areal units, the "Eleven-County Area" which has the Ogallala Aquifer overlying about 58.1 percent of its area, and the "Aquifer Area" itself. These two areal units are the basic areal units used throughout the Colorado A-2 study. Choice of the areal base unit to be used in any specific part of the study was based on the outcomes desired and the data available.

Projection Assumptions. The basic assumption of this study is that the factors which were historically, and are currently, important in influencing the production of either oil or natural gas from conventional processes will

continue into the future. Specifically, the world price of oil and natural gas will continue to rise, mostly under influence of the OPEC cartel, but also from a growing awareness of an increasing world demand for oil and natural gas. However, significant breakthroughs in the near term involving alternative modes of transportation, process efficiencies, solar or other technologies, could weaken this assumption, and thus affect the accompanying projections. In addition it was assumed that price will continue to rise to the extent that, after a major producer leaves a particular field due to submarginal production, other (smaller) producers--individuals, independents, utilities, industry, etc.--will continue to produce from that field at whatever flow rate can be sustained. In other words, production will continue beyond the 'stripper' level to the physical limit of production. The fact that pipelines will be in place, demand will be high, supplies will be short, and special purpose users will be abundant, generally lends support to this assumption.

There will be no new "big" finds of either oil or natural gas in the study area. Southeast Colorado is already partially explored and any further "big" discovery would surprise the experts. Those counties of Northeast Colorado which border on the Denver Basin show considerable future promise, but that future is reflected in the historical production records used in the analysis--consequently the projections will account for the considerable future production from that basin. The Niobrara Formation has been recommended as a "tight sand" area, and if so designated might produce additional amounts of natural gas due to the increased wellhead price. However, this will only affect the timing of the production and not the overall magnitude. A similar situation could occur with respect to the enhanced recovery of crude oil.

The future for conventional crude oil production is not very bright. Most oil wells are "old" and into a secondary recovery phase, and have been for some time. Consequently, the aggregate production of conventional crude oil in the study area based on 10 years of historical data shows an unmistakable decline. The analytical methods used in the projections for crude oil explicitly assume a continuation of that deline as tempered by the best engineering judgment of experienced and knowledgeable professionals.

The future for conventional gas production is somewhat brighter than for conventional crude oil in the study area. This future optimism relative to conventional crude oil production is due to non-associated natural gas. The aggregate production history of conventional natural gas in the study area for the past 10 years, while not exhibiting as clear-cut a case of decline as that for conventional crude oil, does nonetheless strongly indicate either a current decline or a soon-to-be-entered decline phase. Consequently, as in the projection of conventional crude oil, the method used to project conventional natural gas production also assumes a decline. Once again experts were consulted and their opinions taken into consideration.

No explicit adjustment of production projection figures was made to account for any future technological breakthroughs in tertiary production, oil mining, or for substantial production for sub-economic or unconventional sources of either crude oil or natural gas. Only those techniques currently in use and reflected in the historical production record are accounted for in the production projections. Consequently, any breakthroughs would weaken this assumption and affect the projections.

The upper and lower bounds for the "most likely" production projections were assumed to be adequately accounted for by the analysis of the critical parameters governing the mathematical models used in the study, and by the adjustment of those critical parameters to reflect higher or lower levels of projections which together will bracket the "most likely" projections.

The "Eleven-County Area" was chosen as the basic areal unit from which to make projections. "Aquifer Area" projections were subsequently derived from these basic projections. Selection of the "Eleven-County Area" was based on the following reasoning: First, the county unit, rather than the Ogallala Aquifer, is more readily identifiable and corresponds more with the other available data bases. Second, factors such as employment, socio-economic impacts, etc., would seem to be more sensitive to a county or regional energy production forecast than to a more narrowly defined areal unit which does not coincide with presently recognized governmental or planning boundaries. Third, statistical notions support forecasting from one large data base rather than from several relatively small data bases (note that this was borne out by preliminary analysis--see the "projection techniques" section). Finally, because the projections will indicate constantly declining production, changes in original data "dampen out" quickly over the estimated forecast period.

Projection Techniques.* While any projections of production through the year 2020, 40 years into the future, are inherently suspect, it is felt from discussions with experts that the analytical methodology used in this study is as unassailable as any methodology currently in widespread use by the

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*Note: The actual development of the crude oil and natural gas production projection methodology was by Energy Development Consultants, Inc., Golden, Colorado, in consultation with industry representatives.

contemporary petroleum industry for making projections. In addition, this methodology is enhanced by the accuracy and availability of historical production data encompassing the study area.

The crude oil and natural gas production projections in this study are the outcomes of analysis of the results of four separate analytical methodologies "tried" on the historical production records of both crude oil and natural gas, separately. In brief, the methodology first considered different ways of "fitting" an analytical production function to the known, historical, annual production record for the period 1969-1978; it then analyzed how well each particular function described the past production history; and finally it extrapolated the chosen production functions to cover the forecasting period, 1980 to 2020 inclusive.

The production functions considered were as follows:

1. Exponential functions of the form:

$$P_t = e^{(a + Bt)} = e^d \, e^{Bt}$$

2. Harmonic functions of the form:

$$P_t = kP_{t-1}$$

3. Non-linear rate (power) functions of the form:

$$P_t = d + B\,(r)^t$$

4. Polynomial functions of the form:

$$P_t = a + bt + ct^2$$

where:

"t" is a variable representing time, in years;

"P_t" is a variable representing production in year "t";

"d", "B", "r", "k", "a", "b", "c", are fixed constants determined by analysis.

The methodologies utilized in determining the necessary parameters for the production functions included (1) ordinary least squares regression, (2) empirical analysis, and (3) non-linear least squares regression.

As expected, the polynomial functions were quickly eliminated from consideration by both statistical and empirical evidence. Each of the three remaining functional forms were fit to the 10 year annual historical production data for crude oil and natural gas separately in two ways: first, for each of the eleven counties individually with later aggregation into regional projections, and secondly, to the already aggregated regional production figures from the eleven counties. The results were significantly different. Predictably, the approach which aggregated the historical county productions and forecast from that record was more realistic than was the sum of the individual county forecasts. This is because in the former case, production irregularities were "added out", and thus did not unduly influence the production forecasts. For this reason the approach involving aggregation and then forecasting was chosen.

In the next stage, two different modes of analysis were applied to each of the three classes of production functions: 1) a technical analysis, and 2) a subjective analysis mode. In the technical analysis, classical statistical analysis was performed on the standard analysis of variation (AOV) table for regression-produced estimates, and also included investigation of the coefficient of determination (R^2 value), the computed F statistic, the mean square error, and the standard error of estimate. In the subjective analysis, actual comparisons of the production forecasts from the three different forecast functions (exponential, harmonic, and non-linear power function) were made and contracted with estimates of potential ultimate recovery of the oil

and gas resource in the study area. Part of this analysis was in the form of the expert engineering judgement of professionals at the Colorado School of Mines, the Potential Gas Agency, and the Colorado Oil and Gas Conservation Commission.

The technical analysis teogether with the subjective analysis indicated that the best approach was an exponential decline function for projection of the "Eleven-County Area" crude oil production, and a harmonic decline (constant rate decline) for projection of the "Eleven-County Area" natural gas production.

The "most likely" crude oil production projections were derived from an exponential decline production function through the year 2020. The "low" and "high" bounds projections were derived by changing the values of the exponential parameters by two standard deviation, estimates of which were produced by the ordinary least squares analysis.

In the case of the "most likely" natural gas production projections, the rate for the constant decline production function was subjectively determined by examining the total historical production and aggregate projected future production (as a function of rate) in light of estimates of the original resource in place in the "Eleven-County Area". The rates for the constant decline production functions for the "low" and "high" bounds were determined in a like manner. Knowledgeable consultants were used extensively during this phase of the modeling.

Both crude oil and natural gas production projections for the "Aquifer Area" were derived from those generated for the "Eleven-County Area". This was for the reasons mentioned previously, and because it was felt with relative certainty that even if a separate analysis of the production within the

Ogallala Aquifer were performed, the methodologies found to be most appropriate to forecast future production would be identical to those of the "Eleven-County Area" forecasts. Furthermore, the data base size would be only about one-half of that previously used and therefore would not "add out" small erratic changes as well. Consequently, it was determined that to repeat the extensive analysis and modeling effort of the "Eleven-County Area" for the "Aquifer Area" would be a waste of time and money.

To forecast the future production of both crude oil and natural gas in the "Aquifer Area", a conversion factor was applied to the "Eleven-County Area" forecasts for 1980, 1985, 1990, 2000, and 2020. The conversion factor was derived from an analysis of the magnitude and trend of the proportion of the annual production from the "Eleven-County Area" for the years from 1969-1978 inclusive which were attributable to the "Aquifer Area". Specifically, the average 1969-1978 percentage of the "Eleven-County Area" production attributable to the "Aquifer Area" plus an annual percentage change in that percentage was used to derive a function of the form:

$$P_{tA} = P_{tE} \times (a + b_{t_o - t_i})$$

"P_{tA}" is a variable representing production in the "Aquifer Area" in the year "t";

"P_{tE}" is a variable representing production in the "Eleven-County Area" in the year "t";

"a" is a constant derived for the average annual percentage for 1969-1978;

"b" is a constant derived for the average annual change in percentage for 1969-1978;

"t_i" is a variable representing any year after 1978;

"t_0" is 1978.

The "Eleven-County Area" forecasts for each specified year was multiplied by the above function to derive the "Aquifer Area" forecasts.

Electric Energy Requirements and Production

Baseline Data. The historical baseline data for electric energy requirements and production were obtained from the records of various public agencies such as the Federal Power Commission, Department of Energy, and the Colorado Public Utilities Commission and from the correspondence and records provided by personnel of the various electric utilities serving the Colorado High Plains Area.

Electric energy requirements, defined as total end-sales by electric utilities serving the "Eleven-County Area" were derived from the 1969-1978 individual utilities' Annual Reports to the Colorado Public Utilities Commission Fixed Utilities Division. Annual system-wide end-sales totals for each electric utility as reported in its Annual Report were modified to reflect only that portion of the total sold within the "Eleven-County Area". The factor which was used to modify each electric utility's annual system-wide end-sales total was a figure which represented the summation of the percentages of that utilities' sales which occurred in any of counties included in the "Eleven-County Area"--county-by-county percentages for individual electric utilities had previously been estimated for the Colorado Office of Energy Conservation by BBC (Bickert, Browne, and Coddington) Consultants (Denver, Colorado) in a 1978 study using 1977 Colorado Public Utilities Commission data. Finally, each individual electric utility's modified annual end-sales total, repre-

senting end-sales in counties included in the "Eleven-County Area" were aggregated to obtain an annual regional total.

Generation facilities existing within the "Eleven-County Area" during the 1969-1978 study period were identified from maps and reports of the Federal Power Commission, Department of Energy (Energy Information Administration), Colorado Public Utilities Commission, and the Colorado Land Use Commission. Utilities with identified generating facilities were then contacted to ascertain the past status (operating, emergency standby, or retired) and capacity, and future generation plans. This information was then aggregated on an annual basis (1969-1978) into "producing", "standby", and "total", generation capacity categories.

Actual electric energy produced within the "Eleven-County Area" was compiled from reports and correspondence provided by individual electric utility personnel. It should be noted that during the period 1969-1978 only five utilities out of the three major wholesalers, seven primary rural electric associations, and eleven municipalities (a total of twenty-one utilities) generated any of their own power within the study area.

Projection Assumption. The basic assumption of this part of the study, like all others, is that the future can be forecast from experiences of the past, i.e., "business as usual". One aspect of this is that the cost of electric energy will continue to escalate because of increased costs per kilowatt of installed generating capacity for new plants and because of increased fuel costs. This will especially be true on the High Plains of Colorado where existing generation is fueled either by natural gas or fuel oil or a combination of both and where the prime wholesale suppliers, Colorado-Ute Electric,

and Tri-State Generation and Transmission, can no longer depend on "cheap" Bureau of Reclamation power nor on low interest loans from the Rural Electric Association for the construction of needed generating facilities. It is assumed that fuel costs will increase faster than capital costs during the first part of the period, but that this situation will be reversed during the latter part of the period.

Demand for electric energy in the "Eleven-County Area" will continue to grow, but at a declining rate. The basis for this assumption is that 1) there will be no new major users of electricity in the study area, 2) increasing price will not cause a major decrease in use of electricity, 3) weather will be "normal", and 4) irrigation demand, now about one-half of the total load, will increase slowly because there will be a limited number of conversions, and because there will be a modification in energy utilization due to the use of low pressure center-pivot irrigation systems and the use of load management techniques.

In regard to supply it is assumed that supply will be adequate, although, as noted above, each unit consumed will be more expensive. It is felt that neither oil and natural gas allocation policies nor a capital shortage will have a drastic adverse effect on the supply in the study area. However, because there will be no new major generating facilities on the Colorado High Plains, there will be an increasing dependence on power generated outside the region. In addition, it is assumed that there will not be a widespread availability of new, low-cost, decentralized generating technologies to supplement existing generating capacity. Finally, it is assumed that utilities will, within contract limits, attempt to minimize the cost of electricity from all available generating sources.

More specifically, for electric energy requirements (to meet sales and power system losses) this study assumes in addition to the above, that the county proportions within each utility system will remain constant to that determined by the 1978 BBC Consultants for the Colorado Office of Energy Conservation. For the "Low" and "High" bound situation it was further assumed that the energy demand growth rate would be 25 percent less and 25 percent more than the "Most Likely" situation, respectively.

For the projection of generating capacity, in addition to the foregoing assumptions, specific assumptions were made for each forecast situation. The "Most Likely" situation assumes that generators will be retired, due to the burden or maintenance, fifteen years after being placed on "standby"; that Tri-State will retire its generators when they have completed their expected 35 years of production life (i.e., in 2009 and 2011); and that Lamar, for reasons of partial independence, will maintain a generating capacity equivalent to that of its newest turbine plant throughout the period. In the "Low" bounds situation it was assumed that generators would be retired five years after being placed on "standby"; that Tri-State would retire its high-cost, fuel oil powered turbine peaking generators early, after only 25 years of production life (in 1999 and 2001), due to the high cost of fuel oil; and that Lamar would continue to use only its newest (1972) natural gas fueled steam-powered generator with a "normal" retirement after 35 years of production life. For the "High" bounds situation it was assumed that all existing generation capacity will be replaced with equivalent sized units at the end of their production life--i.e., generation capacity will remain constant throughout the period, 1980-2020.

In order to project electric energy production, in addition to the above assumptions, it was assumed that for all forecast situations, "Most Likely", "Low", and "High", each individual electric utility's load requirements and generating capacity would be as projected in this study for each of those forecast situations, respectively. An average generation availability factor (the proportion of time a generator would be generating) of 95% was used for all projections. Only "producing" generating capacity was used in the "Low" and "Most Likely" forecasts while both "producing" and "standby" generating capacity was used in the "High" forecasts. Also, the average historical annual aggregate capacity factor (see Projection Technique) was modified by the estimated growth rate in electric energy required because it was assumed that there would be a more intensive use of existing generating capacity as electric energy demand increased.

Projection Techniques. The projections in this part of the study were made by the Colorado Office of Energy Conservation from an analysis of historical trends and in consultation with electric energy utility personnel.

Electric energy requirement forecasts for the "Eleven-County Area" are the outcome of the aggregation of individual forecasts for each of the study area electric utilities. For the "Most Likely" projections, the forecasts for the 1980 and 1988 period are the sum of the estimates of annual electric energy load requirements for each electric utility as reported by the utility to the Colorado Public Utilities Commission and reported in that agency's "Eleven-County Area" to system-wide factor (discussed in the "Baseline Data" section) derived from the BBC Consultants 1978 study for the Colorado Office of Energy Conservation; the forecasts for the 1989 to 2020 period are based

on an analysis of historical trends--specifically, the average annual growth rate and the trend of the growth rate for the period 1976 to 1988 were analyzed to provide a model of the form:

$$R_{t_i} = \left[R_{t_o} + R_{t_o} \times (a_{t_o} - t_i - b_{t_o} - ti) \right]$$

where:

"R_{t_i}" is a variable representing requirements in the year "t_i";

"R_{t_o}" is a variable representing requirements in the year 1978;

"a" is a constant derived for the average annual percentage growth;

"b" is a constant derived for the average annual change in percentage growth;

"t_i" is a variable representing a specific forecast year;

"t_o" is the year 1978.

The "Low" and "High" bounds projections were derived from the application of the same model, but with change rates which were 25 percent lower and 25 percent faster, respectively.

Generation capacity for the "Eleven-County Area" was forecast by simply applying the aforementioned assumptions, noting the years in which generators were retired, and aggregating the remaining megawatts of generating capacity.

Electric energy production was projected by using a modified annual aggregate capacity factor technique. First, annual aggregate capacity factors for each baseline year were calculated separately for municipal generation

and rural electric cooperative generation: for each year, generating capacity in megawatts was multiplied by an output factor of 8.322 (derived from an assumption of 95 percent availability and conversion of megawatts to kilowatt hours) to obtain themaximum possible annual electric energy production which was then divided into the actual annual electric energy production to find the annual aggregate capacity factor. Ten-year averages were then computed separately for municipalities (44.4 percent) and for rural electric cooperatives (3.2 percent). To project future electric energy production, the average annual aggregate capacity factors for both municipalities and rural electric cooperatives were separately increased by the projected rate of growth in electric energy required for each bound, "Low", "Most Likely", and "High", to reflect the assumption that existing generating facilities will be used more intensively as electric energy requirements increase. Maximum possible electric energy production for each bound and projection year was then derived separately for municipalities and rural electric cooperatives by multiplying projected generating capacity by the output factor (as described above). Next, the modified annual aggregate capacity factors were multiplied by estimates of maximum possible electric energy production to provide estimates of actual electric energy production. Finally, the separate estimates of electric energy production for municipalities and rural electric cooperatives were aggregated to provide projections for specific bounds, "Low", "Most Likely", and "High" and projection years.

TABLE II - 1

Six-State High Plains-Ogallala Aquifer Area Study
State Research Element A-2
Energy Production Impacts

Colorado
Crude Oil Production
Millions of Barrels

Historical[1]

Year	Ogallala Region* Actual
1969	8.382
1970	7.632
1971	6.799
1972	6.103
1973	5.262
1974	4.748
1975	4.523
1976	4.327
1977	3.925
1978	3.599

Projected[2]

	Ogallala Region		
Year	Low	Most Likely	High
1980	2.687	2.889	3.105
1985	1.600	1.805	2.036
1990	0.951	1.127	1.336
2000	0.336	0.440	0.557
2020	0.047	0.067	0.107

*Eleven-County Area

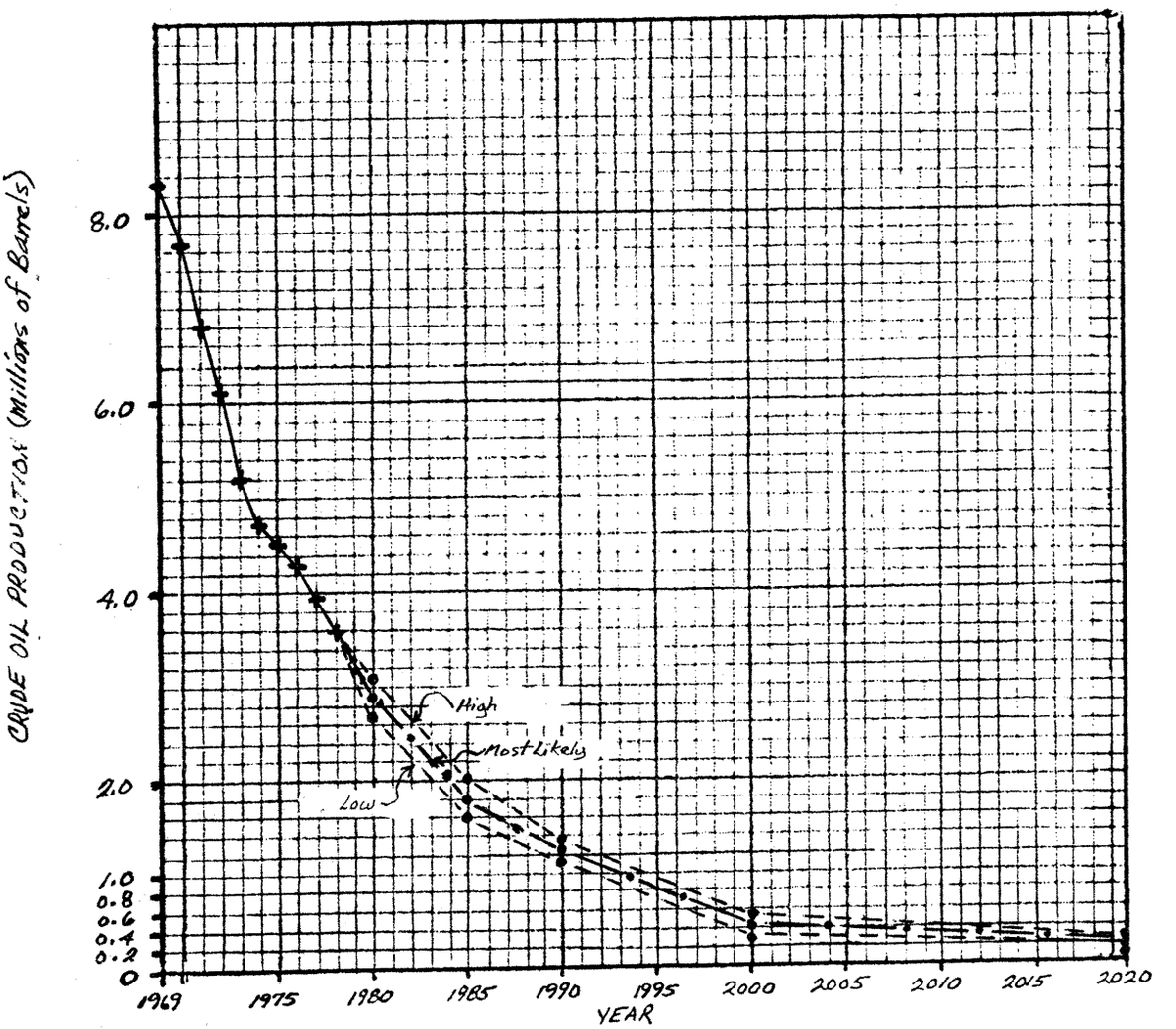
Sources: 1) Colorado Oil and Gas Conservation Commission, Annual Reports 1969-1978.

2) Energy Development Consultants, Inc. (Golden, Colorado).

FIGURE II-1

Colorado Crude Oil Production in the Eleven-County Area

(Millions of Barrels)



+ denotes historical data

Source: Colorado Oil and Gas Conservation Commission Annual Reports, 1969-1978; Energy Development Consultants, Inc. (Golden, CO.), 1980-2020.

TABLE II - 2

Six-State High Plains-Ogallala Aquifer Area Study
State Research Element A-2
Energy Production Impacts

Colorado
Crude Oil Production
Millions of Barrels

Historical[1]

Year	Ogallala Region* Actual
1969	2.190
1970	2.322
1971	2.059
1972	1.937
1973	1.784
1974	1.684
1975	1.745
1976	1.733
1977	1.573
1978	1.422

Projected[2]

	Ogallala Region		
Year	Low	Most Likely	High
1980	1.086	1.167	1.254
1985	0.683	0.771	0.869
1990	0.428	0.507	0.601
2000	0.167	0.218	0.236
2020	0.025	0.039	0.063

*Aquifer Area

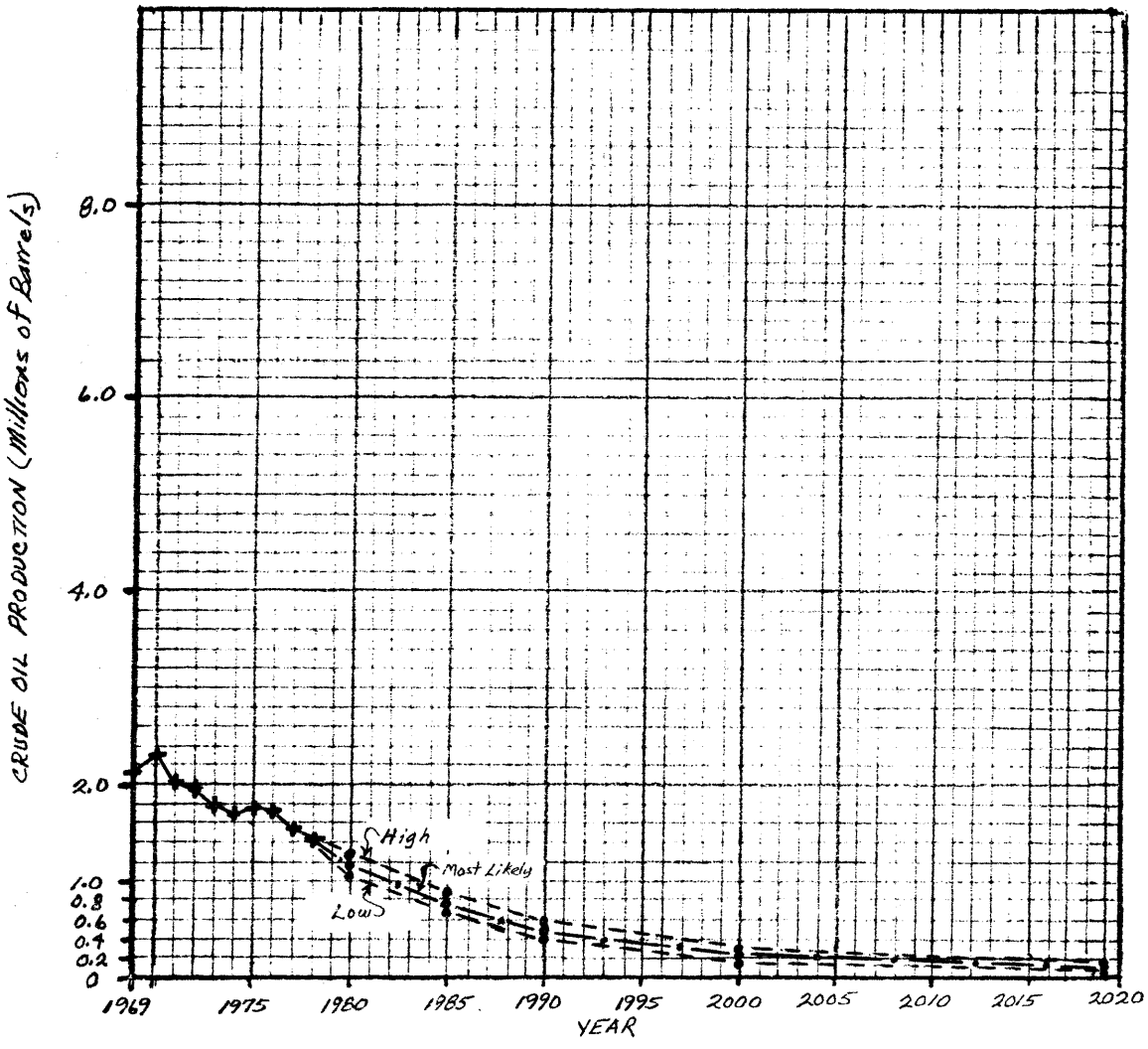
Source: 1) Colorado Oil and Gas Conservation Commission, Annual Reports 1969-1978.

2) Colorado Office of Energy Conservation (derived from Energy Development Consultants, Inc. projections for the Eleven-County Area).

FIGURE II-2

Colorado Crude Oil Production in the Ogallala Aquifer Area

(Millions of Barrels)



+ denotes historical data

Source: Colorado Oil and Gas Conservation Commission Annual Reports, 1969-1978; Energy Development Consultants, Inc. (Golden, CO.), 1980-2020.

TABLE II - 3

Six-State High Plains-Ogallala Aquifer Area Study
State Research Element A-2
Energy Production Impacts

Colorado
Natural Gas Production
Billions of Cubic Feet

Historical[1]

Year	Ogallala Region* Actual
1969	12.661
1970	11.753
1971	11.128
1972	10.857
1973	10.539
1974	9.392
1975	9.621
1976	11.899
1977	11.400
1978	10.262

Projected[2]

Year	Ogallala Region		
	Low	Most Likely	High
1980	8.971	9.755	10.037
1985	6.411	8.595	9.497
1990	4.581	7.573	8.986
2000	2.339	5.879	8.045
2020	0.610	3.543	6.449

*Eleven-County Area

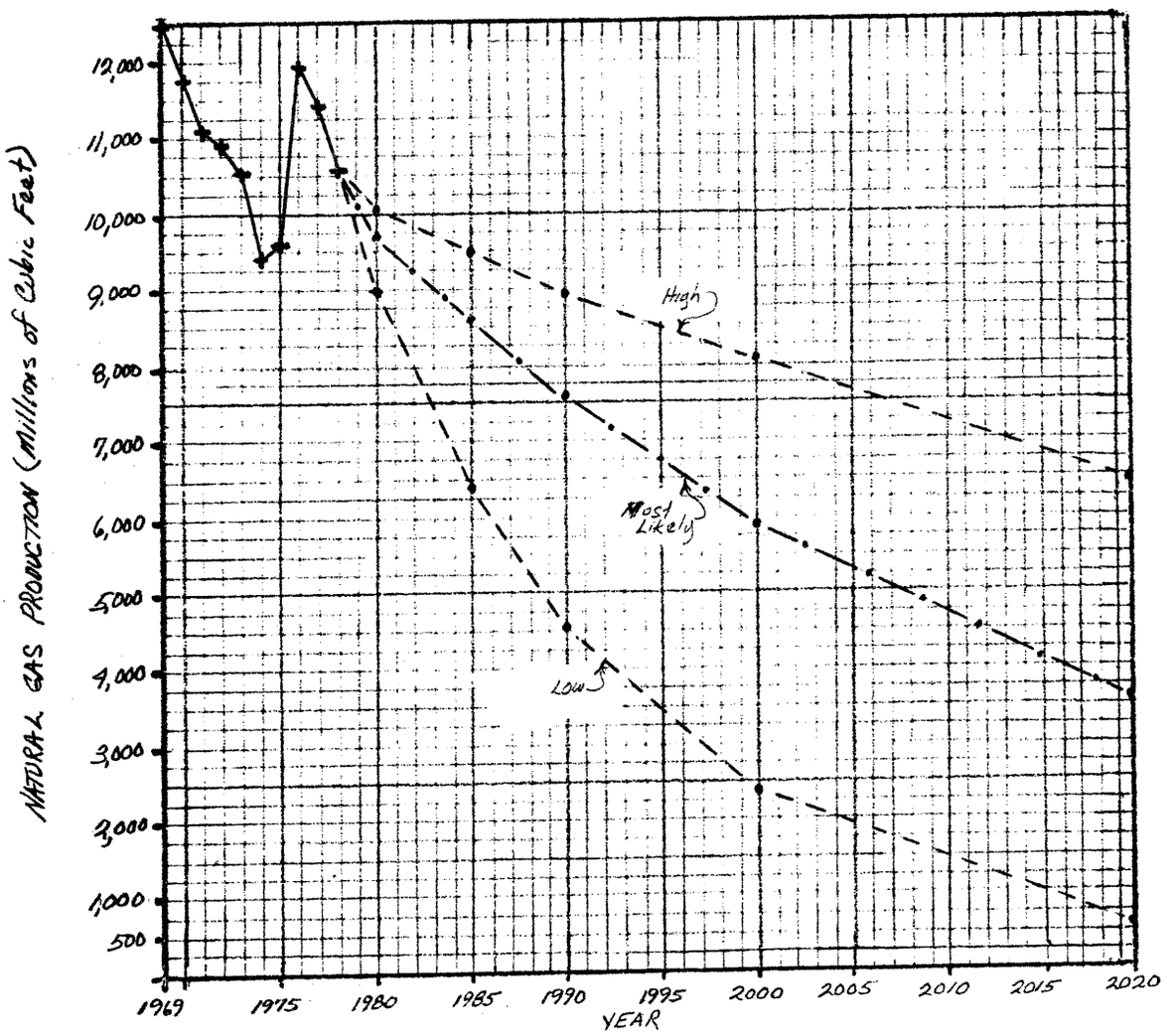
Source: 1) Colorado Oil and Gas Conservation Commission, Annual Reports 1969-1978.

2) Energy Development Consultants, Inc. (Golden, Colorado)

FIGURE II-3

Colorado Natural Gas Production in the Eleven-County Area

(Millions of Cubic Feet)



+ denotes historical data

Source: Colorado Oil and Gas Conservation Commission Annual Reports, 1969-1978; Energy Development Consultants, Inc. (Golden, CO.), 1980-2020.

TABLE II - 4

Six-State High Plains-Ogallala Aquifer Area Study
State Research Element A-2
Energy Production Impacts

Colorado
Natural Gas Production
Billions of Cubic Feet

Historical[1]

Year	Ogallala Region* Actual
1969	6.143
1970	5.667
1971	5.293
1972	5.036
1973	5.695
1974	4.427
1975	4.307
1976	6.005
1977	5.889
1978	5.268

Projected[2]

	Ogallala Region		
Year	Low	Most Likely	High
1980	4.647	5.053	5.199
1985	3.423	4.590	5.071
1990	2.520	4.165	4.942
2000	1.361	3.422	4.682
2020	0.394	2.289	4.063

*Aquifer Area

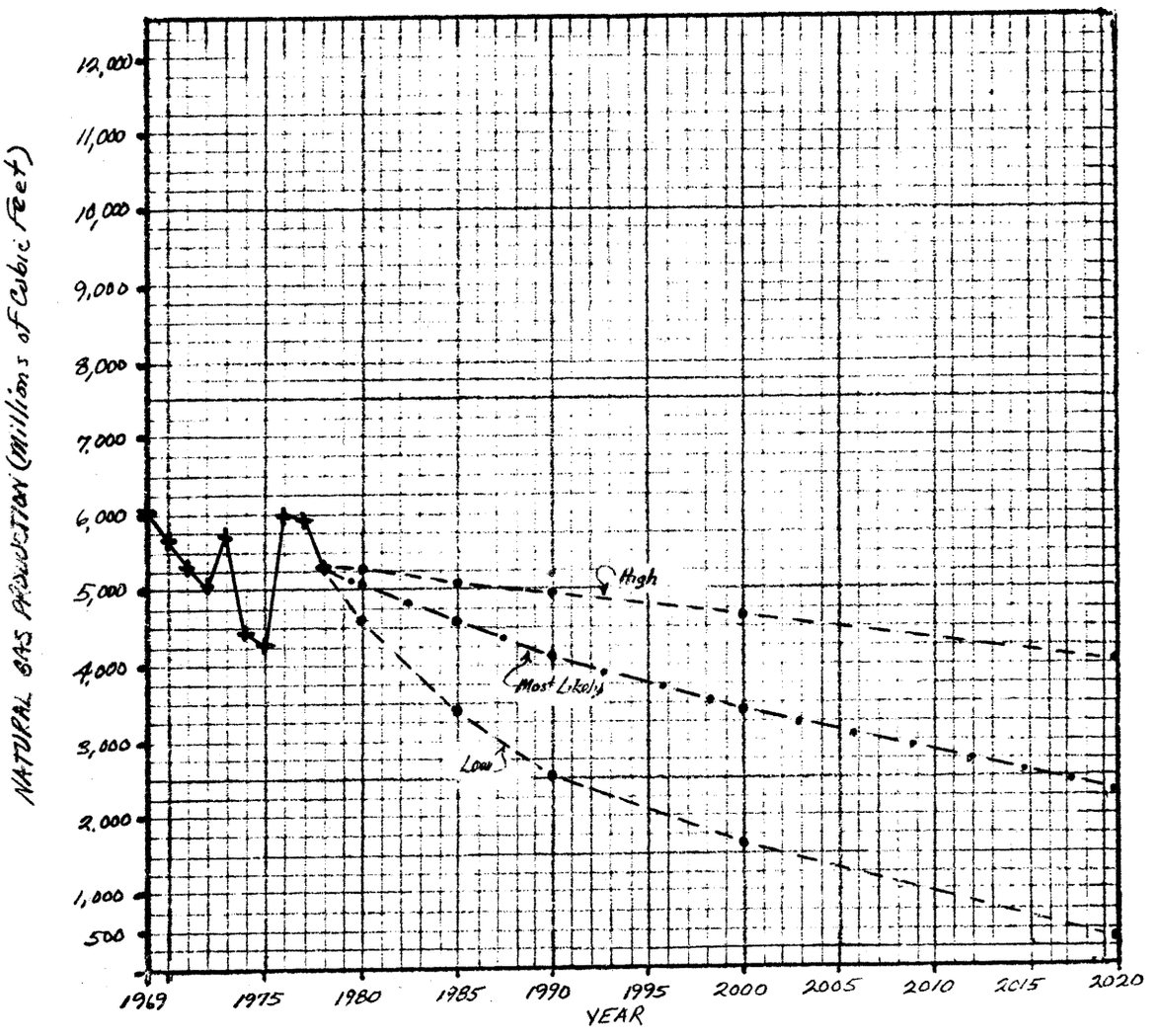
Sources: 1) Colorado Oil and Gas Conservation Commission, Annual Reports 1969-1978.

2) Colorado Office of Energy Conservation (derived from Energy Development Consultants, Inc. projections for the Eleven-County Area).

FIGURE II-4

Colorado Natural Gas Production in the Ogallala Aquifer Area

(Millions of Cubic Feet)



+ denotes historical data

Source: Colorado Oil and Gas Conservation Commission Annual Reports, 1969-1978; Energy Development Consultants, Inc. (Golden, CO.), 1980-2020.

TABLE II - 5

Six-State High Plains-Ogallala Aquifer Area Study
State Research Element A-2
Energy Production Impacts

Colorado
Electric Energy Requirements
Millions of kwh

Historical[1]

Year	Ogallala Region* Actual
1969	305.17
1970	344.77
1971	373.94
1972	410.35
1973	447.368
1974	552.957
1975	651.753
1976	819.041
1977	773.151
1978	893.238

Projected[2]

Year	Ogallala Region		
	Low	Most Likely	High
1980	1144.19	1149.03	1206.28
1985	1339.24	1480.41	1556.30
1990	1534.22	1720.36	1888.30
2000	1924.15	2265.42	2606.31
2020	2704.01	3355.58	4014.64

*Eleven-County Area

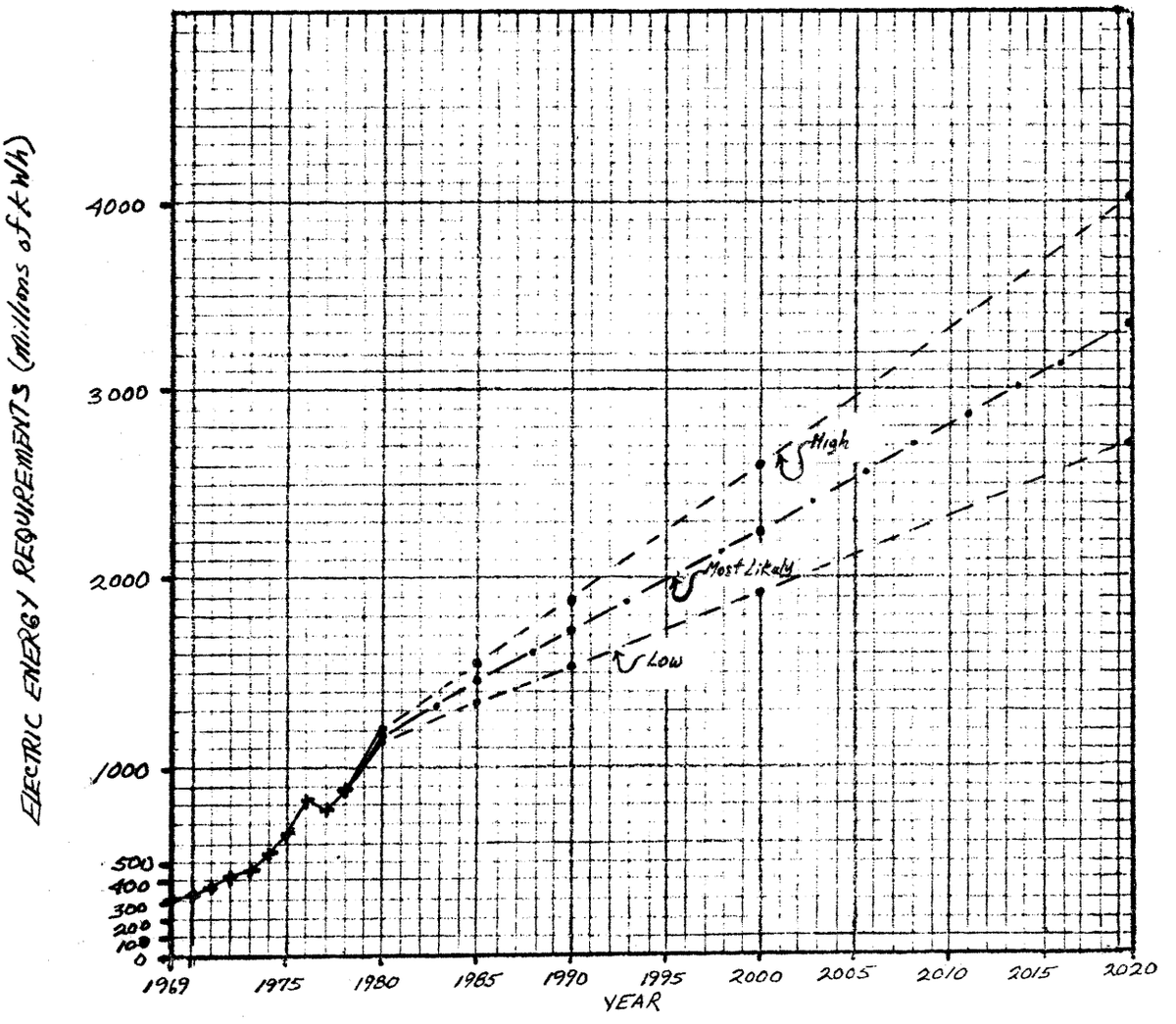
Sources: 1) Colorado Public Utilities Commission Annual Reports, 1969-1978, as modified by the 1978 BBC-OEC Study.

2) Colorado Office of Energy Conservation Projections.

FIGURE II-5

Colorado Electric Energy Requirements in the Eleven-County Area

(Millions of Kilowatt Hours)



+ denotes historical data

Source: Colorado Public Utilities Commission Annual Reports, as modified by 1978 BBC-OEC study, 1969-1978; Colorado Office of Energy Conservation, 1980-2020.

TABLE II - 6

Six-State High Plains-Ogallala Aquifer Area Study
State Research Element A-2
Energy Production Impacts

Colorado
Electric Energy Production
Generating Capacity MW

Historical[1]

Year	Ogallala Region* Actual		
	Producing	Standby	Total
1969	21.00	11.22	32.22
1970	21.00	11.22	32.22
1971	21.00	11.22	32.22
1972	34.80	21.22	56.02
1973	34.80	21.22	56.02
1974	34.80	21.22	56.02
1975	225.30	23.72	249.02
1976	225.30	23.72	249.02
1977	322.80	26.22	349.02
1978	319.80	29.22	349.02

Projected[2]

Year	Ogallala Region		
	Low	Most Likely	High
1980	330.50	344.40	349.02
1985	320.50	338.35	349.02
1990	320.50	335.50	349.02
2000	125.50	325.50	349.02
2020	0.70	24.80	349.02

*Eleven-County Area and Ogallala Aquifer Area

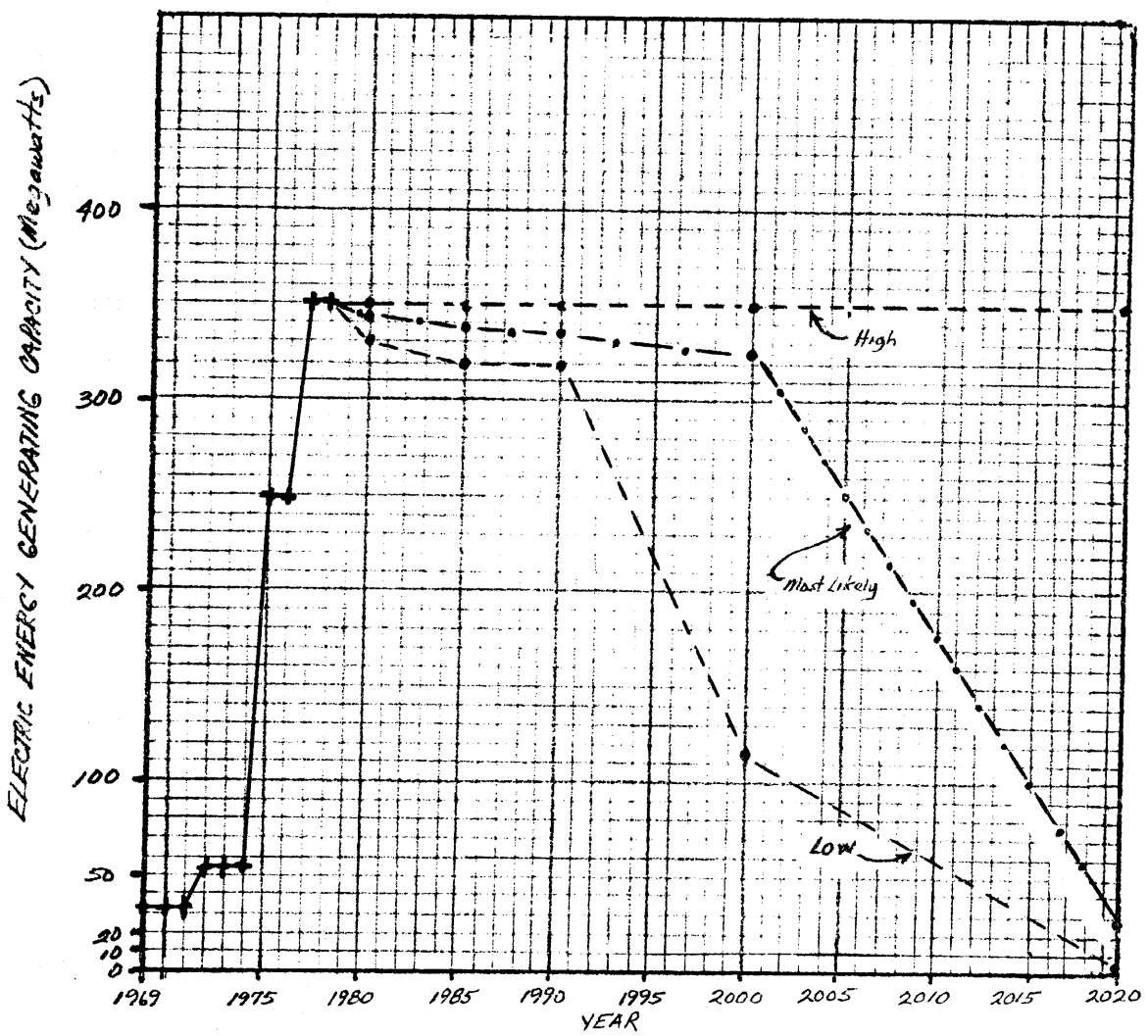
Sources: 1) Correspondence and interviews with individual producing utilities.

2) Colorado Office of Energy Conservation Projections

FIGURE II-6

Colorado Electric Energy Generating Capacity in the Eleven-County Area

(Megawatts)



+ denotes historical data

Source: Colorado High Plains Electric Utilities' Records, 1969-1978; Colorado Office of Energy Conservation, 1980-2020.

TABLE II - 7

Six-State High Plains-Ogallala Aquifer Area Study
State Research Element A-2
Energy Production Impacts

Colorado
Electric Energy Production
Energy Produced in Million kwh

Historical[1]

Year	Ogallala Region* Actual
1969	82.94
1970	92.23
1971	96.32
1972	104.09
1973	107.96
1974	115.38
1975	179.79
1976	187.98
1977	143.41
1978	140.43

Projected[2]

Year	Ogallala Region		
	Low	Most Likely	High
1980	165.29	196.06	263.54
1985	193.40	237.46	334.15
1990	216.62	261.71	399.84
2000	178.66	332.27	538.20
2020	0.00	206.39	661.52

*Eleven-County Area and Aquifer Area

Sources: 1) Annual Reports and Annual Power System Statements to the Federal Power Commission (1969-1976) and to the Department of Energy (1977 to 1978).

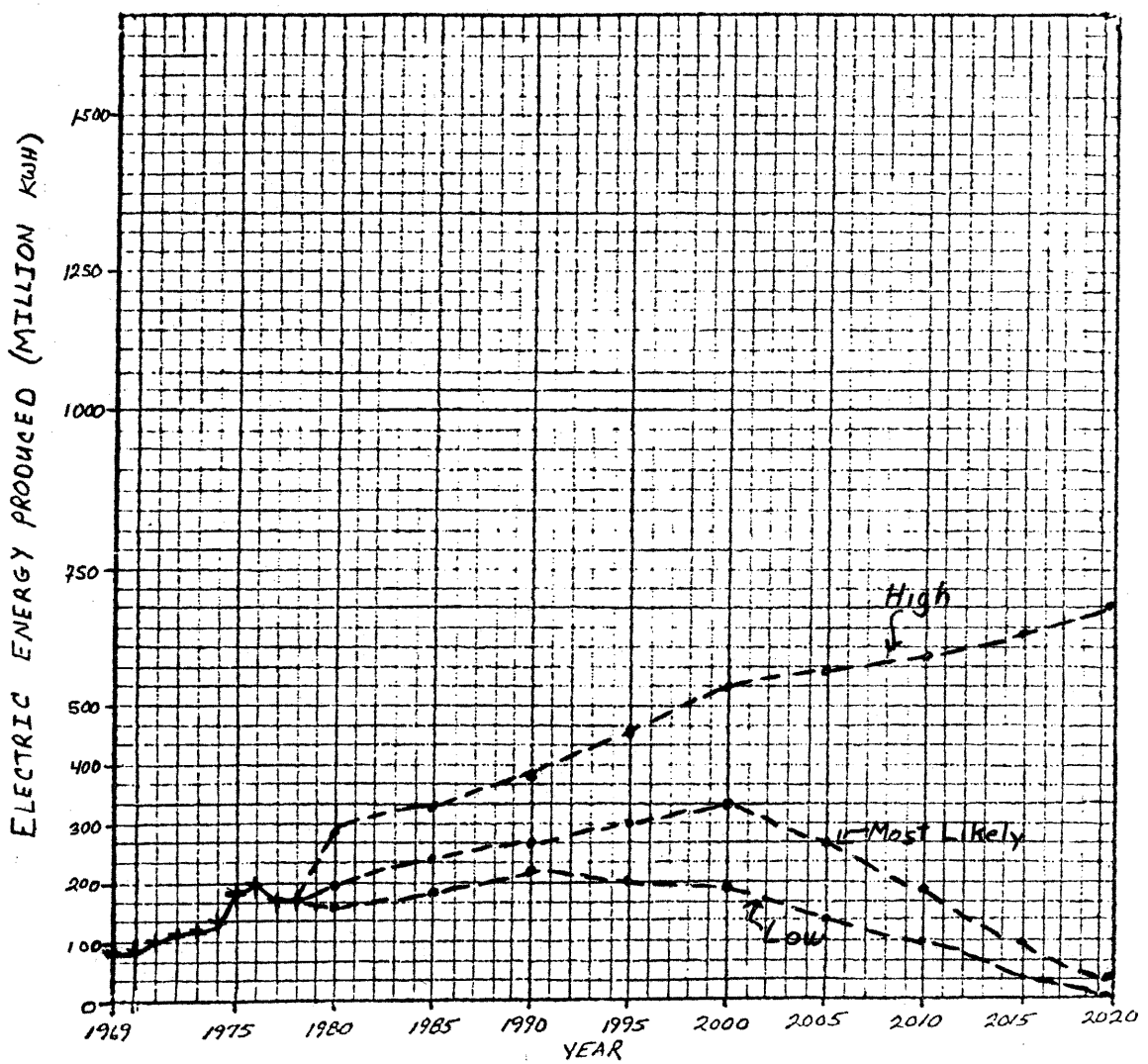
2) Colorado Office of Energy Conservation Projections.

FIGURE II-7

Colorado Electric Energy Produced in the

Eleven-County Area

(Million Kilowatt Hours)



+ denotes historical data

Source: Annual Reports and Annual Power System Statements to the Federal Power Commission or to the Department of Energy, 1969-1978; Colorado Office of Energy Conservation, 1980-2020.

III. WORKING PAPER

ENERGY PRODUCTION IMPACTS: 1. EMPLOYMENT AND INCOME

INTRODUCTION

The purpose of this working paper is to provide historical time profiles of the employment and income attributable to the energy industry in the "Eleven-County Area" of the Colorado High Plains. As was mentioned previously, investigation revealed no production or significant resource potential for either surface or deep minable coal or for uranium. Consequently, this working paper focuses on employment and income arising from crude oil and natural gas production, electric energy production, and energy transportation.

The total number of persons employed and income received from petroleum (crude oil and natural gas combined) are illustrated in Figure III-1 and Figure III-2, respectively. Tables III-1 and III-2 summarize the data which was used to construct those figures. This information is further subdivided into the number of persons employed and income received from crude oil and natural gas, individually and separately, as is illustrated in Figures III-3 to III-6 and summarized in Tables III-3 to III-6.

Electric energy production employment and income are graphically displayed in Figures III-7 and III-8 and summarized in Tables III-7 and III-8. Information about employment and income from energy transportation follows, with the number of persons employed described in Figure III-9 and Table III-9 and income received in Figure III-10 and Table III-10.

A review of the Colorado Division of Employment, U.I. Reporting Systems records indicated that there was no employment within the study area in oil refining, oil products manufacturing, and petroleum production field equipment manufacturing. Figure III-11 and Table III-11 summarize the historical and projected oil and gas proprietors' income.

METHODOLOGY

Baseline Data

The historical baseline data for employment and income related to the energy industry were derived primarily from the records of the Colorado Division of Employment, U.I. Reporting Systems. Data were available on a county basis by Standard Industrial Code Number categories for the years 1972 to 1978 inclusive. Data for the year 1969, 1970, and 1971 were not available without extensive searching and time consuming aggregation as this was prior to the computerization of their records. Consequently, the historical base is only seven years rather than ten as in other parts of the study.

The procedure used first defined the various desired employment and income categories in terms of Standard Industrial Code (SIC) Numbers. Once the employment and income categories were defined, the Division of Employment completed a preliminary screening of randomly selected quarters to determine which of the SIC categories appeared on their records for any of the counties of the "Eleven-County Area". Computer runs were then begun, which resulted in quarterly information on the number of persons employed and income received by SIC category for the region as a whole. Regional totals rather than county totals had to be used to avoid problems of disclosure and

confidentiality. The primary information from the Division of Employment was then aggregated and disaggregated as is described below.

For this study, employment and income resulting from crude oil and natural gas production was arrived at by summing the average annual data from four SIC codes: SIC No. 1311 (Crude Petroleum and Natural Gas--"Establishments primarily engaged in operating oil and gas field properties."), SIC No. 1381 (Drilling Oil and Gas Wells--"Establishments primarily engaged in drilling wells for oil or gas field operations for others on a contract, fee, or similar basis."), SIC No. 1382 (Oil and Gas Field Exploration Services--"Establishments primarily engaged in performing geophysical, geological, and other exploration services for oil and gas on a contract, fee, or similar basis."), and SIC No. 1389 (Oil and Gas Field Services, Not Elsewhere Classified). In order to report crude oil employment and income separately from natural gas employment and income, the above annual totals were disaggregated in the following manner: An annual well-by-well examination of production records from the Colorado Oil and Gas Commission was used to classify a well as an "oil producer", "gas producer", or "combination producer"; this count, with "combination producer" wells being allocated equally among "gas" and "oil", was used to arrive at an annual proportion figure (expressed as a percentage) which in turn was applied to the annual SIC No. 1311 data to arrive at the number of persons and income resulting from crude oil production and natural gas production, individually and separately. An identical procedure was followed for SIC Nos. 1381, 1382, and 1389, except that wildcat and development wells drilled annually were categorized into "oil producers", and "gas producers", with plugged and abandoned wells being

allocated on an equal basis to each of those categories. The annual results from these two disaggregations were then summed separately for crude oil and natural gas.

The Colorado Division of Employment provided information on the number of persons employed and income received in SIC No. 4911 (Electric Services--"Establishments engaged in the generation, transmission and/or distribution of electric energy for sale."). However, because in this study employment and income resulting from electric energy "production" was defined as only those engaged in generation, the historical data was based on interviews and correspondence with personnel of electric utilities which had generating facilities during the period 1969 to 1978. What is reported is the number of persons and income resulting from the generation of electric energy.

Employment and income resulting from energy transportation was arrived at by aggregating the data provided by the Colorado Division of Employment for SIC No. 4920 (Gas Production and Distribution--an aggregation of SIC No. 4922, Natural Gas Transmission; SIC No. 4923, Natural Gas Transmission and Distribution; SIC No. 4924, Natural Gas Distribution; and SIC No. 4925, Mixed, Manufactured or Liquified Petroleum Gas Production and/or Distribution, which was necessary to avoid disclosure and confidentiality limitations) and for SIC No. 4911 (Electric Services--"Establishments engaged in the generation, transmission and/or distribution of electric energy for sale.") minus those engaged in generation as described above. It was not possible to include SIC No. 4610 (Pipe Lines, Except Natural Gas) because of the absence of data during most quarters, and the confidentiality of the data when reported.

Information from the Department of Commerce, Bureau of Economic Analysis, Regional Economic Analysis was provided by Black and Veatch on the average 1976-1978 ratio of earnings (wages and salaries, other labor income, and proprietors' income) to wages and salaries for oil and gas extraction; for Colorado it was 1.26, while for the Ogallala Aquifer Region as a whole it was 1.3. The Colorado ratio value was then applied to reported annual baseline year wages and salaries for oil and gas extraction to derive oil and gas proprietors' income.

Projection Assumptions and Techniques

The projection assumptions and projection techniques are explained as part of the Colorado High Plains A-3 modeling.

TABLE III - 1

Six-State High Plains-Ogallala Aquifer Area Study
State Research Element A-2
Energy Production Impacts

Colorado
Employment Directly Related to the Energy Industry
Number of Persons Employed in Petroleum (Crude Oil and Natural Gas) Production

Historical[1]

Year	Ogallala Region* Actual		
	Field Operations[a]	Exploration, Drilling & Services[b]	Total
1969	NA**	NA**	NA**
1970	NA**	NA**	NA**
1971	NA**	NA**	NA**
1972	33	265	298
1973	32	339	371
1974	26	208	234
1975	61	232	293
1976	12	206	218
1977	12	304	316
1978	15	365	380

Projected[2]

Year	Ogallala Region		
	Low	Most Likely	High
1980			
1985	To Be Provided by Colorado A-3		
1990	Input-Output Model.		
2000			
2020			

*Eleven-County Area

**Not available (Division of Employment data not easily retrievable).

Sources: 1) Colorado Division of Employment, U.I. Reporting Systems.
2) Colorado High Plains A-3 Projections.

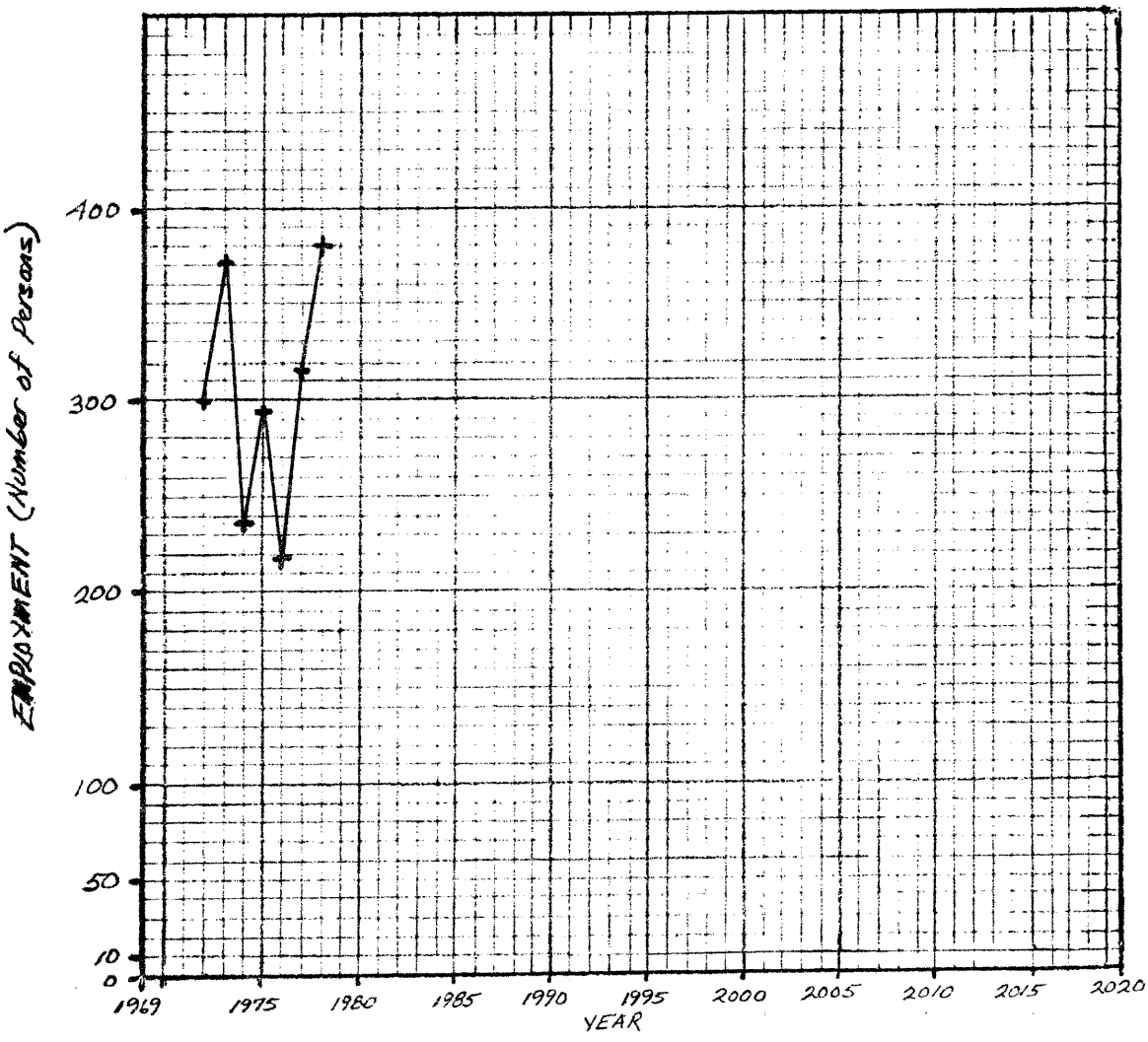
a Standard Industrial Code Number 1311.

b Standard Industrial Code Numbers 1381, 1382, 1389.

FIGURE III-1

Colorado Employment in Petroleum (Crude Oil and Natural Gas) Production in the Eleven-County Area

(Number of Persons)



+ denotes historical data

Source: Colorado Division of Employment, U.I. Reporting Systems, 1972-1978; Colorado High Plains A-3 Projections, 1980-2020.

TABLE III - 2

Six-State High Plains-Ogallala Aquifer Area Study
State Research Element A-2
Energy Production Impacts

Colorado
Employment Directly Related to the Energy Industry
Income Derived From Petroleum (Crude Oil and Natural Gas) Production
Millions of Constant 1977 Dollars.)
Historical[1]

Year	Ogallala Region* Actual		
	Field Operations[a]	Exploration, Drilling & Services[b]	Total
1969	NA**	NA**	NA**
1970	NA**	NA**	NA**
1971	NA**	NA**	NA**
1972	0.563	3.786	4.349
1973	0.493	4.575	5.068
1974	0.379	2.843	3.222
1975	1.081	3.608	4.689
1976	0.174	3.066	3.240
1977	0.160	4.320	4.480
1978	0.187	5.532	5.719

Projected[2]

Year	Ogallala Region		
	Low	Most Likely	High
1980			
1985	To be provided by Colorado A-3 Input-Output Model.		
1990			
2000			
2020			

* Eleven-County Area

** Not available (Division of Employment not easily retrievable).

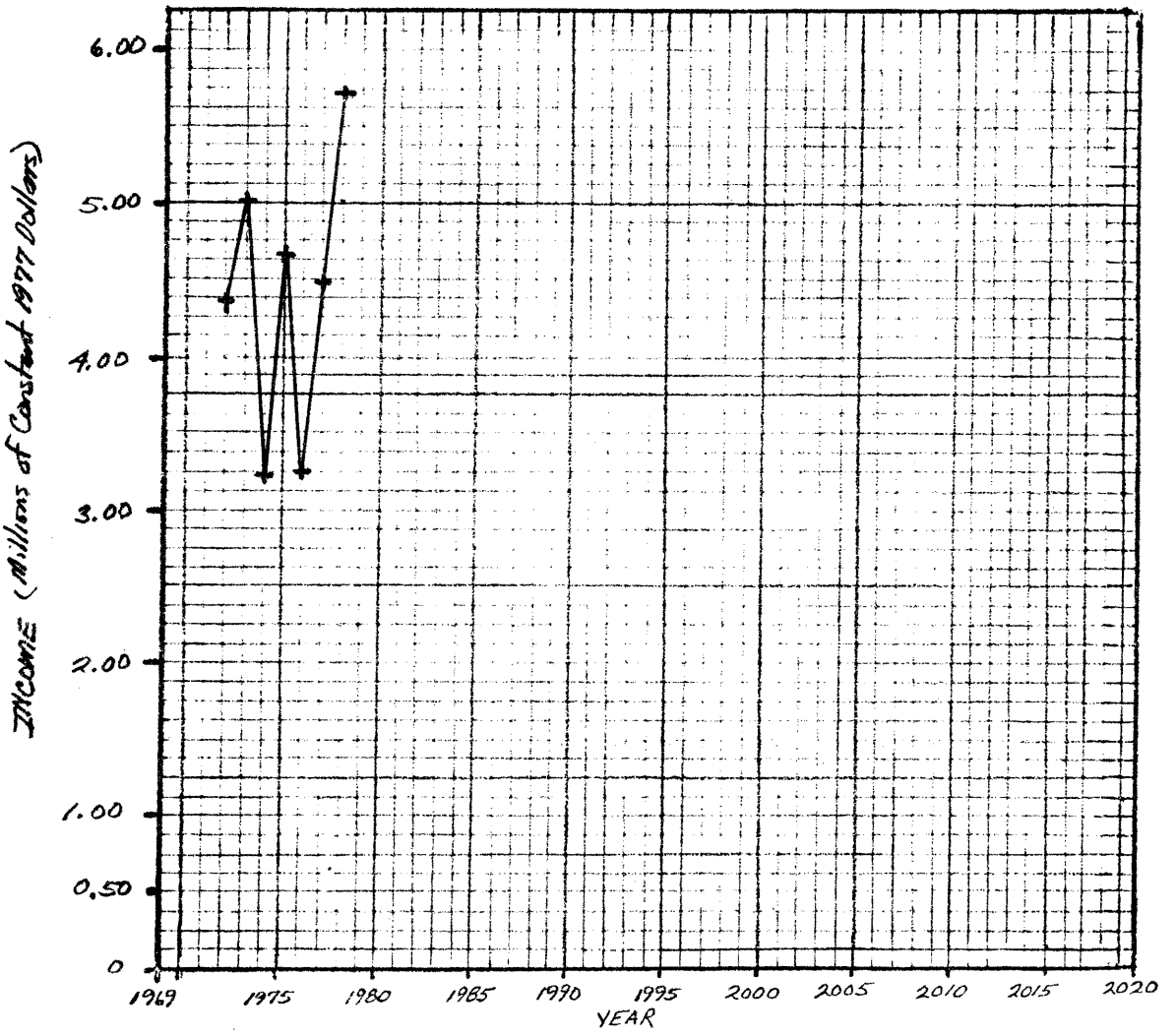
Sources: 1) Colorado Division of Employment, U.I. Reporting Systems.
2) Colorado High Plains A-3 Projections.

a Standard Industrial Code Number 1311.

b Standard Industrial Code Numbers 1381, 1382, 1389.

FIGURE III-2

Colorado Income Derived from Employment in Petroleum (Crude Oil and Natural Gas) Production in the Eleven-County Area (Millions of Constant 1977 Dollars)



+ denotes historical data

Source: Colorado Division of Employment, U.I. Reporting Systems, 1972-1978; Colorado High Plains A-3 Projections, 1980-2020.

TABLE III - 3

Six-State High Plains-Ogallala Aquifer Area Study
State Research Element A-2
Energy Production Impacts

Colorado
Employment Directly Related to the Energy Industry
Number of Persons Employed in Crude Oil Production

Historical[1]

Year	Ogallala Region* Actual		
	Field Operations	Exploration, Drilling & Services	Total
1969	NA**	NA**	NA**
1970	NA**	NA**	NA**
1971	NA**	NA**	NA**
1972	25	174	199
1973	24	185	209
1974	19	119	138
1975	45	118	163
1976	9	99	108
1977	8	68	76
1978	10	57	67

Projected[2]

Year	Ogallala Region		
	Low	Most Likely	High
1980			
1985	To be derived from Colorado A-3 Input-Output Model.		
1990			
2000			
2020			

*Eleven-County Area

**Not available (Division of Employment data not in easily retrievable form).

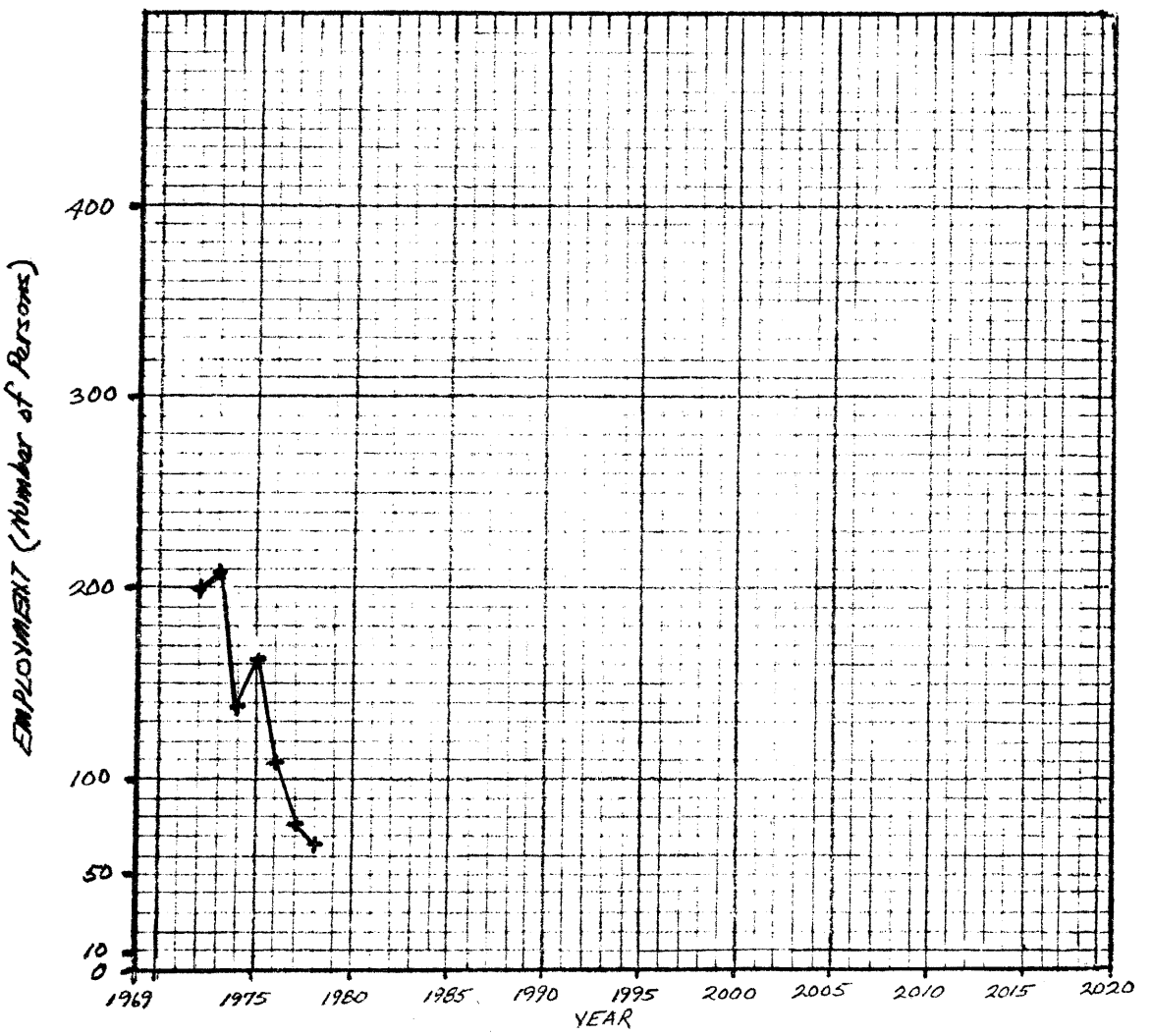
Sources: 1) Colorado Division of Employment, U.I. Reporting Systems adjusted by well production and drilling activity ratios.

2) Colorado High Plains Study, A-3 Projections adusted by well productions and drilling activity ratios.

FIGURE III-3

Colorado Employment in Crude Oil Production in the Eleven-County Area

(Number of Persons)



+ denotes historical data

Source: Colorado Division of Employment, U.I. Reporting Systems, adjusted by well production and drilling activity data from the Colorado Oil and Gas Conservation Commission, 1972-1978; Colorado High Plains A-3 Projections, 1980-2020.

TABLE III - 4

Six-State High Plains-Ogallala Aquifer Area Study
State Research Element A-2
Energy Production Impacts

Colorado
Employment Directly Related to the Energy Industry
Income Derived From Crude Oil Production (Millions of Constant 1977 Dollars)

Historical[1]

Year	Ogallala Region* Actual		
	Field Operations	Exploration, Drilling & Services	Total
1969	NA**	NA**	NA**
1970	NA**	NA**	NA**
1971	NA**	NA**	NA**
1972	0.420	2.480	2.900
1973	0.366	2.493	2.859
1974	0.280	1.632	1.912
1975	0.795	1.829	2.624
1976	0.131	1.475	1.606
1977	0.110	0.968	1.078
1978	0.123	0.863	0.986

Projected[2]

Year	Ogallala Region		
	Low	Most Likely	High
1980			
1985	To be derived from Colorado A-3		
1990	Input-Output Model.		
2000			
2020			

*Eleven-County Area

**Not available (Division of Employment data not in easily retrievable form).

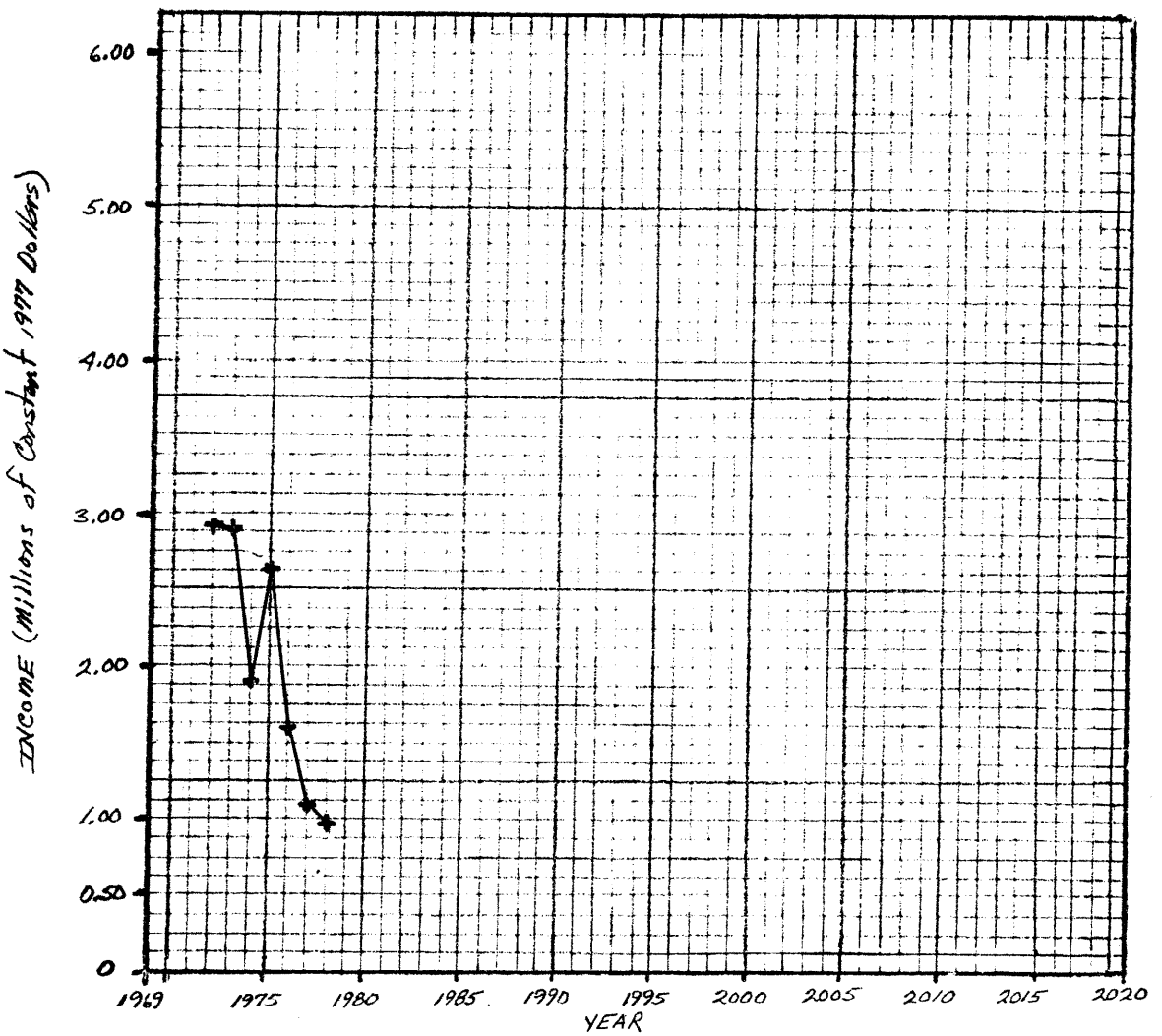
Sources: 1) Colorado Division of Employment, U.I. Reporting Systems, adjusted by well production and drilling activity ratios.

2) Colorado High Plains Study, A-3 Projections adjusted by well production and drilling activity ratios.

FIGURE III-4

Colorado Income Derived from Employment in Crude Oil Production in the Eleven-County Area

(Millions of Constant 1977 Dollars)



+ denotes historical data

Source: Colorado Division of Employment, U.I. Reporting Systems, adjusted by well production and drilling activity data from the Colorado Oil and Gas Conservation Commission, 1972-1978; Colorado High Plains A-3 Projections, 1980-2020.

TABLE III - 5

Six-State High Plains-Ogallala Aquifer Area Study
State Research Element A-2
Energy Production Impacts

Colorado
Employment Directly Related to the Energy Industry
Number of Persons Employed in Natural Gas Production

Historical[1]

Year	Ogallala Region* Actual		
	Field Operations	Exploration, Drilling & Services	Total
1969	NA**	NA**	NA**
1970	NA**	NA**	NA**
1971	NA**	NA**	NA**
1972	8	92	100
1973	8	154	162
1974	7	89	96
1975	16	114	130
1976	3	107	110
1977	4	236	240
1978	5	308	313

Projected[2]

Year	Ogallala Region		
	Low	Most Likely	High
1980			
1985	To be derived from Colorado A-3		
1990	Input-Output Model.		
2000			
2020			

*Eleven-County Area

**Not available (Division of Employment data not in easily retrievable form).

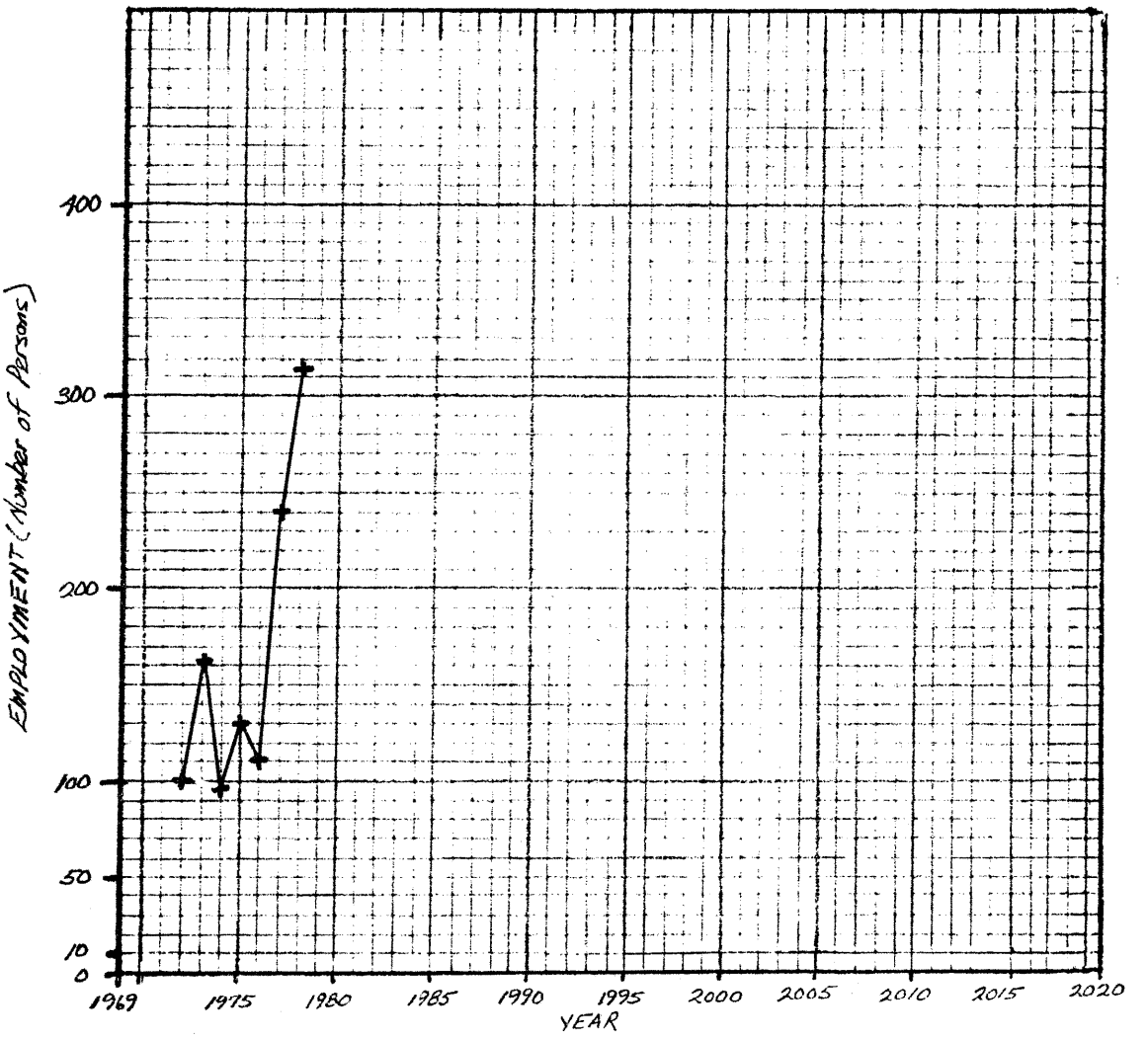
Sources: 1) Colorado Division of Employment, U.I. Reporting Systems, adjusted by well production and drilling activity ratios.

2) Colorado High Plains Study, A-3 Projections adjusted by well production and drilling activity ratios.

FIGURE III-5

Colorado Employment in Natural Gas Production in the Eleven-County Area

(Number of Persons)



+ denotes historical data

Source: Colorado Division of Employment, U.I. Reporting Systems, adjusted by well production and drilling activity data from the Colorado Oil and Gas Conservation Commission, 1972-1978; Colorado High Plains A-3 Projections, 1980-2020.

TABLE III - 6

Six-State High Plains-Ogallala Aquifer Area Study
State Research Element A-2
Energy Production Impacts

Colorado
Employment Directly Related to the Energy Industry
Income Derived From Natural Gas Production (Millions of Constant 1977 Dollars)

Historical[1]

Year	Ogallala Region* Actual		
	Field Operations	Exploration, Drilling & Services	Total
1969	NA**	NA**	NA**
1970	NA**	NA**	NA**
1971	NA**	NA**	NA**
1972	0.142	1.307	1.449
1973	0.127	2.082	2.209
1974	0.098	1.211	1.309
1975	0.286	1.779	2.065
1976	0.044	1.591	1.635
1977	0.050	3.352	3.402
1978	0.064	4.669	4.733

Projected[2]

Year	Ogallala Region		
	Low	Most Likely	High
1980			
1985	To be derived from Colorado A-3		
1990	Input-Output Model.		
2000			
2020			

*Eleven-County Area

**Not Available (Department of Employment data not in easily retrievable form).

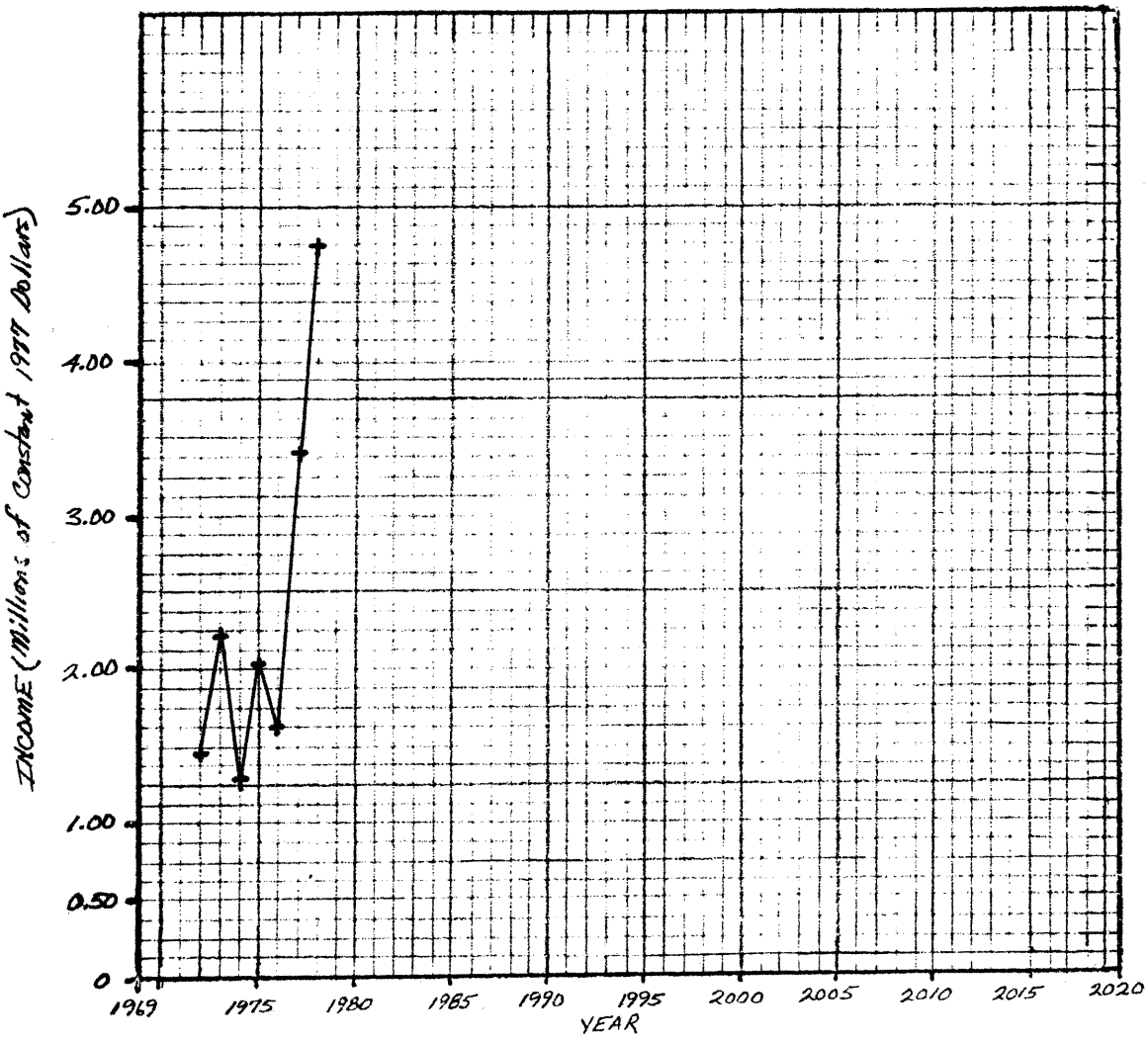
Sources: 1) Colorado Division of Employment, U.I. Reporting Systems, adjusted by well production and drilling activity ratios.

2) Colorado High Plains Study, A-3 Projections adjusted by well production and drilling activity ratios.

FIGURE III-6

Colorado Income Derived from Employment in Natural Gas Production in the Eleven-County Area

(Millions of Constant 1977 Dollars)



+ denotes historical data

Sources: Colorado Division of Employment, U.I. Reporting Systems, adjusted by well production and drilling activity data from the Colorado Oil and Gas Conservation Commission, 1972-1978; Colorado High Plains A-3 Projections, 1980-2020.

TABLE III - 7

Six-State High Plains-Ogallala Aquifer Area Study
State Research Element A-2
Energy Production Impacts

Colorado
Employment Directly Related to the Energy Industry
Number of Persons Employed in Electricity Production[a]

Historical[1]

Year	Ogallala Region* Actual
1969	29
1970	29
1971	29
1972	29
1973	29
1974	29
1975	36
1976	32
1977	33
1978	36

Projected[2]

Year	Ogallala Region		
	Low	Most Likely	High
1980			
1985	To be derived from Colorado A-3		
1990	Input-Output Model.		
2000			
2020			

*Eleven-County Area

[a]Includes only those persons employed in electricity generation--persons employed in electricity distribution have been included in Energy Transportation.

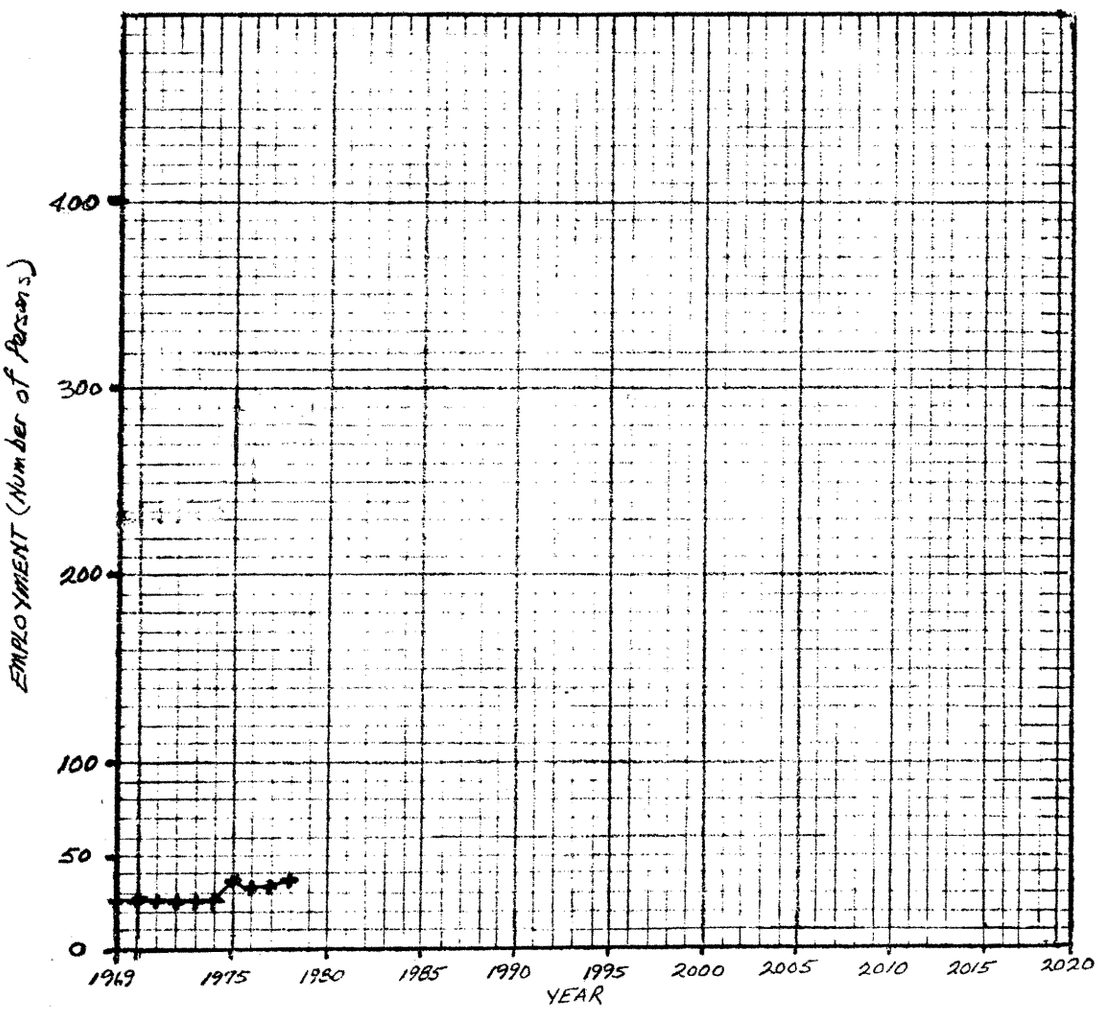
Sources: 1) Correspondence and interviews with individual electricity utility personnel.

2) Colorado High Plains, A-3 Projections as modified by a generation to distribution employment ratios.

FIGURE III-7

Colorado Employment in Electricity Production in the Eleven-County Area

(Number of Persons)



+ denotes historical data

Sources: Colorado High Plains Electric Utilities' Records, 1969-1978; Colorado High Plains A-3 Projections, 1980-2020.

TABLE III - 8

Six-State High Plains-Ogallala Aquifer Area Study
State Research Element A-2
Energy Production Impacts

Colorado
Employment Directly Related to the Energy Industry
Income Derived From Electricity Production (Millions of Constant 1977 Dollars)[a]

Historical[1]

Year	Ogallala Region* Actual
1969	0.354
1970	0.389
1971	0.422
1972	0.432
1973	0.389
1974	0.405
1975	0.451
1976	0.408
1977	0.432
1978	0.445

Projected[2]

Year	Ogallala Region		
	Low	Most Likely	High
1980	To be derived from Colorado A-3 Input-Output Model.		
1985			
1990			
2000			
2020			

*Eleven-County Area

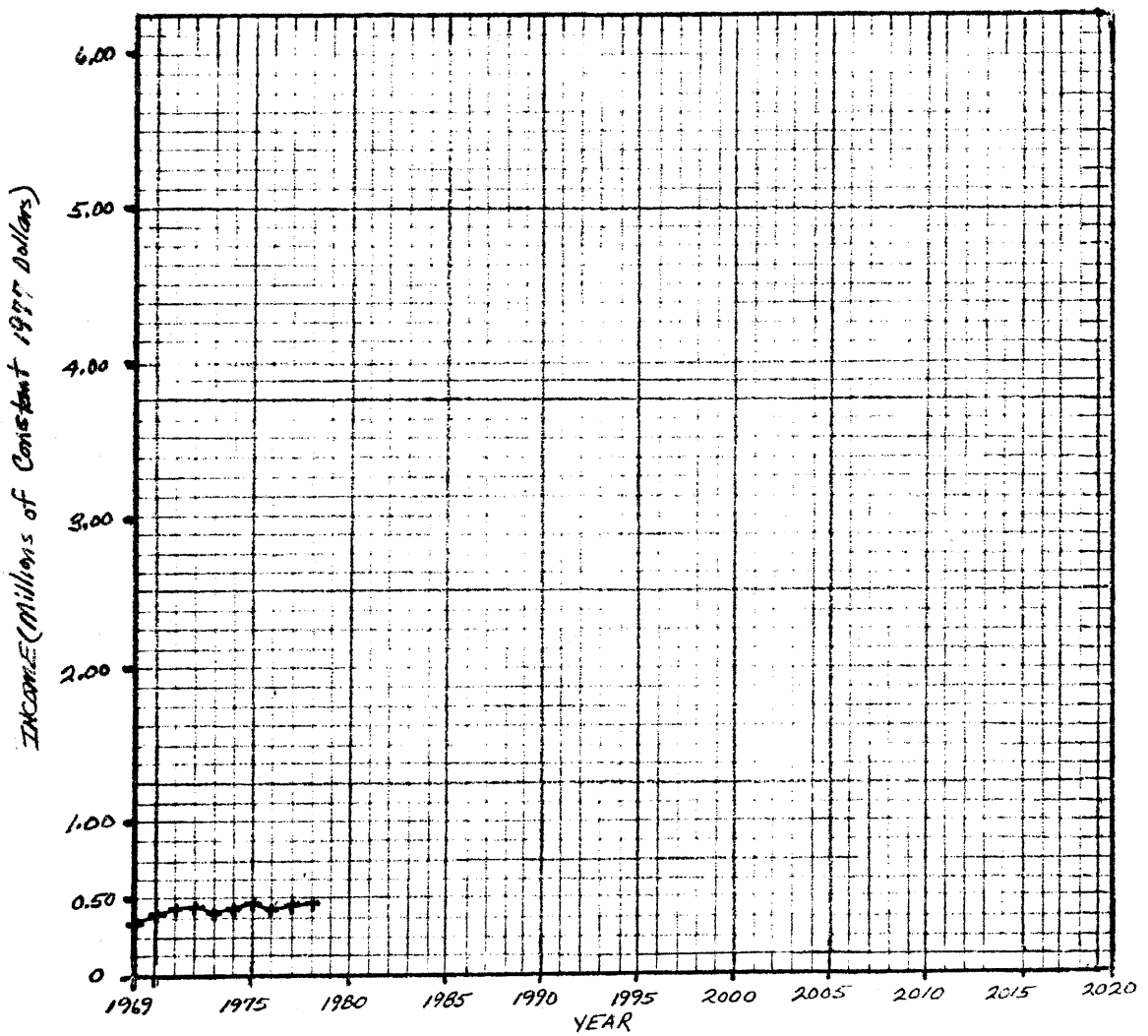
a Includes only those persons employed in electricity generation--persons employed in electricity distribution have been included in Energy Transportation.

Sources: 1) Correspondence and interviews with individual electricity producing utility personnel.

2) Colorado High Plains A-3 Projections modified by a generation to distribution employment-income ratio.

FIGURE III-8

Colorado Income Derived from Employment in Electricity Production in the Eleven-County Area (Millions of Constant 1977 Dollars)



+ denotes historical data

Source: Colorado High Plains Electric Utilities' Records, 1969-1978; Colorado High Plains A-3 Projections, 1980-2020.

TABLE III - 9

Six-State High Plains-Ogallala Aquifer Area Study
State Research Element A-2
Energy Production Impacts

Colorado
Employment Indirectly Related to the Energy Industry
Number of People Employed in Energy Transportation

Historical[1]

Year	Ogallala Region* Actual		
	Electric Distribution[a]	Natural Gas Distribution[b]	Total
1969	NA**	NA**	NA**
1970	NA**	NA**	NA**
1971	NA**	NA**	NA**
1972	111	103	214
1973	122	117	239
1974	95	114	209
1975	101	115	216
1976	106	115	221
1977	113	122	235
1978	109	125	234

Projected[2]

Year	Ogallala Region		
	Low	Most Likely	High
1980	To be derived from Colroado A-3 Input-Output Model.		
1985			
1990			
2000			
2020			

*Eleven-County Area
**Not available (Division of Employment data not in easily retrievable form).
Note: Pipelines, other than Natural Gas (SIC 4610), was not available due to confidentiality limitations.
Sources: 1) State of Colorado Division of Employment, U.I. Reporting Systems.
2) Colorado High Plains A-3 Projections modified by electric generation to distribute ratio.

TABLE III - 9 cont.

Footnotes continue:

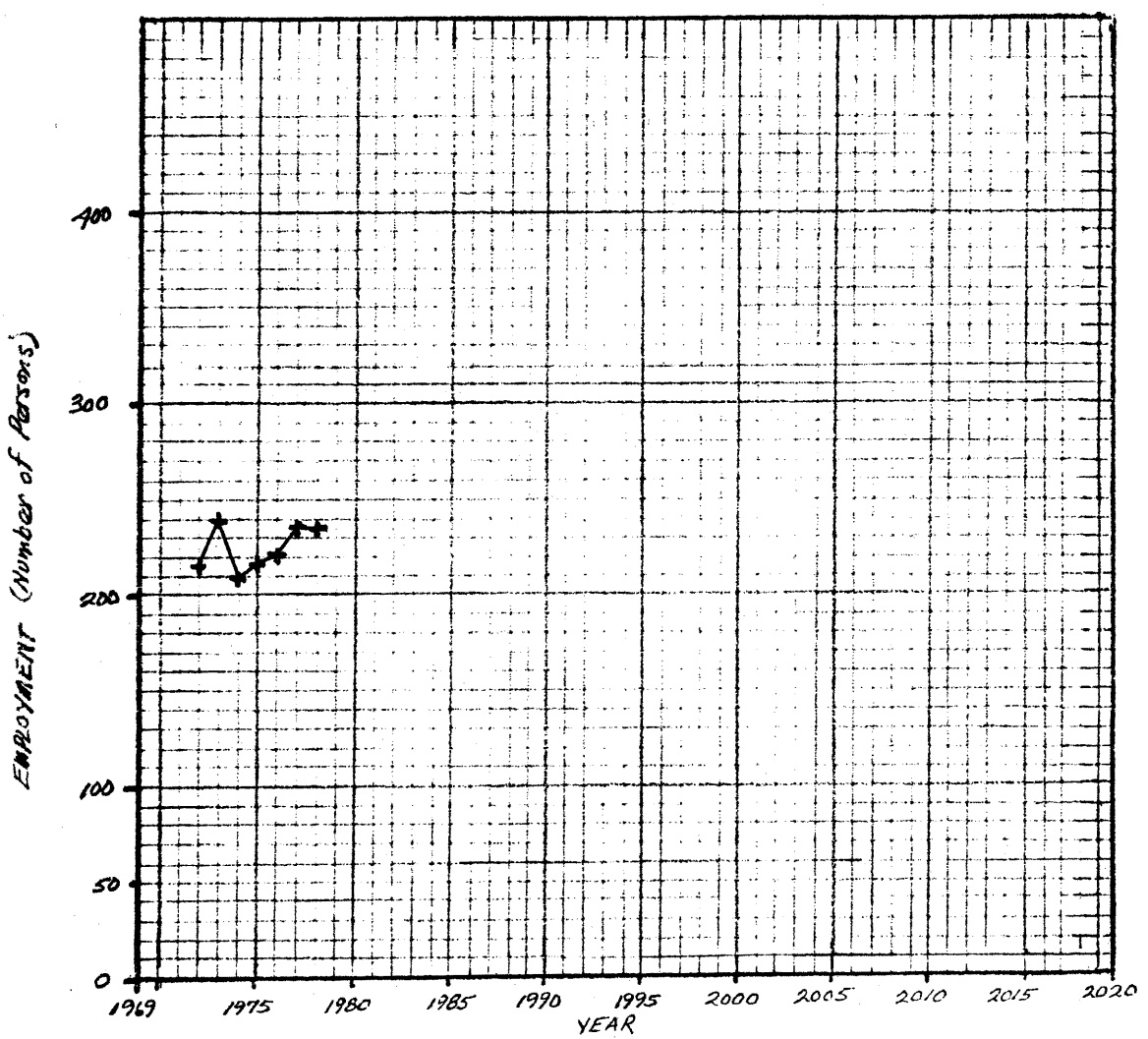
[a]Standard Industrial Code Number 4911 (Electric Services: Generation, Transmission, and/or Distribution of Electric Energy for Sale) minus persons employed in generation as reported by individual electric utility personnel.

[b]Standard Industrial Code Number 4920 (Note: 1973, 1974, and 1975 are estimates because of incomplete data due to confidentiality limitations.)

FIGURE III-9

Colorado Employment in Energy Transportation in the Eleven-County Area

(Number of Persons)



+ denotes historical data

Source: Colorado Division of Employment, U.I. Reporting Systems modified by Colorado High Plains Electric Utilities' Records, 1972-1978; Colorado High Plains A-3 Projections, 1980-2020.

TABLE III - 10

Six-State High Plains-Ogallala Aquifer Area Study
State Research Element A-2
Energy Production Impacts

Colorado
Employment Indirectly Related to the Energy Industry
Income Derived From Energy Transporation (Millions of Constant 1977 Dollars)

Historical[1]

Year	Ogallala Region* Actual		
	Electric Distribution[a]	Natural Gas Distribution[b]	Total
1969	NA**	NA**	NA**
1970	NA**	NA**	NA**
1971	NA**	NA**	NA**
1972	1.693	1.489	3.182
1973	1.805	1.212	3.017
1974	1.286	1.174	2.460
1975	1.381	1.353	2.734
1976	1.534	1.428	2.962
1977	1.828	1.558	3.386
1978	1.571	1.695	3.266

Projected[2]

Year	Ogallala Region		
	Low	Most Likely	High
1980	To be derived form Colorado A-3 Input-Output Model.		
1985			
1990			
2000			
2020			

*Eleven-County Area
**Not available (Division of Employment data not in easily retrievable form).
Note: Pipelines other than Natural Gas (SIC 4610) was not available due to confidentiality limitations.
Sources: 1) State of Colorado Division of Employment, U.I. Reporting Systems.
2) Colorado High Plains A-3 Projections modified by electric generation to distribution ratio.

Footnotes continue:

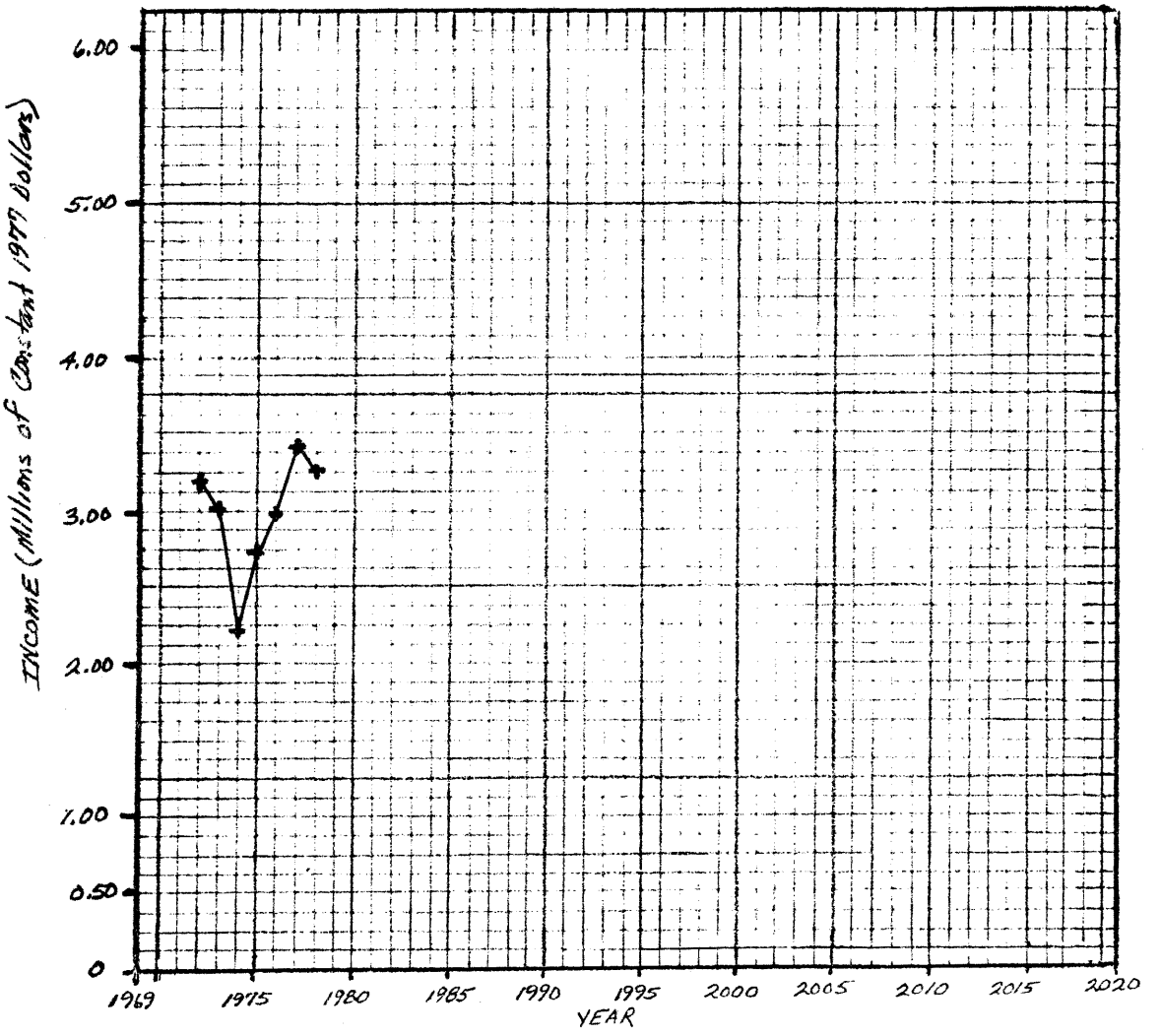
a Standard Industrial Code Number 4911 (Electric Services: Generation, Transmission and/or Distribution of Electirc Energy for Sale) minus income from employment in generation as reported by individual electric utility personnel.

b Standard Industrial Code Number 4920 (Note: 1973, 1974, and 1975 are estimates because of incomplete data due to confidentiality limitations.

FIGURE III-10

Colorado Income Derived from Employment in Energy Transportation in the Eleven-County Area

(Millions of 1977 Constant Dollars)



+ denotes historical data

Source: Colorado Division of Employment, U.I. Reporting Systems, modified by Colorado High Plains Electric Utilities' Records, 1972-1978; Colorado High Plains A-3 Projections, 1980-2020.

TABLE III - 11

Six-State High Plains-Ogallala Aquifer Area Study
State Research Element A-2
Energy Production Impacts

Colorado
Oil and Gas Proprietors' Income (Millions of Constant 1977 Dollars)

Historical

Year	Ogallala Region* Actual
1969	-----
1970	-----
1971	-----
1972	1.305
1973	1.520
1974	0.967
1975	1.407
1976	0.972
1977	1.344
1978	1.716

Projected

Year	Ogallala Region		
	Low	Most Likely	High
1980			
1985	To be derived from data provided		
1990	by Colorado A-3 Input-Output Model.		
2000			
2020			

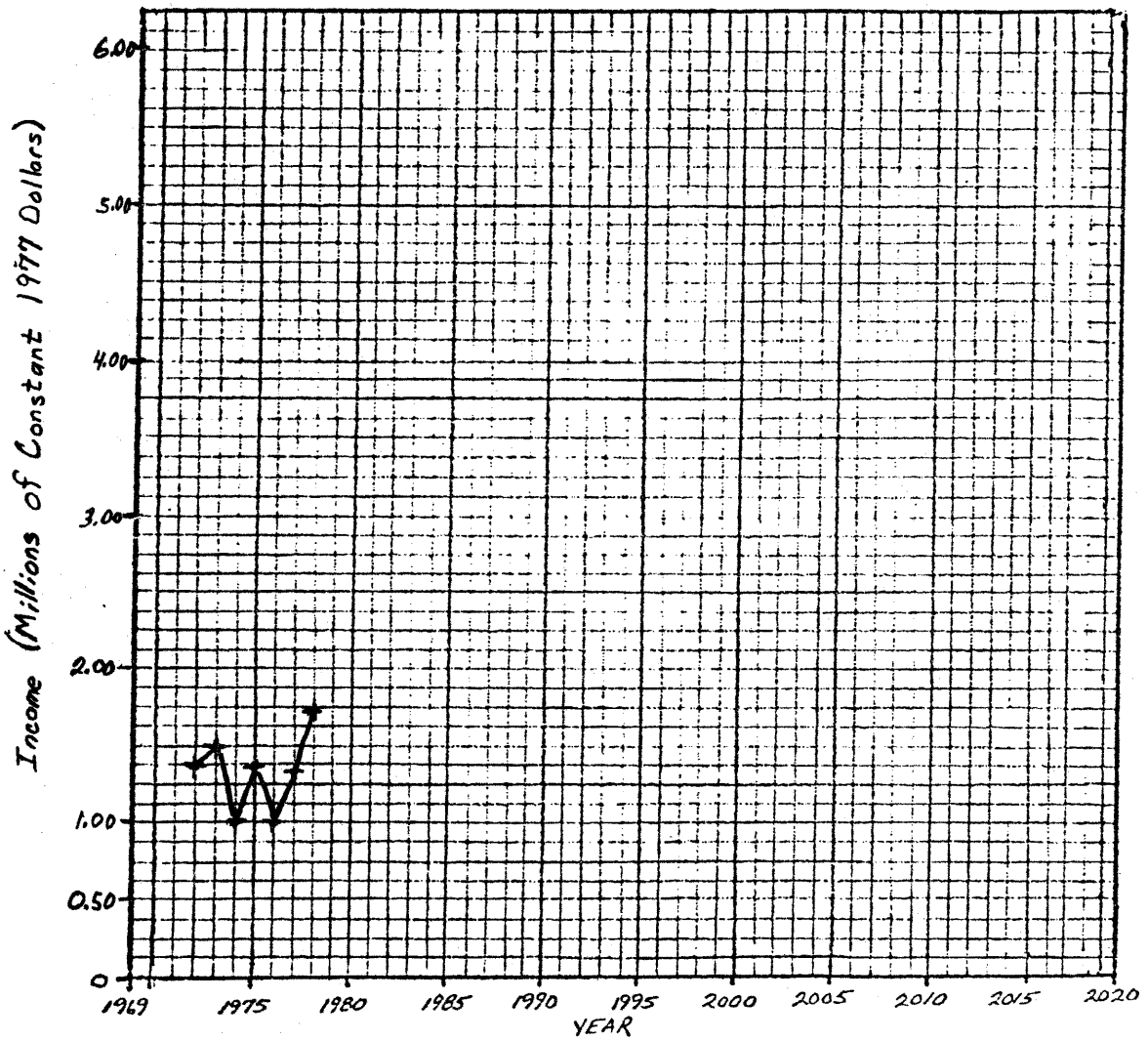
*Eleven-County Area

Source: State of Colorado Division of Employment, U.I. Reporting Systems' data modified by U.S. Department of Commerce, Bureau of Economic Analysis, Regional Economic Analysis ratio (See: Methodology Section).

FIGURE III - 11

COLORADO OIL AND GAS PROPRIETORS' INCOME

(Millions of Constant 1977 Dollars)



+ denotes historical data

Source: State of Colorado Division of Employment, U.I. Reporting Systems' data modified by U.S. Department of Commerce, Bureau of Economic Analysis, Regional Economic Analysis ratio (See: Methodology section)

IV. WORKING PAPER

ENERGY PRODUCTION IMPACTS: 2. WATER FOR ENERGY PRODUCTION

INTRODUCTION

The purpose of this working paper is to project time profiles of both surface and ground water used in the production of energy in the "Aquifer Area" of the Colorado High Plains Study Area. Because of the absence of any current production and of any significant resource potential for coal or uranium, as was noted previously, this working paper focuses only on water for crude oil and natural gas production and electric energy production. Total historical and projected surface and ground water use for crude oil and natural gas production is summarized for the Eleven-County Area in Figure IV-1 and Table IV-1 and for the Ogallala Aquifer Area in Figure IV-2 and Table IV-2. Figure IV-3 and Figure IV-4, along with associated Tables IV-3 and IV-4, display historical and projected ground water use and surface water use for crude oil and natural gas production, respectively. Water requirements for electric energy production are illustrated in Figure IV-5 and Tables IV-5 and IV-6.

METHODOLOGY

Baseline Data

The historical baseline data for water used in the production of crude oil and natural gas were derived from interviews with personnel of various oil and gas well-drilling and well-servicing companies and the drilling and water injection records of the Colorado Oil and Gas Conservation Commission. Total annual water consumed was first estimated separately for 1) well

drilling, 2) hydraulic fracturing, and 3) water injection for enhanced oil recovery for both the Aquifer Area and the Eleven-County Area. Totals for each type of use were then disaggregated into the categories of surface water and ground water. Annual water consumed during well drilling operations was estimated by multiplying the number of wells drilled annually by the estimated average water use of eleven thousand barrels of water (about 440,000 gallons or 1.35 acre feet) per well drilled. Forty percent was surface water and sixty percent was ground water. For water use by hydraulic fracturing, the annual number of "successful" (total wells drilled minus those which were plugged and abandoned) were multiplied by an estimated average water use of two thousand barrels (about 0.25 acre feet; 10 percent surface, 90 percent ground water) per well assumed to be fractured. The approach for water for fracturing results in an actual undercounting of water used because of wells in the "plugged and abandoned" category which might have been fractured; however, it also results in an overcounting when a well does not have to be fractured before becoming productive (although this is rarely true of the study area). Finally, annual water used for injection to enhance recovery of wells in the study area was taken directly from the records of the Colorado Oil and Gas Conservation Commission. Once these individual annual totals were estimated separately for surface water and ground water, they were aggregated to get the data shown in the tables and figures noted above.

The historical baseline data for water in the producton of electric energy were obtained from information provided by personnel of utilities with generation facilities. For most of the utilities, no water was consumed in the production of electric energy either because of a closed system of

evaporative cooling or because of discharge into an irrigation canal; only Tri-State had consumptive water use during generation which was estimated to be about 15 gallons per minute of operation and was derived solely from ground water. The annual time of operation (in minutes) was simply multiplied by the water use per minute to arrive at the gallons consumed which in turn was converted to acre feet on the basis of 325,830 gallons per acre foot to provide the data in the tables and figures.

Projection Assumptions

The basic assumption in this section, as well as all others, is that factors which were historically, and are currently, important in influencing the consumption of water by energy production will continue into the future. Namely that: 1) the present rapid decline in crude oil and natural gas production will be slowed due to increased efforts (and success) in drilling; 2) wellhead prices of crude oil and natural gas will act to promote drilling activity; 3) there will be no external demands or constraints placed upon water availability for crude oil and natural gas exploration and production; and 4) the prices forecast and the energy production forecast from the previous sections, each with its own essential assumptions, will prove to be accurate. In addition, it is assumed that there will not be any great change in the technology of well drilling, well fracturing, and injection to enhance recovery in the study area and that the existing discovery ratios, need for fracturing, and possibilities for secondary recovery by water injection also will remain unchanged.

Similar assumptions of constancy were made for the factors influencing water use for electric energy production. Specifically, technology will not

change and electric generation capacity and production forecasts from the Working Paper on Energy Production will prove to be accurate.

Projection Technique

As might be expected, water (both surface and ground) consumption for "conventional" petroleum production (drilling and hydraulic fracturing) is correlated with "drilling activity". But "drilling activity" is difficult to forecast because of its random behavior. Consequently, water consumption for "conventional" petroleum production was roughly estimated by using the historical value of water used per dollar of petroleum production in conjunction with estimated production figures from the Working Paper on Energy Production and the Working Paper on Royalty Income. The estimtes were made separately for both the Eleven-County Area and the Ogallala Aquifer Area.

First the annual dollar value of petroleum production for each area in each of the baseline years, 1969-1978, was divided by the annual water use for "conventional" petroleum production for each area to derive the amount of water used per dollar of production. Expressed as acre feet per thousands of constant 1977 dollars, the value varied from lows of 0.006 (Eleven-County Area in 1974) and 0.006 (Ogallala Aquifer Area in 1974) to recent highs of 0.011 (Eleven-County Area in 1978) and 0.012 (Ogallala Aquifer Area in 1978). Since the known increase in drilling activity was reflected in increasing values after 1976, the larger 1977-1978 average values, felt to be more representative of a period where price incentives encourage exploration and development, were used for 1980, 1985, and 1990 projections with an intermediate value for the 2000 projection and the historical low value for the 2020 projection. The "Low", "Most Likely", and "High" bound estimates of

the constant 1977 dollar value of petroleum production in each of the projection years was then multiplied by the appropriate derived factor (acre feet of water per thousands of constant 1977 dollars of production) to obtain an estimate of the water consumed by "conventional" petroleum production for each of the study area.

Next, annual data on water injected for secondary recovery in the Eleven-County Area for each of the baseline years were examined to determine its trend. The amount of water injected generally declined by an average 3.2% per year over the entire baseline period but only by an average 2.3% from the peak year of water injection in 1971. Consequently, the following decline rates were adopted for "Low", "Most Likely", and "High" estimated: 2.9%, 2.3%, and 1.7%. The decline rates were then applied to the known injection water consumption in 1978 to obtain estimates for the projection years. Estimates of water consumed for injection in the Ogallala Aquifer Area were derived using a historical acre feet to dollar of production applied to estimated values of petroleum production as for "conventional" petroleum production.

Finally, the separate estimates of water consumption for "conventional" petroleum production and secondary water injection were aggregated to arrive at the total water consumed for petroleum production for each projection bound ("Low", "Most Likely", and "High") for each projection year, and for each study area (Eleven-County and Ogallala Aquifer) individually. The separate estimates for the Eleven-County Area were also disaggregated into surface water and ground water components based on the average historical surface-to-ground water ratio derived from the baseline data; the components

were then aggregated to obtain estimates of total surface water consumed and total ground water consumed in the Eleven-County Area for each projection bound and year.

A very simple technique was used to project the water used for electric energy production. Historical data from Tri-State Electric Generation and Transmission were used to derive a factor representative of the number of hours operated per kilowatt hour produced. This factor was then applied to the "Low", "Most Likely", and "High" electric energy production forecasts for Tri-State in each of the forecast years to arrive at annual hours operated. These numbers were in turn multiplied by an average of 900 gallons per hour of operation (15 gallons per minute) and converted to acre feet by dividing the result by 325,830 gallons per acre foot.

TABLE IV - 1

Six-State High Plains-Ogallala Aquifer Area Study
State Research Element A-2
Energy Production Impacts

Colorado
Total Water Used for Crude Oil and Natural Gas Production
Thousands of Acre-Feet

Historical[1]

Year	Ogallala Region* Actual
1969	3.4857
1970	3.1476
1971	3.2846
1972	2.6525
1973	2.4568
1974	2.5952
1975	2.6929
1976	2.7427
1977	2.5913
1978	2.1433

Projected[2]

Year	Ogallala Region Low	Most Likely	High
1980	2.2471	2.3190	2.4651
1985	1.8767	2.0983	2.4325
1990	1.4987	1.8569	2.2504
2000	0.7552	1.1715	1.6008
2020	0.0204	0.1735	0.7307

*Eleven-County Area

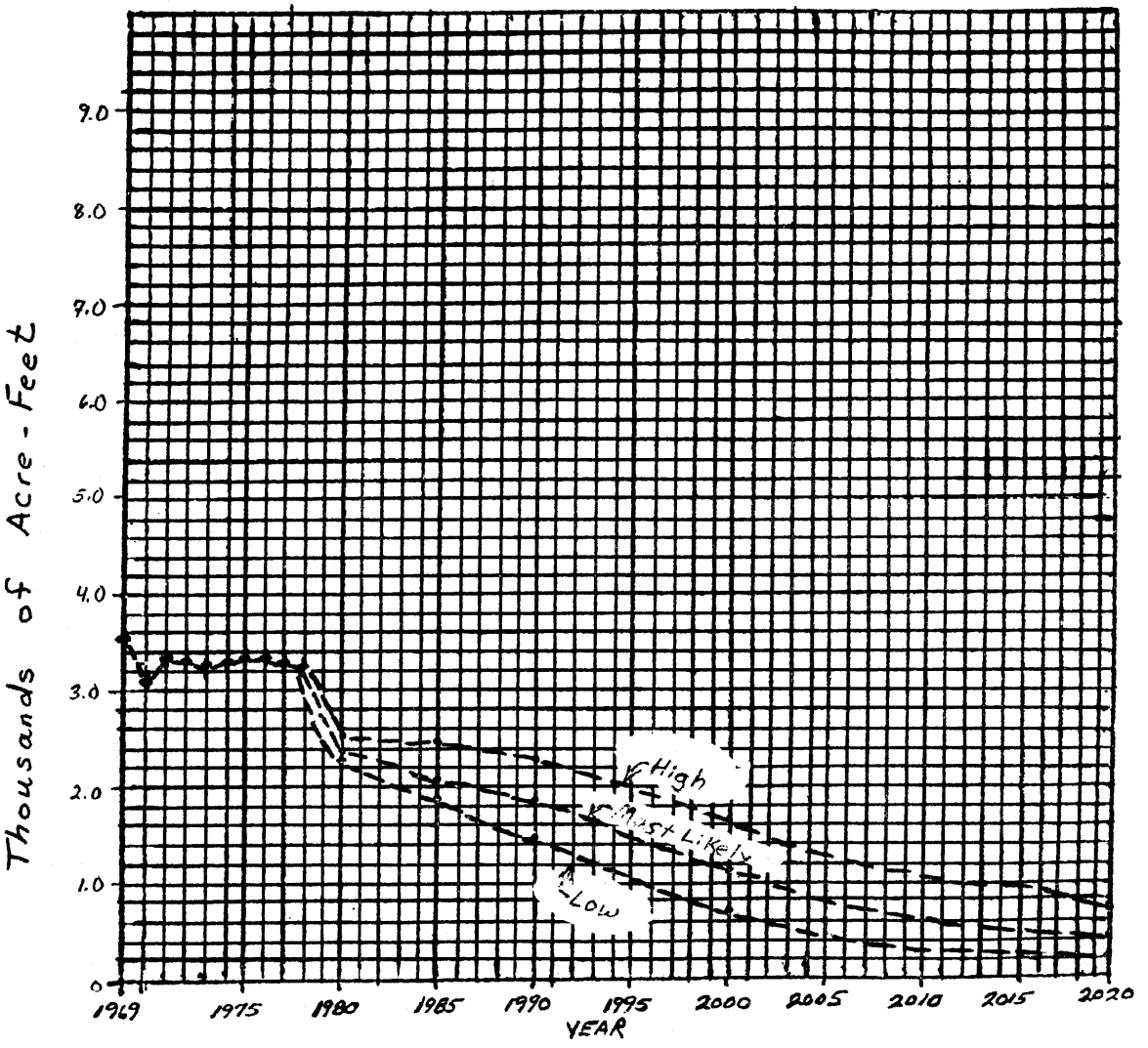
Source: 1) Colorado Office of Energy Conservation estimates based on interviews with petroleum industry personnel and Colorado Oil and Gas Conservation Commission Annual Report data.

2) Colorado Office of Energy Conservation Projection.

FIGURE IV - 1

Total Surface and Ground Water Used for Crude Oil and Natural Gas Production in the Colorado Eleven-County Area

(Thousands of Acre-Feet)



+ denotes historical data

Source: Colorado Oil and Gas Conservation Commission Annual Reports and Colorado petroleum industry estimates, 1969-1978; Colorado Office of Energy Conservationprojections, 1980-2020.

TABLE VI - 2

Six-State High Plains-Ogallala Aquifer Area Study
State Research Element A-2
Energy Production Impacts

Colorado
Total Water Used For Crude Oil and Natural Gas Production
Thousands of Acre-Feet

Historical[1]

Year	Ogallala Region* Actual
1969	0.2541
1970	0.1727
1971	0.2062
1972	0.2148
1973	0.1809
1974	0.1597
1975	0.2130
1976	0.2410
1977	0.2753
1978	0.2914

Projected[2]

Year	Ogallala Region		
	Low	Most Likely	High
1980	0.3851	0.4147	0.4831
1985	0.3193	0.4060	0.5534
1990	0.2490	0.3882	0.5491
2000	0.1001	0.2212	0.3354
2020	0.0154	0.0803	0.1689

*Aquifer Area

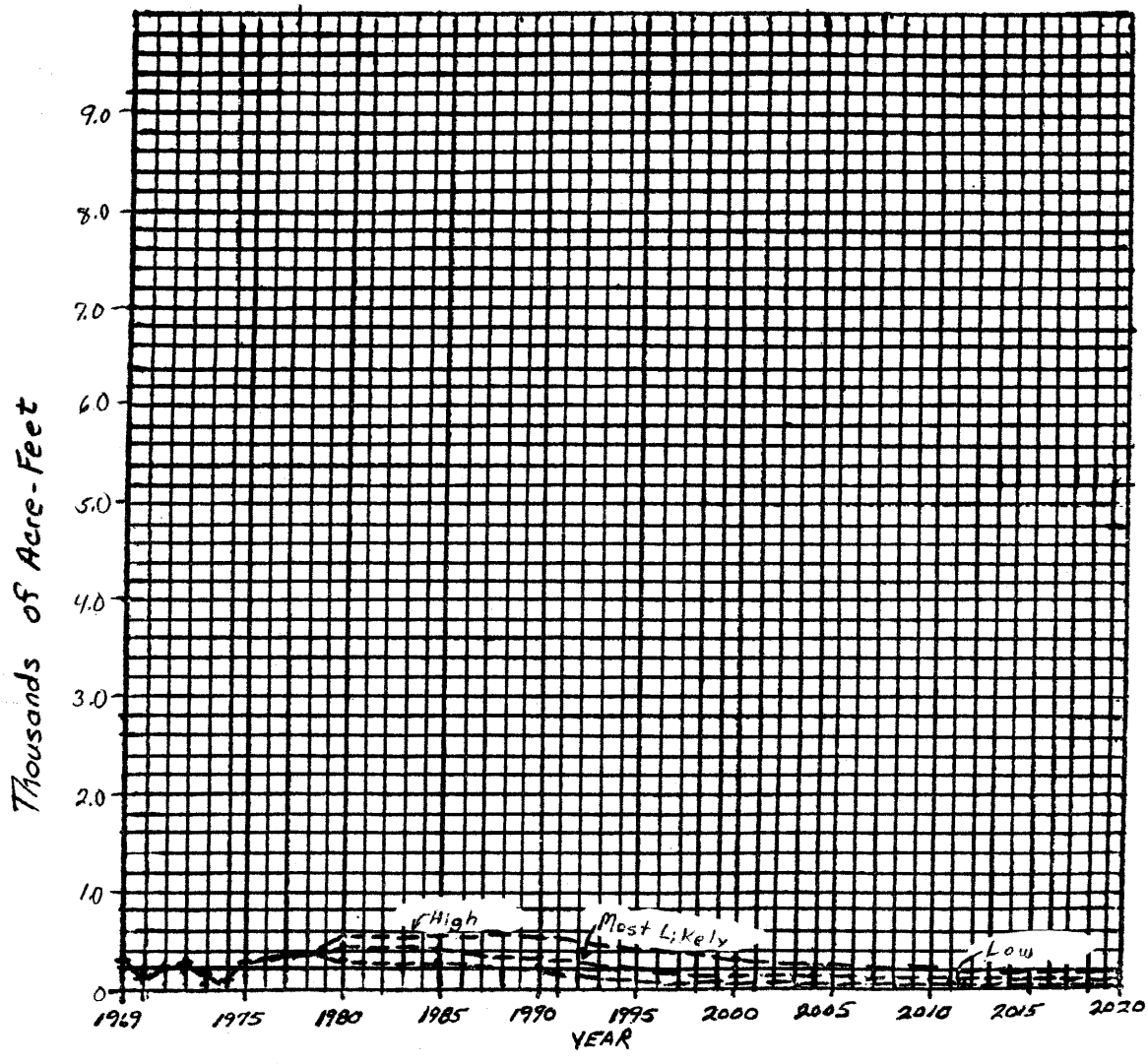
Source: 1) Colorado Office of Energy Conservation estimates based on interviews with petroleum industry personnel and Colorado Oil and Gas Conservation Commission Annual Report data.

2) Colorado Office of Energy Conservation Projection.

FIGURE IV - 2

Total Surface and Ground Water Used for Crude Oil and Natural Gas Production in the Colorado Ogallala Aquifer Area

(Thousands of Acre-Feet)



+ denotes historical data

Source: Colorado Oil and Gas Conservation Commission Annual Reports and Colorado petroleum industry estimates, 1969-1978; Colorado Office of Energy Conservation projections, 1980-2020.

TABLE IV - 3

Six-State High Plains-Ogallala Aquifer Area Study
State Research Element A-2
Energy Production Impacts

Colorado
Ground Water Used For Crude Oil and Natural Gas Production
Thousands of Acre-Feet

Historical[1]

Year	Ogallala Region* Actual
1969	3.2275
1970	2.9953
1971	3.1254
1972	2.4956
1973	2.3207
1974	2.4618
1975	2.5038
1976	2.5643
1977	2.3941
1978	1.9398

Projected[2]

	Ogallala Region		
Year	Low	Most Likely	High
1980	1.9655	2.0156	2.1087
1985	1.6488	1.8067	2.0299
1990	1.3277	1.5859	1.8645
2000	0.6928	1.0268	1.3685
2020	0.0118	0.1245	0.6248

*Eleven-County Area

Source: 1) Colorado Office of Energy Conservation estimates based on interviews with petroleum industry personnel and Colorado Oil and Gas Conservation Commission Annual Report data.

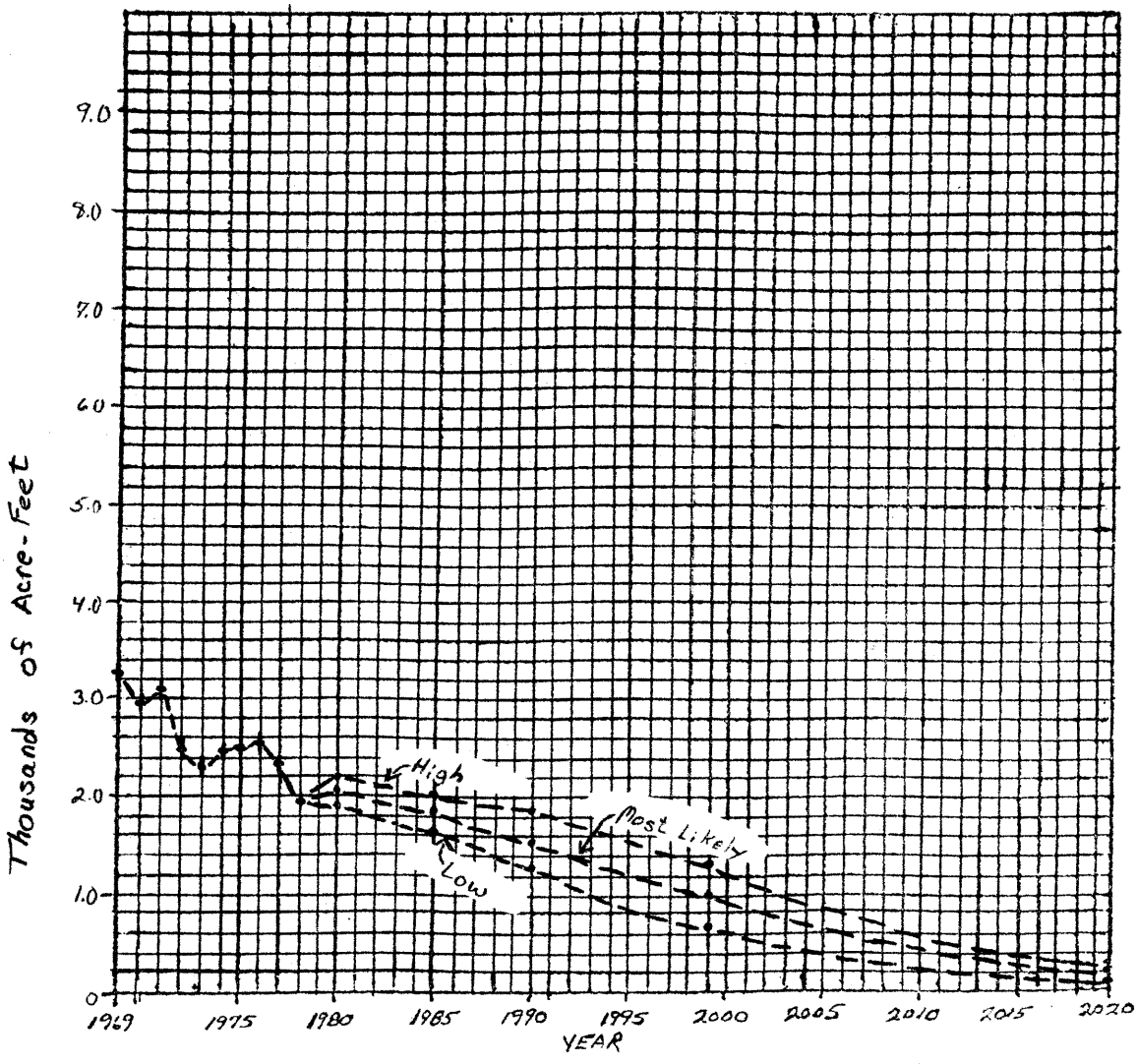
2) Colorado Office of Energy Conservation Projection.

FIGURE IV - 3

Ground Water Used for Crude Oil and

Natural Gas Production in the Colorado Eleven-County Area

(Thousands of Acre-Feet)



+ denotes historical data

Source: Colorado Oil and Gas Conservation Commission Annual Reports and Colorado petroleum industry estimates, 1969-1978; Colorado Office of Energy Conservation, 1980-2020.

TABLE IV - 4

Six-State High Plains-Ogallala Aquifer Area Study
State Research Element A-2
Energy Production Impacts

Colorado
Surface Water Used For Crude Oil and Natural Gas Production
Thousands of Acre-Feet

Historical[1]

Year	Ogallala Region* Actual
1969	0.2582
1970	0.1523
1971	0.1592
1972	0.1569
1973	0.1361
1974	0.1334
1975	0.1891
1976	0.1784
1977	0.1972
1978	0.2035

Projected[2]

Year	Ogallala Region		
	Low	Most Likely	High
1980	0.2816	0.3034	0.3564
1985	0.2279	0.2916	0.4026
1990	0.1710	0.2710	0.3859
2000	0.0624	0.1447	0.2323
2020	0.0086	0.0490	0.1059

*Eleven-County Area

Source: 1) Colorado Office of Energy Conservation estimates based on interviews with petroleum industry personnel and Colorado Oil and Gas Conservation Commission Annual Report data.

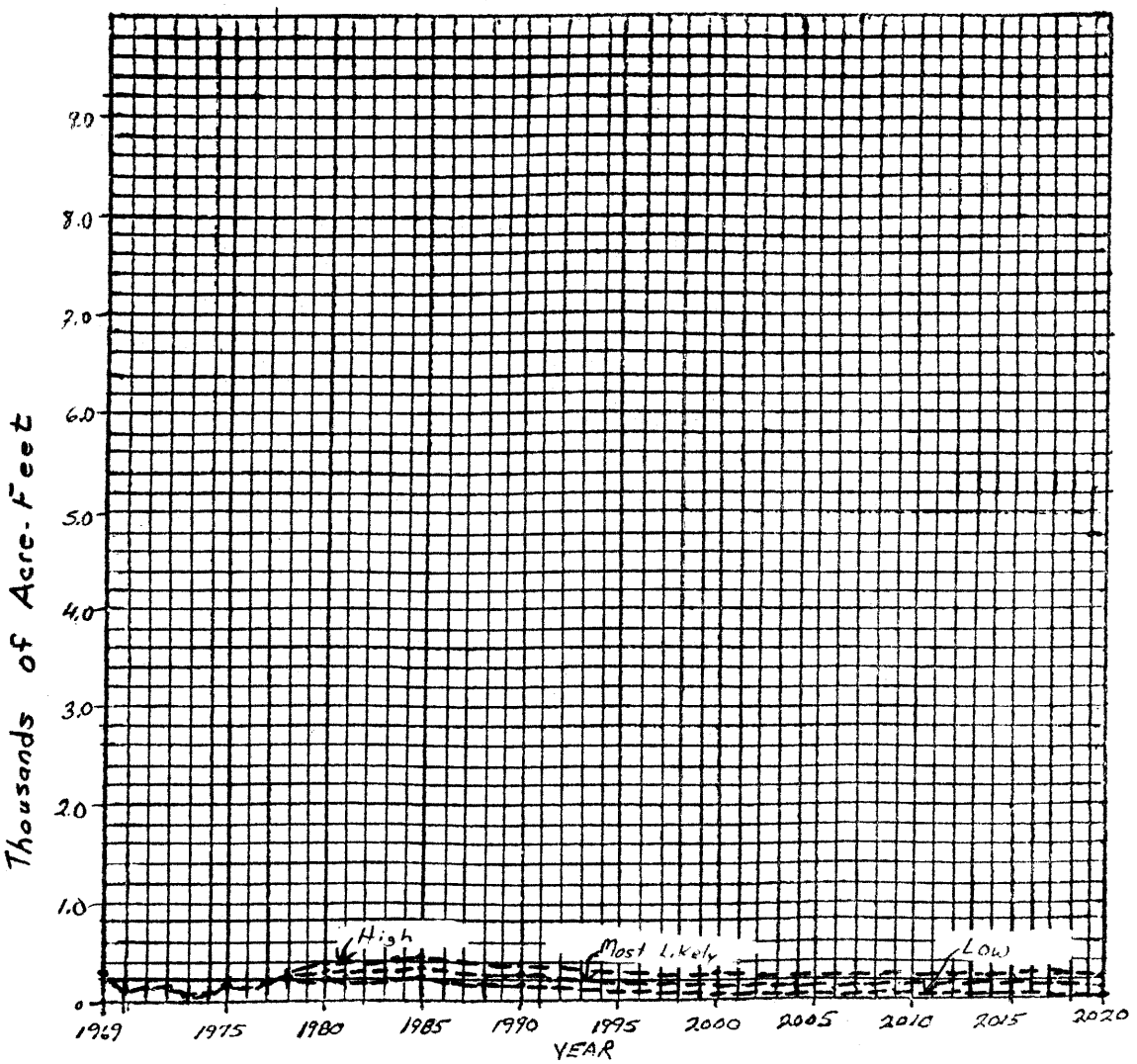
2) Colorado Office of Energy Conservation Projection.

FIGURE IV - 4

Surface Water Used for Crude Oil and

Natural Gas Production in the Colorado Eleven-County Area

(Thousands of Acre-Feet)



+denotes historical data

Source: Colorado Oil and Gas Conservation Commission Annual Reports and Colorado petroleum industry estimates, 1969-1978; Colorado Office of Energy Conservation, 1980-2020.

TABLE IV - 5

Six-State High Plains-Ogallala Aquifer Area Study
State Research Element A-2
Energy Production Impacts

Colorado
Ground Water Used for Electric Power Production
Thousands of Acre-Feet

Historical[1]

Year	Ogallala Region* Actual
1969	0
1970	0
1971	0
1972	0
1973	0
1974	0
1975	0.0037
1976	0.0046
1977	0.0030
1978	0.0027

Projected[2]

Year	Ogallala Region		
	Low	Most Likely	High
1980	0.0096	0.0114	0.0154
1985	0.0113	0.0139	0.0195
1990	0.0125	0.0153	0.0198
2000	0.0104	0.0194	0.0314
2020	0.0000	0.0120	0.0386

*Aquifer Area

Source: 1) Colorado Office of Energy Conservation estimates based on interviews and correspondence with electric utility personnel.

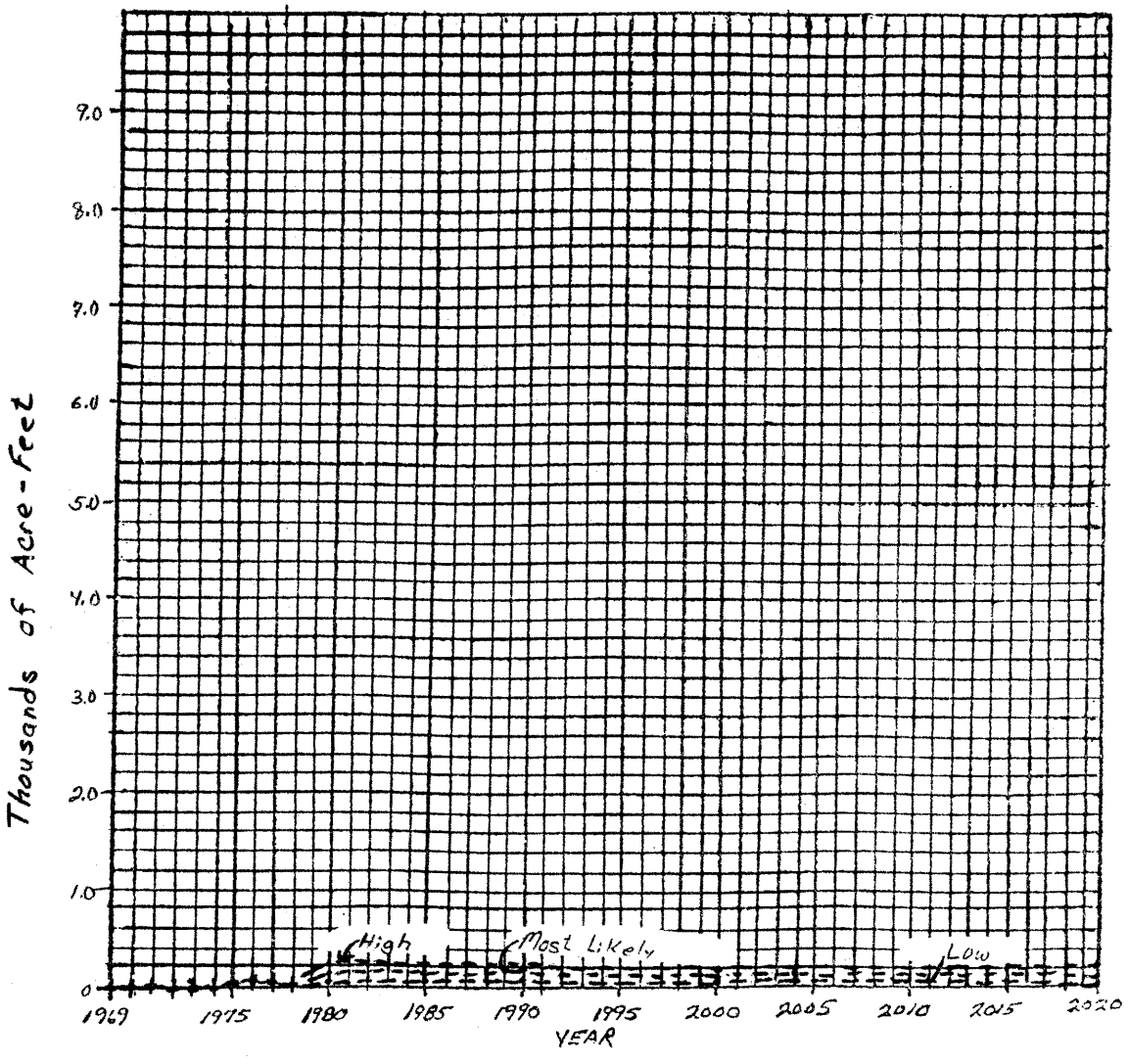
2) Colorado Office of Energy Conservation Projection.

FIGURE IV - 5

Ground Water Used for

Electricity Production in the Colorado Eleven-County Area

(Thousands of Acre-Feet)



+ denotes historical data

Source: Colorado High Plains Electric Utilities' Records, 1969-1978;
Colorado Office of Energy Conservation, 1980-2020.

TABLE IV - 6

Six-State High Plains-Ogallala Aquifer Area Study
State Research Element A-2
Energy Production Impacts

Colorado
Surface Water Used For Electric Power Production
Thousands of Acre-Feet

Historical[1]

Year	Ogallala Region* Actual
1969	0
1970	0
1971	0
1972	0
1973	0
1974	0
1975	0
1976	0
1977	0
1978	0

Projected[2]

	Ogallala Region		
Year	Low	Most Likely	High
1980	0	0	0
1985	0	0	0
1990	0	0	0
2000	0	0	0
2020	0	0	0

*Aquifer Area

Source: Colorado Office of Energy Conservation estimates based on interviews and correspondence with electric utility personnel.

V. WORKING PAPER

ENERGY PRODUCTION IMPACTS: 3. ROYALTY PAYMENTS

INTRODUCTION

The purpose of this working paper is to provide both past and future time profiles of royalty payments resulting from the production of energy in the "Aquifer Area". Because, as was mentioned in an earlier working paper, investigation revelaed that there was neither production nor significant resource potential for either surface or deep minable coal or uranium, this working paper examines only royalty payments which result from crude oil and natural gas production. Tables V-1 and V-2 show the estimated Windfall Profit Tax on Crude Oil for 1980, 1985, and 1990 for the Eleven-County Area and Ogallala Aquifer Area respectively. Figure V-1 and Table V-3 summarize and graphically illustrate the total annual historical and projected royalty payments to all leaseholders (government and private) resulting from the combined production of crude oil (adjusted for the windfall profit tax) and natural gas for the Eleven-County Area; Figure V-2 and Table V-4 show the same information for the Ogallala Aquifer Area. In Figure V-3 and Table V-5 royalty payments to all leaseholders in the Eleven-County Area from the production of crude oil as adjusted by the windfall profit tax is shown separately, as is that for natural gas production in Figure V-5 and Table V-7; the comparable data for the Ogallala Aquifer Area is shown in Figure V-4 and Table V-6 (adjusted crude oil royalties) and in Figure V-6 and Table V-8. Figures V-7, V-9, V-11 display the data when it is disaggregated into the categories of "royalty payments to government

leaseholders", "royalty payments to resident and nonresident private leaseholders", and "royalty payments to resident private leaseholders", respectively, for the Eleven-County Area; Tables V-9, V-11, and V-13 summarize the data on which these figures were based. The comparable disaggregated data figures and tables for the Ogallala Aquifer Area are Figures V-8, V-10, V-12 and Tables V-10, V-12, and V-14.

METHODOLOGY

Baseline Data

The historical baseline data for royalty payments resulting from energy production--or more specifically for this study area, from crude oil and natural gas production--were obtained from the records and opinions of the personnel of the Colorado Oil and Gas Conservation Commission and from the lease records of the Colorado State Land Board. These sources provided information about annual production of both crude oil and natural gas in the "Aquifer Area", the average annual wellhead price for both products, common royalty practices, and actual dollar amounts to specific State of Colorado leases.

Royalty payments resulting from both crude oil and natural gas production in both the Eleven-County Area and the Ogallala Aquifer Area were calculated in the same manner. First, the annual production from the area was multiplied by the annual average wellhead price to obtain annual revenue from each type of production. Then the royalty factor of one-eighth (12½ percent) was applied to annual revenue to obtain annual royalty payments. The aforementioned royalty factor was applied because it was felt to be the most commonly used factor in the Colorado High Plains area. In fact, it was the opinion

of personnel with the Colorado Oil and Gas Conservation Commission, that probably only the Federal government might receive a higher royalty rate. Then, the separately calculated annual royalty payments to producing crude oil properties and producing natural gas properties were aggregated to derive total annual royalty payments to all leaseholders.

Next, government leases were identified (these were found to be virtually 100 percent State government leases) and Colorado State Land Board records were then used to determine the actual dollar amount of annual royalty paid to each individual state lease. Because the only identified Federal lease appeared as part of a complex private, State, and Federal lease, the Federal royalties could also be determined. Finally, annual individual lease payments to government were summed and then subtracted from estimated total annual royalty payments to arrive at an estimate of "royalty payments to private resident and non-resident leaseholders" ("households").

In order to adjust the 1980, 1985, and 1990 royalty payments for windfall profit tax payments several other assumptions were made (see Projection Technique section):

(1) The proportion of production from stripper oil wells will increase as production decreases and the rate of increase will be greatest where toatl production is lowerst.

(2) The historical growth rate of "new" wells (post-1978) to old wells will continue to be 2.5 percent per year and the new wells will be of equivalent productive capacity to the old wells.

(3) The mix of tiers of production for private lease holdings is the same as for all lease holdings--private plus federal and state.

(4) Colorado has a 3 percent severance tax which qualifies for the severance tax adjustment deduction.

(5) The weighted average removal price for all tiers of production in 1980 is $19.60 (1977 dollars).

(6) The Producer Price Index (PPI) for 1979 is 235.6.

(7) The PPI for 1977 through 1990 will have the same growth rate as the GNP deflator. Thus, 1977 dollar values computed using the PPI will be equivalent to 1977 dollar values using the GNP deflator.

(8) Production by tier in 1980 is equivalent per diem.

Assumption (7) is necessary to ensure that the Tier 3 base price is escalated correctly. Assumption (8) is necessary to account for production through February 29 of 1980 which is not subject to the tax.

Projection Technique

Numerous attempts were made to apply regression analysis to the development of forecasts of royalty payments to leaseholders in the study areas resulting from the production of crude oil and natural gas properties. This approach was finally discarded as unrealistic when the regression equations were shown to reflect almost exclusively price increases with little consideration for production decline. Consequently, a simple multiplication of data from the "Low", "Most Likely", and "High" crude oil and natural gas production projections for each of the study area (Table I-2) by the same year data on the "Low", "Most Likely", and "High" crude oil and natural gas wellhead price projections (Table-1) was used to get total projection year revenues for crude oil and natural gas, individually and separately.

Once annual forecast year revenues were determined individually and separately for crude oil and natural gas, a royalty factor of one-eighth

(12½ percent) was applied to obtain the total annual forecast year royalty payment attributable to crude oil production prior to windfall profit tax adjustment and natural gas production.

In order to estimate the proportion of total royalty payments going to government versus private leaseholders ("households"), the 1969 to 1978 ratios were examined. Because the "government" proportion began to increase after 1976, it was decided to use the average 1976-1978 proportions for the forecast years of 1980 and 1985 (because the active attempts by State government to "develop" their lands is likely to continue into the 80's) and the average 1969-1978 proportions for the forecast years of 1990, 2000, and 2020 (because development of state lands will eventually reach a saturation). Next, forecast year "Low", "Most Likely", and "High" bound estimates for royalties to crude oil production prior to windfall profit tax adjustment and royalties to natural gas production were each separately disaggregated on the basis of the derived historical ratios into projection year estimates for each of the study areas of (1) "royalty payments to government leaseholders for crude oil production", (2) "royalty payments to resident and non-resident private leaseholders for crude oil production prior to windfall profit tax adjustment", (3) "royalty payments to government leaseholders for natural gas production", and (4) "royalty payments to resident and non-resident private leaseholders for natural gas production".

Categories 1 and 3, above, were combined to derive "Low", "Most Likely", and "High" bound projection year estimates of the "total royalty payments to government leaseholders". Derivation of estimates of "total royalty payments to resident and non-resident private leaseholders", because of the windfall

profit tax adjustment, required several additional steps with a methodology developed by Black and Veatch and described below.

The appropriate taxes on production from a specific oil producing property is calculated by the following equation:

$$TAX = RATE\ (P_{removal} - P_{base} - S)$$

Where: TAX = windfall profit tax

RATE = appropriate tax rate (see Table 1)

$P_{removal}$ = posted field price

P_{base} = base price adjusted for inflation and allowable property development expenses

S = State severance taxes on income in excess of base price, tax rate not to exceed 15 percent

The total windfall profit on a barrel cannot exceed 90 per cent of the net income attributable to that barrel of oil. This limitation is property specific. A summary of Windfall Profit Tax Act provisions applicable to royalty payments to private leaseholders are:

Tier	Description	Tax Rate	Base Price (1977 $/bbl) 1980	1985	1990	Comments
1	Production in 1978	70	10.56	10.56	10.56	--
2	Stripper, ≤ 10 bbl/day	60	12.53	12.53	12.53	--
3	Post-'78, heavy oil, incremental tertiary	30	13.88	15.34	16.94	Real escalation is 0.5 per cent per quarter

Windfall profit tax payments for royalty payments to private leaseholders in the Colorado study areas were estimated by using projected production of Tier 1, Tier 2, and Tier 3 crude petroleum. Well-by-well production data for the Eleven-County study area were examined for 1976 and 1979 to determine

the proportion of production from stripper wells (Tier 2) and the proportions of production expected to come from "new" wells (Tier 3). The complex set of assumptions which were necessary are noted in the section above and the resulting estimates of crude oil production by tier applied to the "Most Likely" Eleven-County Projections are noted below:

	1980		1985		1990	
Tier	bbls x 10^6	% Total	bbls x 10^6	% Total	bbls x 10^6	% Total
1	2.196	76	1.137	63	0.564	50
2	0.578	20	0.415	23	0.327	29
3	0.115	4	0.253	14	0.236	21
Total	2.889	100	1.805	100	1.127	100

These projections were used to calculate weighted base prices and windfall profit tax rates for each year to arrive at a royalty payment scalar to adjust royalty payments (calculations for the 1980, 1985, and 1990 "Most Likely" bound scalars are appended to this working paper as Table V-A, V-B, and V-c). The scalars were then applied to the gross royalty payments to all (resident and non-resident) private leaseholders accruing from crude oil production to derive the windfall profit tax. Next (after windfall profit tax adjustment) royalty payments to all private leaseholders in both the Eleven-County Area and the Ogallala Aquifer Area accruing from crude oil production (i.e., the difference between gross royalty payments and windfall profits tax) were recorded for each of the "Low", "Most Likely", and "High" bounds in 1980, 1985, and 1990.

Finally, projections year "Low", "Most Likely", and "High" estimates of royalty payments to all private leaseholders attributable to natural gas production and attributable to crude oil production, as adjusted by the wind-

fall profit tax, were aggregated for each study area to derive total adjusted royalty payments to all private leaseholders. These estimates were later combined with royalty payments to government leaseholders to derive total royalty payments. In addition, the total adjusted royalty payments to all private leaseholders were disaggregated as described in the Baseline Data section to provide projections of royalty payments to resident (persons living within the Eleven-County Area) leaseholders.

TABLE V - 1

Six-State High Plains-Ogallala Aquifer Area Study
State Research Element A-2
Energy Production Impacts

Colorado
Windfall Profits Tax
Millions of Constant 1977 Dollars

Historical[1]

Year	Ogallala Region* Actual
1969	--
1970	--
1971	--
1972	--
1973	--
1974	--
1975	--
1976	--
1977	--
1978	--

Projected[2]

Year	Ogallala Region		
	Low	Most Likely	High
1980	1.441	1.550	2.075
1985	1.173	1.625	2.556
1990	0.632	0.983	1.592
2000	-----	-----	-----
2020	-----	-----	-----

*Eleven-County Area

Source: Colorado Office of Energy Conservation Projections.

TABLE V - 2

Six-State High Plains-Ogallala Aquifer Area Study
State Research Element A-2
Energy Production Impacts

Colorado
Windfall Profits Tax
Millions of Constant 1977 Dollars

Historical[1]

Year	Ogallala Region* Actual
1969	--
1970	--
1971	--
1972	--
1973	--
1974	--
1975	--
1976	--
1977	--
1978	--

Projected[2]

	Ogallala Region		
Year	Low	Most Likely	High
1980	0.583	0.626	0.838
1985	0.500	0.694	1.091
1990	0.284	0.442	0.716
2000	-----	-----	-----
2020	-----	-----	-----

*Ogallala Aquifer Area

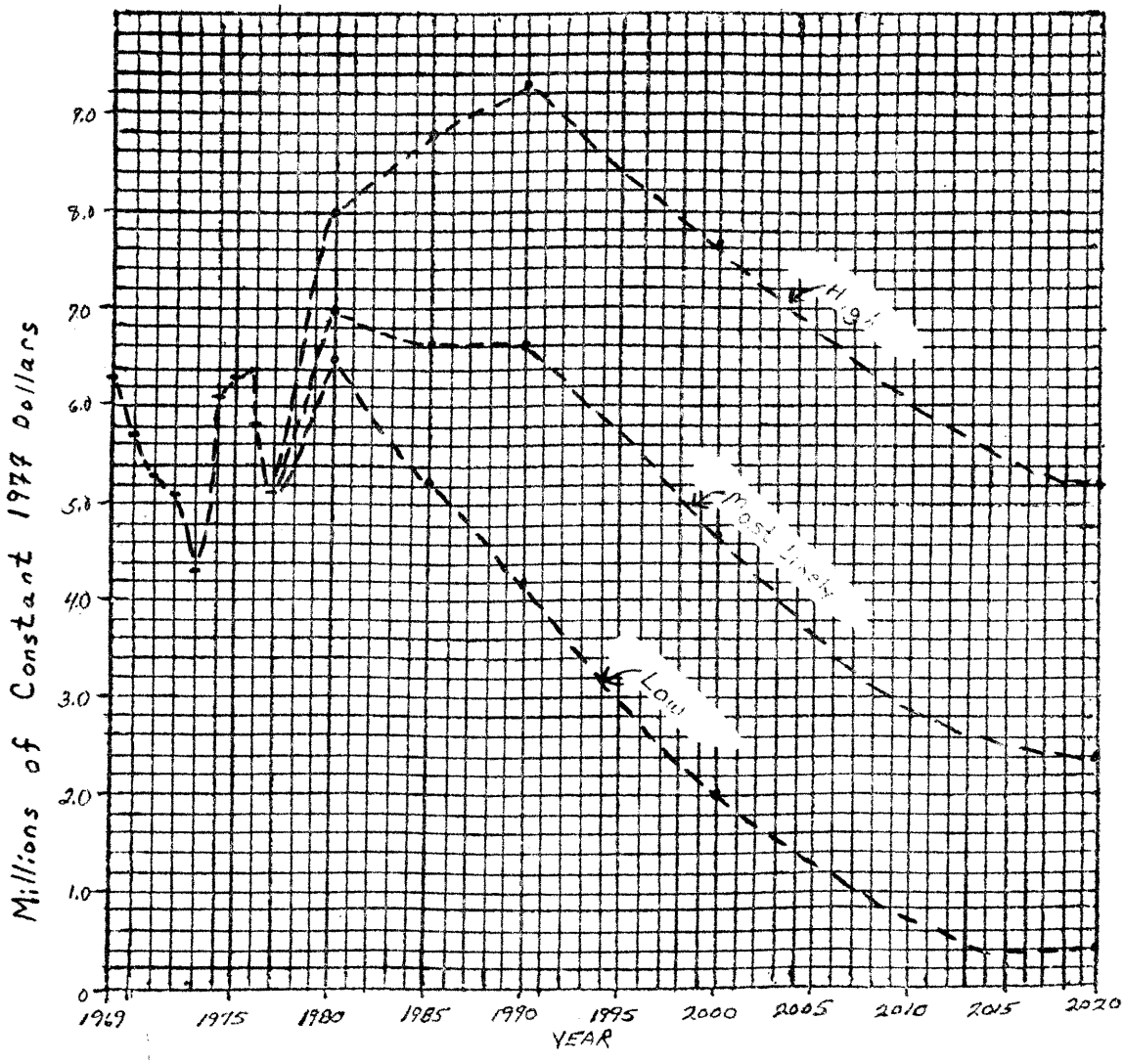
Source: Colorado Office of Energy Conservation Projections.

FIGURE V - 1

Colorado Total Crude Oil and Natural Gas Royalty

Payments to Leaseholders of the Eleven-County Area

(Millions of Constant 1977 Dollars)



\+ denotes historical data

Source: Colorado Oil and Gas Conservation Commission Annual Reports and Estimates, 1969-1978; Colorado Office of Energy Conservation, 1980-2020.

TABLE V - 3

Six-State High Plains-Ogallala Aquifer Area Study
State Research Element A-2
Energy Production Impacts

Colorado
Royalty Payments to all Leaseholders (Total Oil and Gas)
Millions of Constant 1977 Dollars

Historical[1]

Year	Ogallala Region* Actual
1969	6.397
1970	5.722
1971	5.327
1972	5.157
1973	4.369
1974	6.192
1975	6.371
1976	6.487
1977	5.810
1978	5.140

Projected[2]

Year	Ogallala Region		
	Low	Most Likely	High
1980	6.521	7.028	8.003
1985	5.271	6.620	8.830
1990	4.205	6.681	9.321
2000	2.058	4.777	7.665
2020	0.425	2.427	5.240

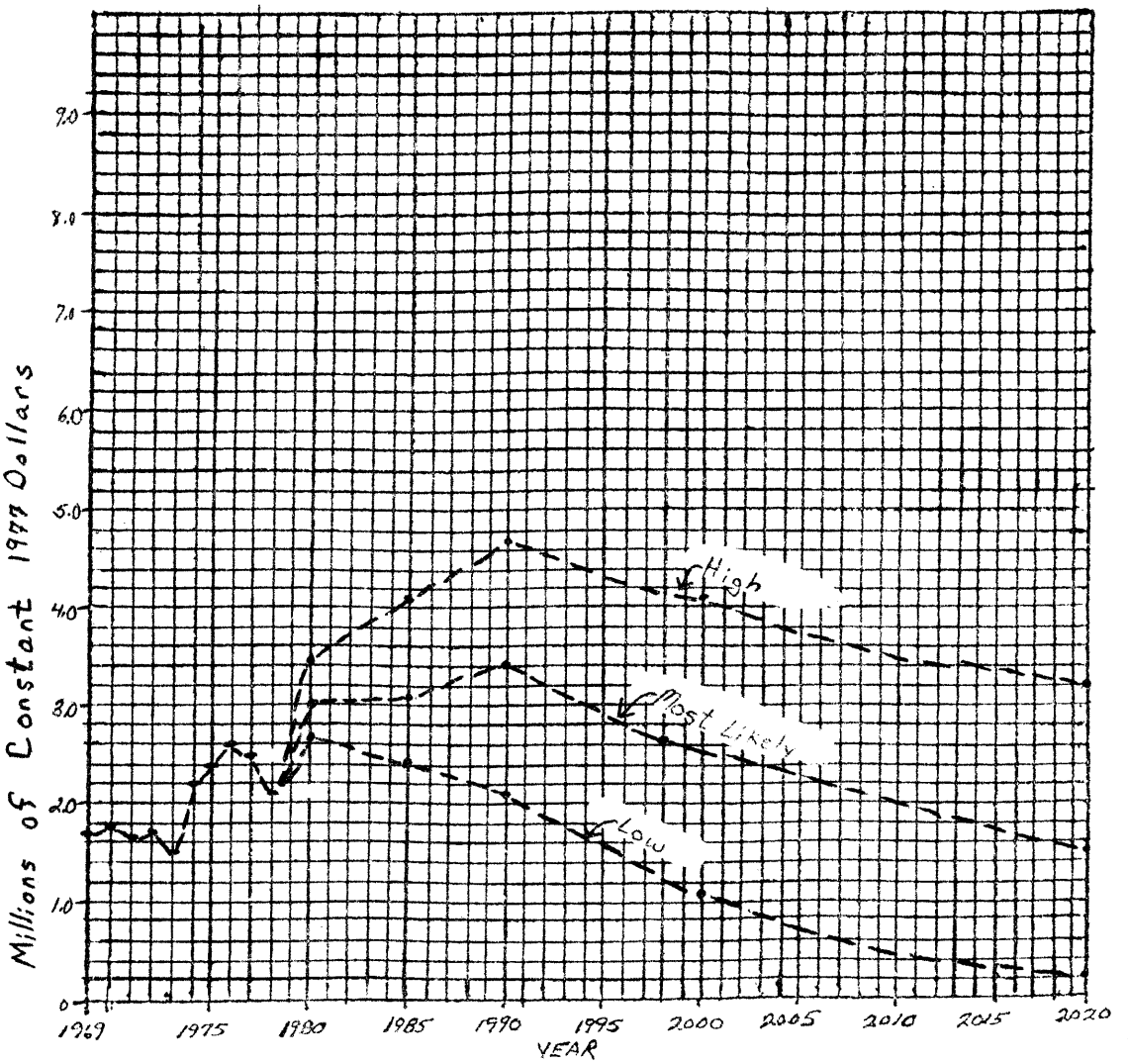
*Eleven-County Area

Source: 1) Colorado Office of Energy Conservation estimates based on data from the Colorado Oil and Gas Conservation Commission Annual Reports.

2) Colorado Office of Energy Conservation Projections--adjusted for the Windfall Profit Tax (see Table V - 1).

FIGURE V - 2

Colorado Total Crude Oil and Natural Gas Royalty Payments to All Leaseholders in the Ogallala Aquifer Area (Millions of Constant 1977 Dollars)



+ denotes historical data

Source: Colorado Oil and Gas Conservation Commission Annual Reports and Estimates, 1969-1978; Colorado Office of Energy Conservation, 1980-2020.

TABLE V - 4

Six-State High Plains-Ogallala Aquifer Area Study
State Research Element A-2
Energy Production Impacts

Colorado
Royalty Payments to All Leaseholders (Total Oil and Gas)
Millions of Constant 1977 Dollars

Historical[1]

Year	Ogallala Region* Actual
1969	1.752
1970	1.799
1971	1.663
1972	1.682
1973	1.543
1974	2.226
1975	2.476
1976	2.686
1977	2.450
1978	2.140

Projected[2]

Year	Ogallala Region		
	Low	Most Likely	High
1980	2.792	3.011	3.425
1985	2.466	3.120	4.190
1990	2.115	3.422	4.786
2000	1.119	2.657	4.118
2020	0.260	1.553	3.283

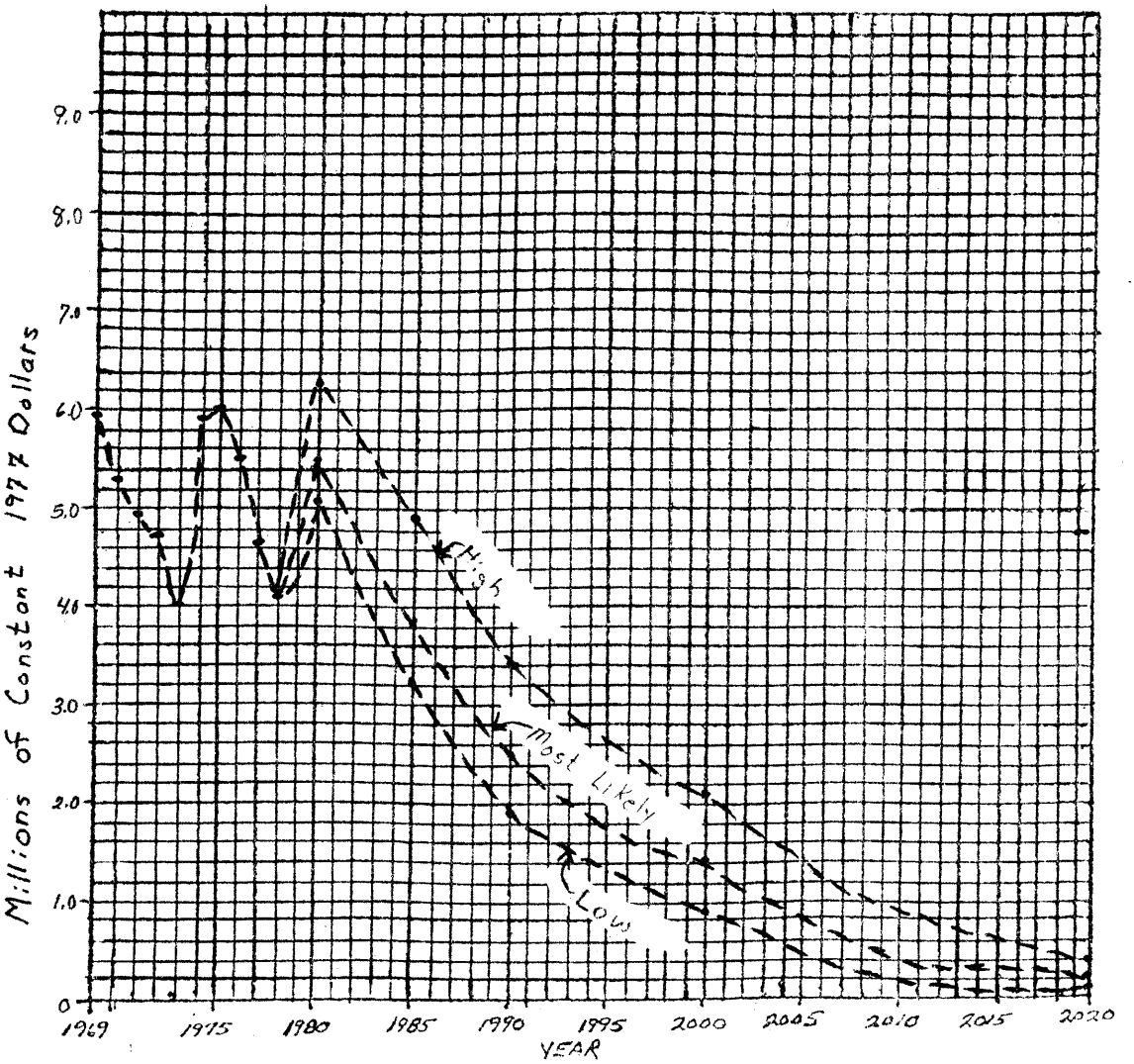
*Ogallala Aquifer Area

Source: 1) Colorado Office of Energy Conservation estimates based on data from the Colorado Oil and Gas Conservation Commission Annual Reports.

2) Colorado Office of Energy Conservation Projections--adjusted for the Windfall Profits Tax (see Table V - 2).

FIGURE V - 3

Colorado Crude Oil Royalty Payments to All Leaseholders in the Eleven-County Area (Millions of Constant 1977 Dollars)



+ denotes historical data

Source: Colorado Oil and Gas Conservation Commission Annual Reports and Estimates, 1969-1978; Colorado Office of Energy Conservation, 1980-2020.

TABLE V - 5

Six-State High Plains-Ogallala Aquifer Area Study
State Research Element A-2
Energy Production Impacts

Colorado
Royalty Payments to All Leaseholders (Crude Oil)
Millions of Constant 1977 Dollars

Historical[1]

Year	Ogallala Region* Actual
1969	5.965
1970	5.342
1971	4.995
1972	4.791
1973	4.027
1974	5.907
1975	6.024
1976	5.540
1977	4.656
1978	4.140

Projected[2]

	Ogallala Region		
Year	Low	Most Likely	High
1980	5.142	5.528	6.309
1985	3.227	3.880	4.901
1990	1.983	2.525	3.401
2000	0.924	1.426	2.165
2020	0.129	0.235	0.452

*Eleven-County Area

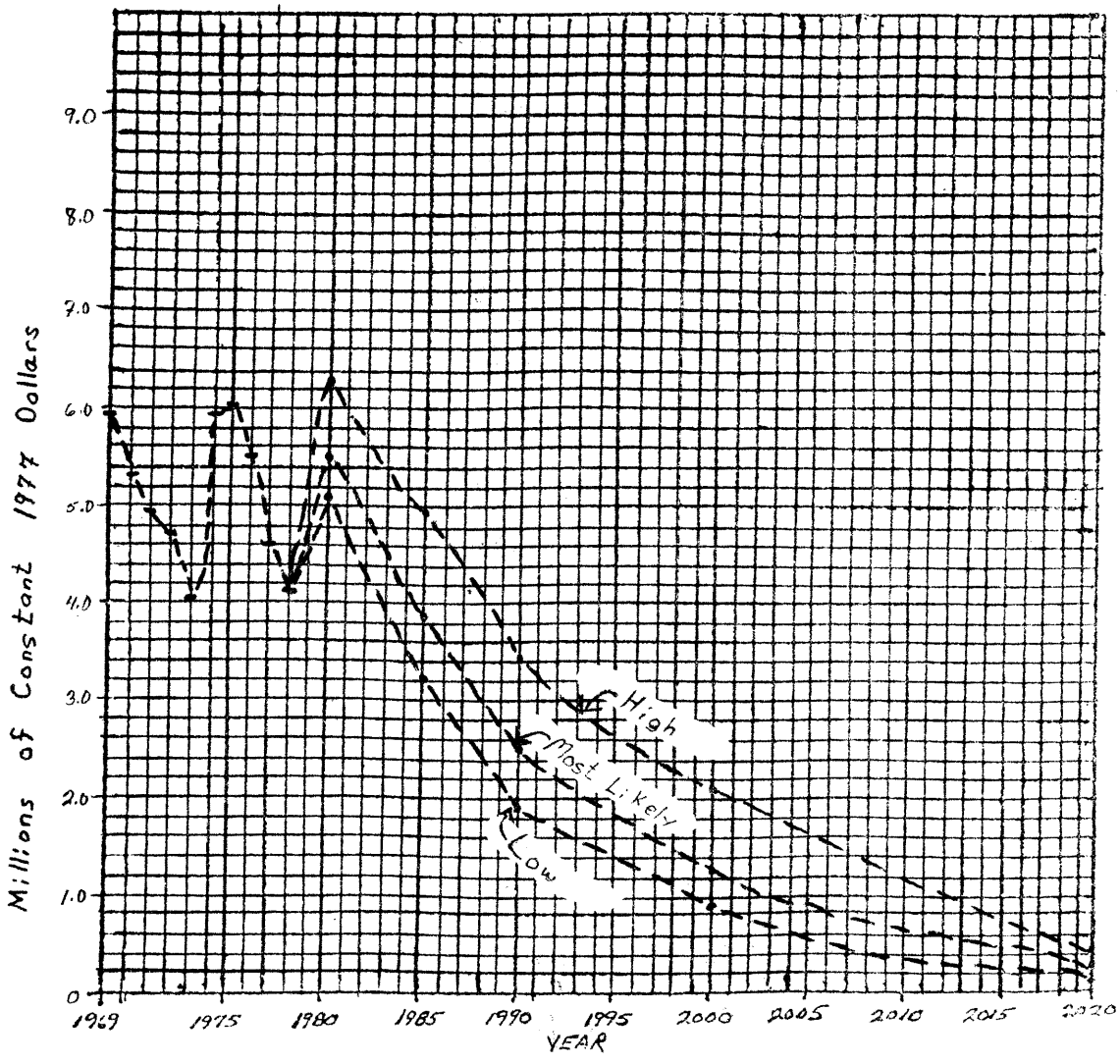
Source: 1) Colorado Office of Energy Conservation estimates based on data from the Colorado Oil and Gas Conservation Commission Annual Reports.

2) Colorado Office of Energy Conservation Projections--adjusted for the Windfall Profits Tax (see Table V - 1).

FIGURE V - 4

Colorado Crude Oil Royalty Payments to All Leaseholders in the Ogallala Aquifer Area

(Millions of Constant 1977 Dollars)



+ denotes historical data

Source: Colorado Oil and Gas Conservation Commission Annual Reports and Estimates, 1969-1978; Colorado Office of Energy Conservation, 1980-2020.

TABLE V - 6

Six-State High Plains-Ogallala Aquifer Area Study
State Research Element A-2
Energy Production Impacts

Colorado
Royalty Payments to All Leaseholders (Crude Oil)
Millions of Constant 1977 Dollars

Historical[1]

Year	Ogallala Region* Actual
1969	1.558
1970	1.625
1971	1.513
1972	1.520
1973	1.366
1974	2.095
1975	2.324
1976	2.219
1977	1.865
1978	1.636

Projected[2]

Year	Ogallala Region		
	Low	Most Likely	High
1980	2.078	2.234	2.548
1985	1.375	1.658	2.092
1990	0.893	1.136	1.530
2000	0.459	0.706	0.917
2020	0.069	0.137	0.266

*Ogallala Aquifer Area

Source: 1) **Colorado Office of Energy Conservation** estimates based on data from the Colorado Oil and Gas Conservation Commission Annual Reports.

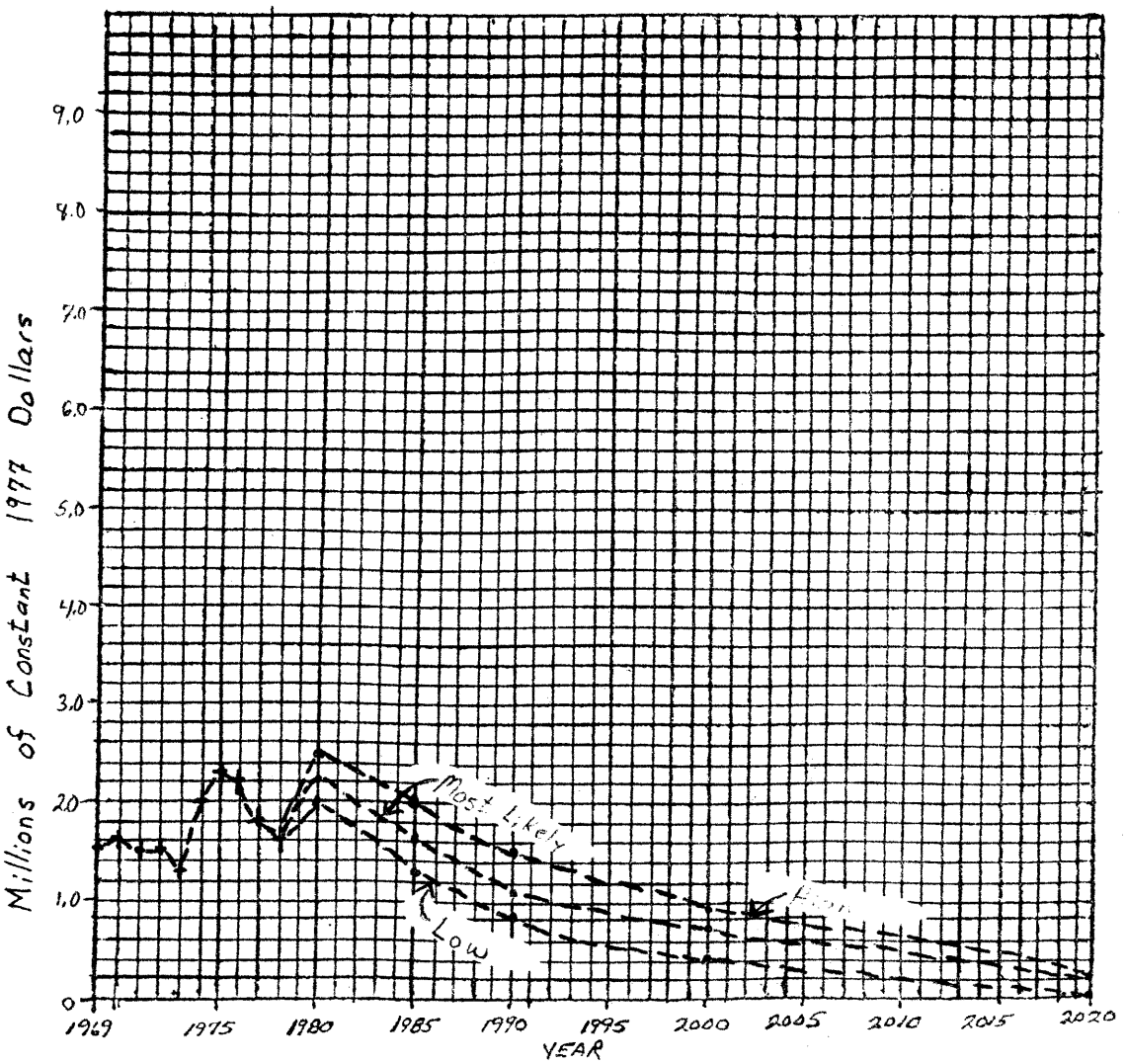
2) Colorado Office of Energy Conservation Projections--adjusted for the Windfall Profits Tax (see Table V - 2).

FIGURE V - 5

Colorado Natural Gas Royalty Payments to All

Leaseholders in the Eleven-County Area

(Millions of Constant 1977 Dollars)



+ denotes historical data

Source: Colorado Oil and Gas Conservation Commission Annual Report and Estimates, 1969-1978; Colorado Office of Energy Conservation, 1980-2020.

TABLE V - 7

Six-State High Plains-Ogallala Aquifer Area Study
State Research Element A-2
Energy Production Impacts

Colorado
Royalty Payments to All Leaseholders (Natural Gas)
Millions of Constant 1977 Dollars

Historical[1]

Year	Ogallala Region* Actual
1969	0.432
1970	0.380
1971	0.332
1972	0.365
1973	0.341
1974	0.285
1975	0.347
1976	0.947
1977	1.154
1978	1.000

Projected[2]

Year	Ogallala Region		
	Low	Most Likely	High
1980	1.379	1.500	1.694
1985	2.044	2.740	3.929
1990	2.222	4.156	5.920
2000	1.134	3.351	5.500
2020	0.296	2.192	4.788

*Eleven-County Area

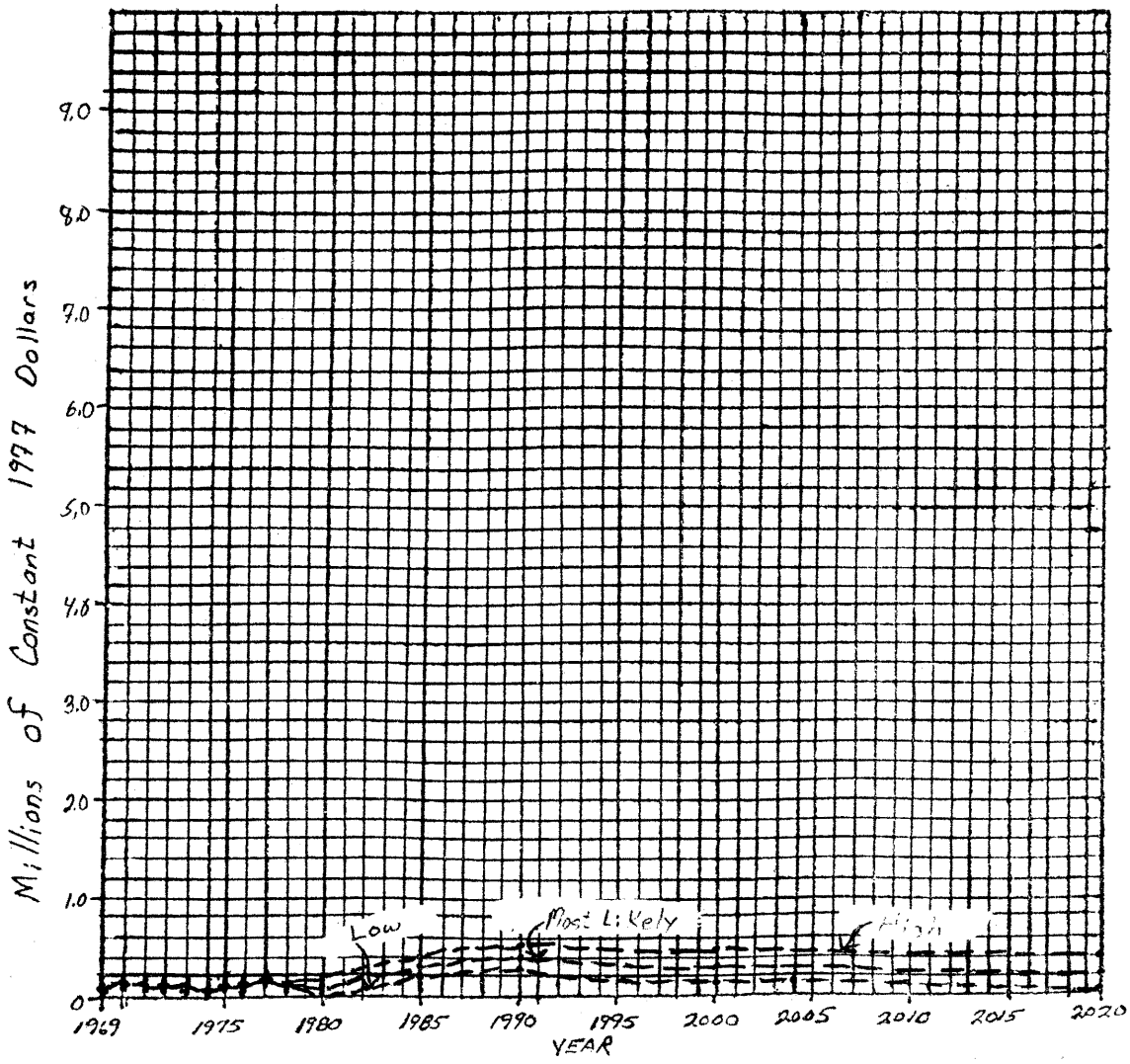
Source: 1) Colorado Office of Energy Conservation estimates based on data from the Colorado Oil and Gas Conservation Commission Annual Reports.

2) Colorado Office of Energy Conservation Projections.

FIGURE V - 6

Colorado Natural Gas Royalty Payments to All Leaseholders in the Ogallala Aquifer Area

(Millions of Constant 1977 Dollars)



+ denotes historical data

Source: Colorado Oil and Gas Conservation Commission Annual Report and Estimates, 1969-1978; Colorado Office of Energy Conservation, 1980-2020.

TABLE V - 8

Six-State High Plains-Ogallala Aquifer Area Study
State Research Element A-2
Energy Production Impacts

Colorado
Royalty Payments to All Leaseholders (Natural Gas)
Millions of Constant 1977 Dollars

Historical[1]

Year	Ogallala Region* Actual
1969	0.194
1970	0.174
1971	0.150
1972	0.162
1973	0.177
1974	0.131
1975	0.152
1976	0.467
1977	0.585
1978	0.504

Projected[2]

	Ogallala Region		
Year	Low	Most Likely	High
1980	0.714	0.777	0.877
1985	1.091	1.463	2.098
1990	1.222	2.286	3.256
2000	0.660	1.951	3.201
2020	0.191	1.416	3.017

*Ogallala Aquifer Area

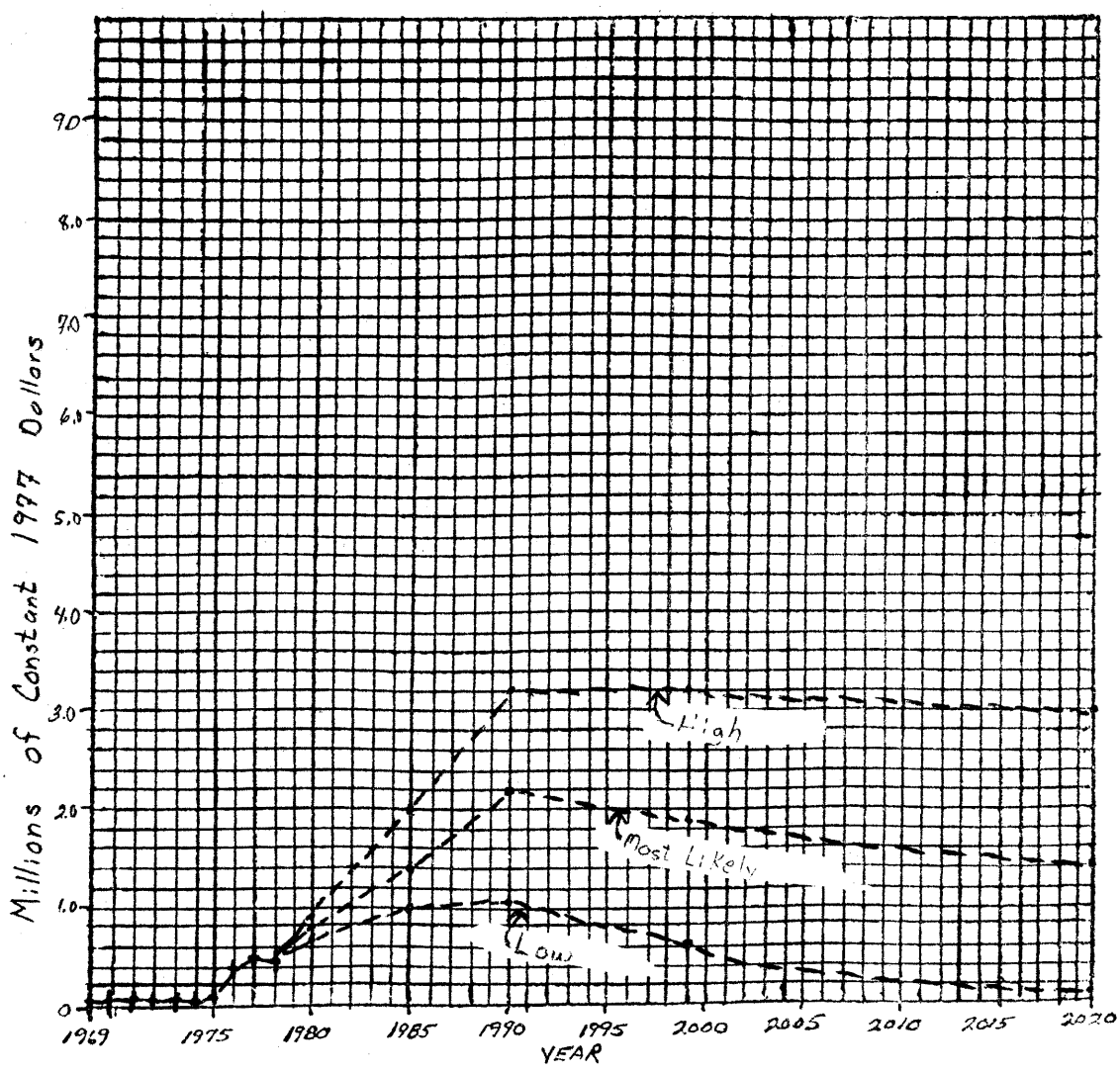
Source: 1) Colorado Office of Energy Conservation estimates based on data from the Colorado Oil and Gas Conservation Commission Annual Reports.

2) Colorado Office of Energy Conservation Projections.

FIGURE V - 7

Colorado Royalty Payments to Government Leaseholders in the Eleven-County Area

(Millions of Constant 1977 Dollars)



+ denotes historical data

Source: Colorado Board of Land Commissioners' records and Colorado Oil and Gas Conservation Commission Annual Reports and estimates, 1969-1978; Colorado Office of Energy Conservation, 1980-2020.

TABLE V - 9

Six-State High Plains-Ogallala Aquifer Area Study
State Research Element A-2
Energy Production Impacts

Colorado
Royalty Payments to Government Leaseholders
Millions of Constant 1977 Dollars

Historical[1]

Year	Ogallala Region* Actual
1969	0.160
1970	0.140
1971	0.139
1972	0.134
1973	0.153
1974	0.192
1975	0.191
1976	0.234
1977	0.291
1978	0.298

Projected[2]

Year	Ogallala Region		
	Low	Most Likely	High
1980	0.382	0.412	0.483
1985	0.309	0.396	0.547
1990	0.165	0.260	0.371
2000	0.070	0.163	0.261
2020	0.014	0.083	0.178

*Eleven-County Area

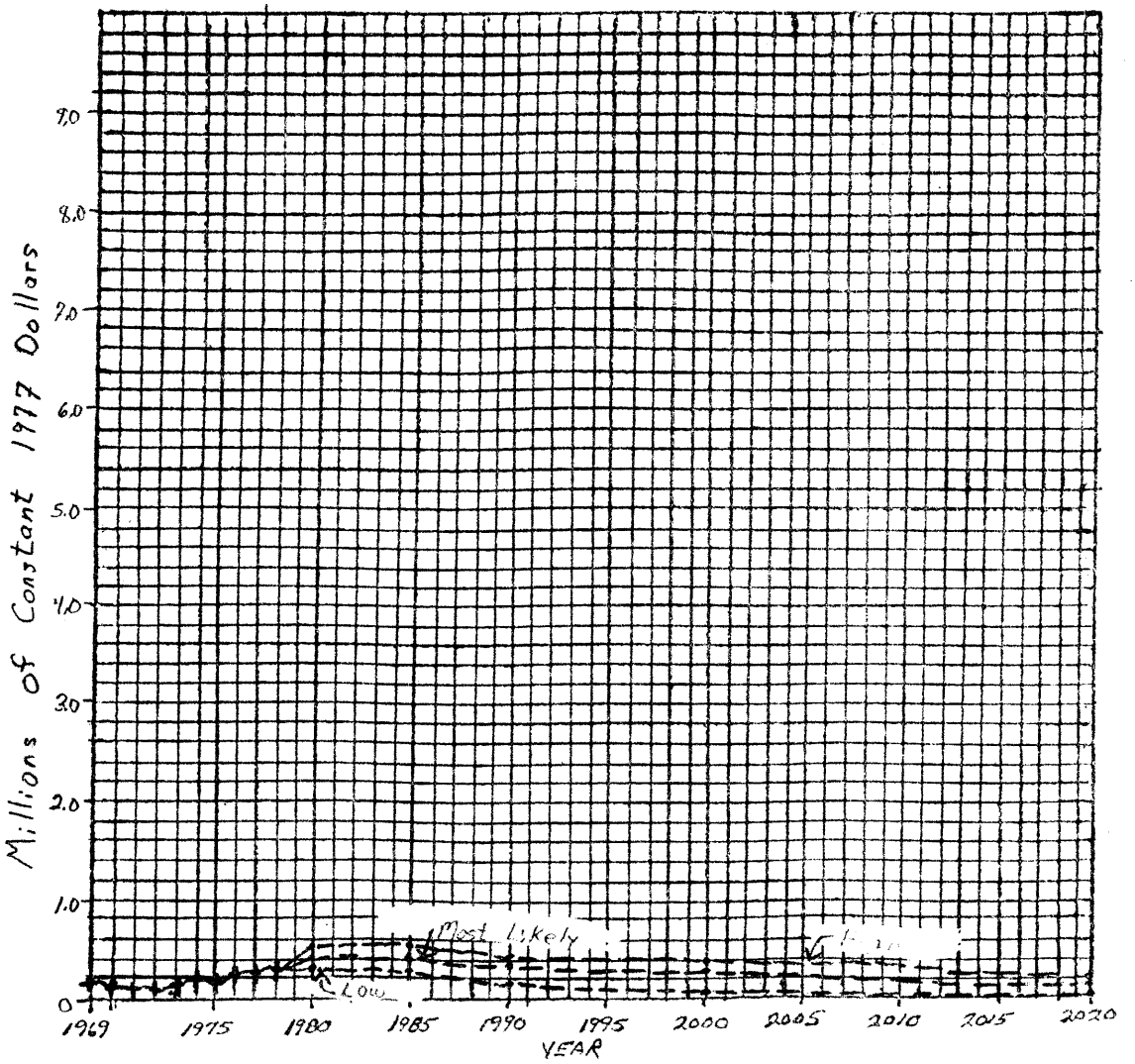
Source: 1) Colorado Office of Energy Conservation estimates based on data from the Colorado Oil and Gas Conservation Commission and the Colorado Board of Land Commissioners.

2) Colorado Office of Energy Conservation Projections.

FIGURE V - 8

Colorado Royalty Payments to Government Leaseholders in the Ogallala Aquifer Area

(Millions of Constant 1977 Dollars)



+ denotes historical data

Source: Colorado Board of Land Commissioners' records and Colorado Oil and Gas Conservation Commission Annual Reports and estimates, 1969-1978; Colorado Office of Energy Conservation, 1980-2020.

TABLE V - 10

Six-State High Plains-Ogallala Aquifer Area Study
State Research Element A-2
Energy Production Impacts

Colorado
Royalty Payments to Government Leaseholders
Millions of Constant 1977 Dollars

Historical[1]

Year	Ogallala Region* Actual
1969	0.044
1970	0.044
1971	0.043
1972	0.044
1973	0.055
1974	0.068
1975	0.075
1976	0.097
1977	0.122
1978	0.124

Projected[2]

	Ogallala Region		
Year	Low	Most Likely	High
1980	0.162	0.174	0.205
1985	0.142	0.183	0.254
1990	0.082	0.132	0.187
2000	0.038	0.090	0.140
2020	0.008	0.053	0.112

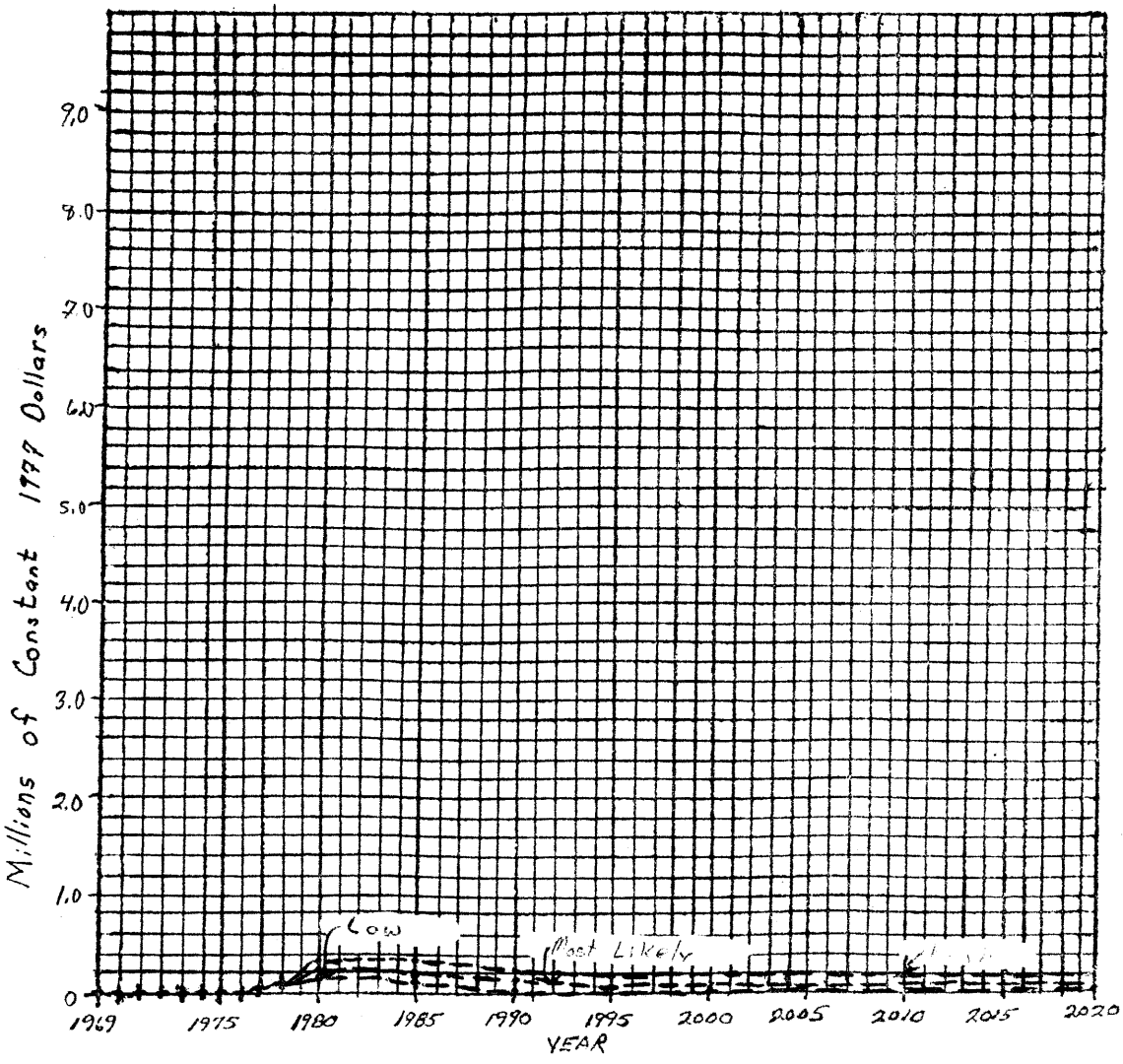
*Ogallala Aquifer Area

Source: 1) Colorado Office of Energy Conservation estimates based on data from the Colorado Oil and Gas Conservation Commission and the Colorado Board of Land Commissioners.

2) Colorado Office of Energy Conservation Projections.

FIGURE V - 9

Colorado Royalty Payments to Resident and Nonresident Private Leaseholders in the Eleven-County Area (Millions of Constant 1977 Dollars)



+ denotes historical data

Source: Colorado Board of Land Commissioners' records and Colorado Oil and Gas Conservation Commission Annual Reports and estimates, 1969-1978; Colorado Office of Energy Conservation, 1980-2020.

TABLE V - 11

Six-State High Plains-Ogallala Aquifer Area Study
State Research Element A-2
Energy Production Impacts

Colorado
Royalty Payments to Resident and Nonresident Private Leaseholders
Millions of Constant 1977 Dollars

Historical[1]

Year	Ogallala Region* Actual
1969	6.237
1970	5.585
1971	5.188
1972	5.023
1973	4.216
1974	6.000
1975	6.180
1976	6.253
1977	5.520
1978	4.842

Projected[2]

Year	Ogallala Region		
	Low	Most Likely	High
1980	6.139	6.616	7.520
1985	4.962	6.217	8.283
1990	4.040	6.421	8.950
2000	1.988	4.614	7.404
2020	0.411	2.344	5.062

*Eleven-County Area

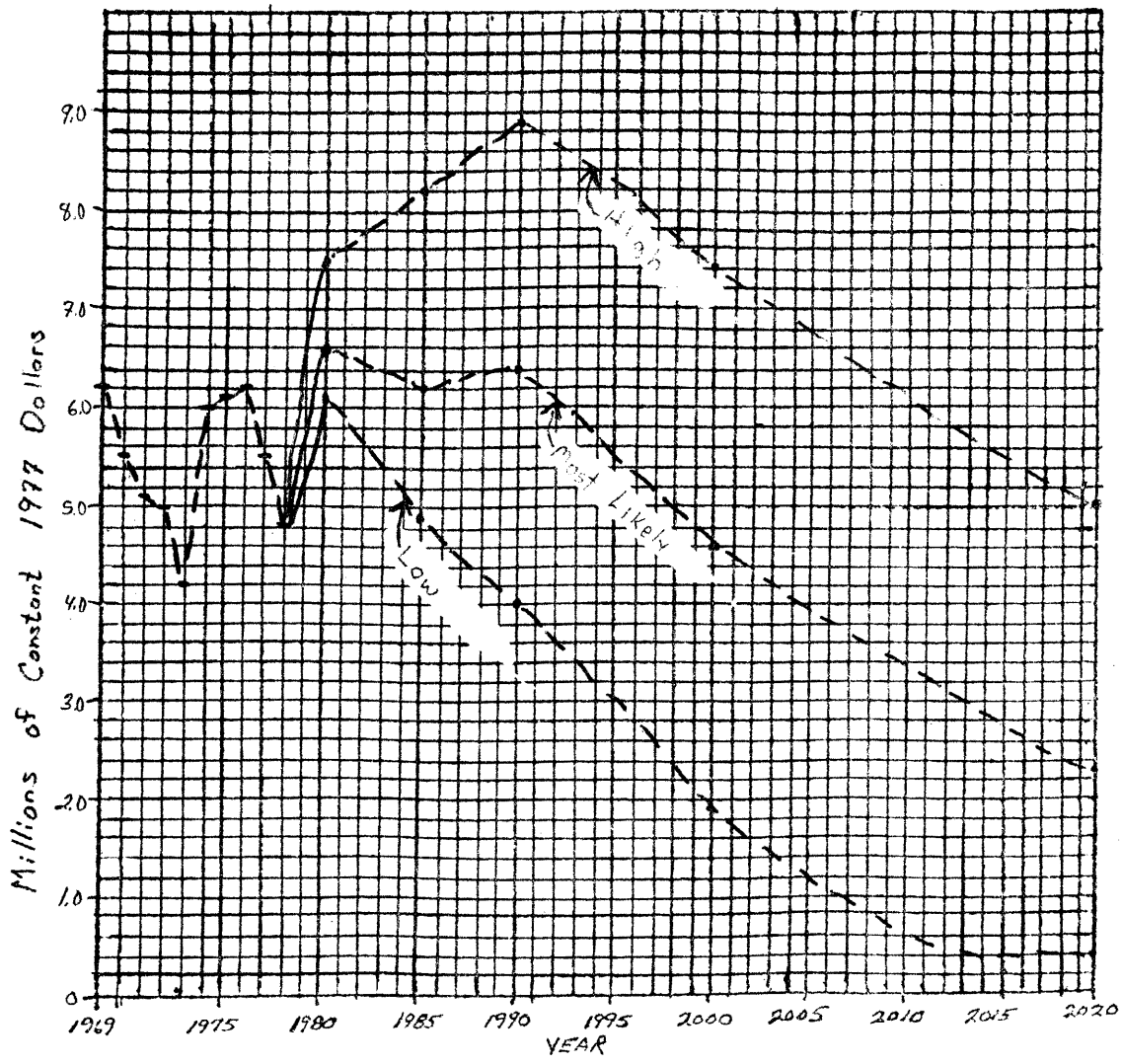
Source: 1) Colorado Office of Energy Conservation estimates based on data from the Colorado Oil and Gas Conservation Commission and the Colorado Board of Land Commissioners.

2) Colorado Office of Energy Conservation Projections--adjusted for the Windfall Profits Tax (see Table V - 1).

FIGURE V - 10

Colorado Royalty Payments to Resident and Nonresident Private Leaseholders in the Ogallala Aquifer Area

(Millions of Constant 1977 Dollars)



+ denotes historical data

Source: Colorado Board of Land Commissioners' records and Colorado Oil and Gas Conservation Commission Annual Reports and estimates, 1969-1978; Colorado Office of Energy Conservation, 1980-2020.

TABLE V - 12

Six-State High Plains-Ogallala Aquifer Area Study
State Research Element A-2
Energy Production Impacts

Colorado
Royalty Payments to Resident and Nonresident Private Leaseholders
Millions of Constant 1977 Dollars

Historical[1]

Year	Ogallala Region* Actual
1969	1.708
1970	1.755
1971	1.620
1972	1.638
1973	1.488
1974	2.158
1975	2.401
1976	2.589
1977	2.328
1978	2.016

Projected[2]

	Ogallala Region		
Year	Low	Most Likely	High
1980	2.630	2.837	3.220
1985	2.324	2.938	3.936
1990	2.033	3.290	4.599
2000	1.081	2.567	3.978
2020	0.252	1.500	3.171

*Ogallala Aquifer Area

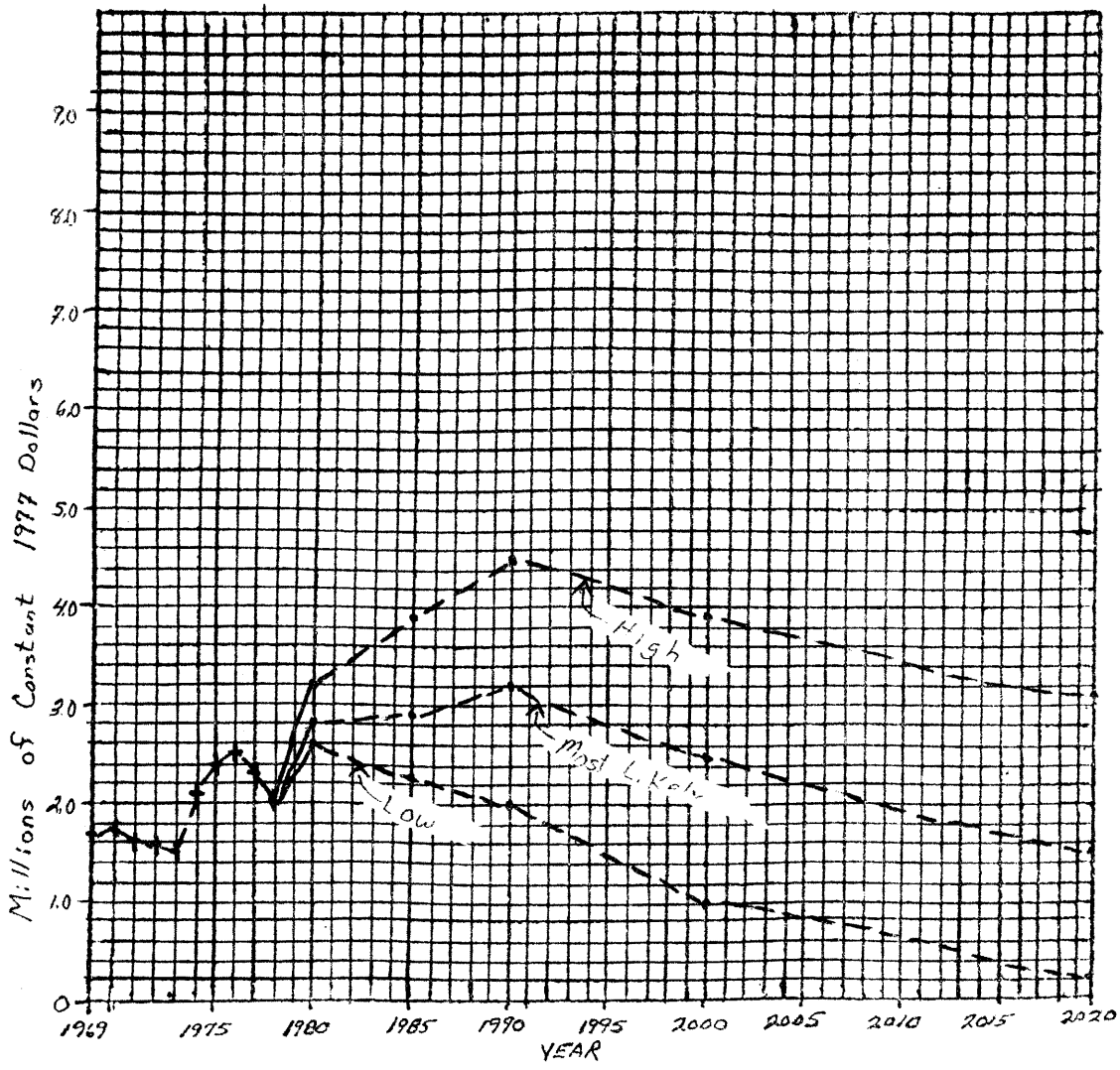
Source: 1) Colorado Office of Energy Conservation estimates based on data from the Colorado Oil and Gas Conservation Commission and the Colorado Board of Land Commissioners.

2) Colorado Office of Energy Conservation Projections--adjusted for the Windfall Profits Tax (see Table V - 2).

FIGURE V - 11

Colorado Royalty Payments to Resident Private Leaseholders in the Eleven-County Area

(Millions of Constant 1977 Dollars)



+ denotes historical data

Source: Colorado Board of Land Commissioners' records and Colorado Oil and Gas Conservation Commission Annual Reports and estimates, 1969-1978; Colorado Office of Energy Conservation, 1980-2020.

TABLE V - 13
Six-State High Plains-Ogallala Aquifer Area Study
State Research Element A-2
Energy Production Impacts

Colorado
Royalty Payments to Resident Private* Leaseholders
Millions of Constant 1977 Dollars

Historical[1]

Year	Ogallala Region** Actual
1969	4.990
1970	4.468
1971	4.150
1972	4.018
1973	3.373
1974	4.800
1975	4.944
1976	5.003
1977	4.416
1978	3.874

Projected[2]

	Ogallala Region**		
Year	Low	Most Likely	High
1980	4.911	5.293	6.016
1985	3.970	4.974	6.626
1990	3.232	5.137	7.160
2000	1.590	3.692	5.923
2020	0.329	1.875	4.050

*Payments to persons within the Colorado study area.
**Eleven-County Area

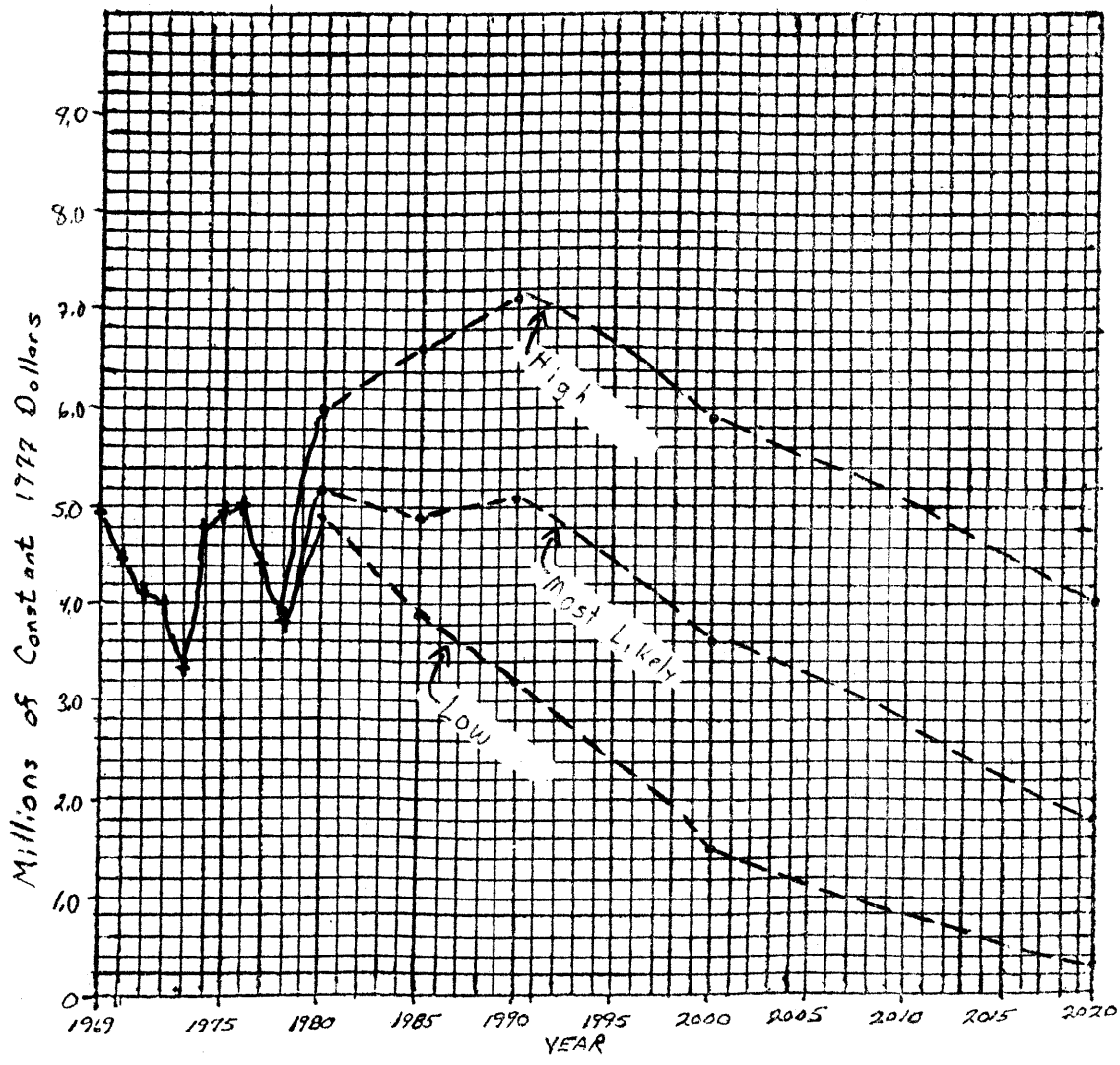
Source: 1) Colorado Office of Energy Conservation estimates based on data from the Colorado Oil and Gas Conservation Commission and the Colorado Board of Land Commissioners.

2) Colorado Office of Energy Conservation Projections--adjusted for the Windfall Profits Tax (see Table V - 1).

FIGURE V - 12

Colorado Royalty Payments to Resident Private Leaseholders in the Ogallala Aquifer Area

(Millions of Constant 1977 Dollars)



+ denotes historical data

Source: Colorado Board of Land Commissioners' records and Colorado Oil and Gas Conservation Commission Annual Reports and estimates, 1969-1978; Colorado Office of Energy Conservation, 1980-2020.

TABLE V - 14

Six-State High Plains-Ogallala Aquifer Area Study
State Research Element A-2
Energy Production Impacts

Colorado
Royalty Payments to Resident* Private Leaseholders
Millions of Constant 1977 Dollars

Historical[1]

Year	Ogallala Region** Actual
1969	1.365
1970	1.404
1971	1.298
1972	1.310
1973	1.191
1974	1.725
1975	1.920
1976	2.070
1977	1.862
1978	1.613

Projected[2]

	Ogallala Region**		
Year	Low	Most Likely	High
1980	2.104	2.270	2.576
1985	1.859	2.350	3.149
1990	1.626	2.632	3.679
2000	0.865	2.054	3.182
2020	0.202	1.200	2.539

*Payments to persons within the Colorado Study Area.
**Ogallala Aquifer Area

Source: 1) Colorado Office of Energy Conservation estimates based on data from the Colorado Oil and Gas Conservation Commission and the Colorado Board of Land Commissioners.

2) Colorado Office of Energy Conservation Projections--adjusted for the Windfall Profits Tax (see Table V - 2).

TABLE V - A

COMPUTATION OF SCALAR FOR 1980 MOST LIKELY PROJECTION OF ROYALTY PAYMENTS TO PRIVATE LEASE HOLDERS (1977 DOLLARS)

Weighted Average Base Price (P_{base}):

$(0.76 \times 10.56) + (0.20 \times 12.53) + (0.04 \times 13.88) = \$11.09/bbl$

Weighted Average Windfall Profit Tax Rate (RATE):

$(0.76 \times 0.70) + (0.20 \times 0.60) + (0.04 \times 0.30) = 0.66$

Market Value---from B&V Price Projections:

$P_{removal} = \$19.60/bbl$

Windfall Profit*:

$(1 - 0.03)\ (19.60 - 11.09) = \$8.25/bbl$

Windfall Profit Tax (TAX):

$(8.25)\ (0.66) = \$5.45/bbl$

Adjusted Price---tax only applied to production after February 1980:

$(0.16)\ (19.60) + (0.84)\ (19.60 - 5.45) = \$15.02/bbl$

Royalty Payment Scalar:

$15.02/19.60 = 0.77$

---

*$WP = P_{removal} - P_{base} - S$

Where: $S = (\text{severance tax rate})\ (P_{removal} - P_{base})$

TABLE V - B

COMPUTATION OF SCALAR FOR 1985 MOST LIKELY PROJECTION OF ROYALTY PAYMENTS TO PRIVATE LEASE HOLDERS (1977 DOLLARS)

Weighted Average Base Price (P_{base}):

$(0.63 \times 10.56) + (0.23 \times 12.53) + (0.14 \times 15.34) = \$11.68/bbl$

Weighted Average Windfall Profit Tax Rate (RATE):

$(0.63 \times 0.70) + (0.23 \times 0.60) + (0.14 \times 0.30) = 0.62$

Market Value---from B&V Price Projections:

$P_{removal} = \$24.40/bbl$

Windfall Profit:

$(1 - 0.03)\ (24.40 - 11.68) = \$12.34/bbl$

Windfall Profit Tax (TAX):

$(12.34)\ (0.62) = \$7.65/bbl$

Adjusted Price:

$24.40 - 7.65 = \$16.75/bbl$

Royalty Payment Scalar:

$16.75/24.40 = 0.69$

TABLE V - C

COMPUTATION OF SCALAR FOR 1990 MOST LIKELY PROJECTION OF ROYALTY PAYMENTS TO PRIVATE LEASE HOLDERS (1977 DOLLARS)

Weighted Average Base Price (P_{base}):

$(0.50 \times 10.56) + (0.29 \times 12.53) + (0.21 \times 16.94) = \$12.47/bbl$

Weighted Average Windfall Profit Tax Rate (RATE):

$(0.50 \times 0.70) + (0.29 \times 0.60) + (0.21 \times 0.30) = 0.59$

Market Value---from B&V Price Projections:

$P_{removal} = \$24.90/bbl$

Windfall Profit:

$(1 - 0.03)\ (24.90 - 12.47) = \$12.06/bbl$

Windfall Profit Tax (TAX):

$(12.06)\ (0.59) = \$7.11/bbl$

Adjusted Price:

$24.90 - 7.11 = \$17.79/bbl$

Royalty Payment Scalar:

$17.79/24.90 = 0.71$

VI. WORKING PAPER

IRRIGATION AND ENERGY

INTRODUCTION

The purpose of this Working Paper is to provide historical time profiles of irrigation and energy related elements for the Ogallala Aquifer Area, specifically, (1) the number of irrigation wells by energy source and in total and (2) the billions of BTUs of energy used for irrigation pumping by energy source and in total.

Figures VI-1 through VI-3 which are based on the data summarized in Tables VI-1 through VI-3, illustrate the trends and expectations related to the total number of irrigation wells, wells powered by natural gas, and wells powered by electricity, respectively.

Figures VI-4 through VI-6 which are based on the data summarized in Tables VI-4 through VI-7, relate to total energy used by irrigation, energy used to power natural gas pumps, and energy used to power electric pumps, respectively.

METHODOLOGY

Baseline Data

The historical baseline data for this Working Paper were derived from the records of the Colorado State Water Engineer and Colorado High Plains natural gas and electric utility records.

The historical component was arrived at by using the records of the natural gas and electric utilities serving the study area. The two natural gas utilities serving the Colorado High Plains provided information on the

average annual number of irrigation meters served (data were not available for the actual number of irrigation pumps connected) and the annual natural gas sales to those metered customers in those service areas which roughly correspond spatially with the study area--because the reporting area is somewhat larger than the study area, the number of natural gas pumps and the BTU's consumed by natural gas pumps may be overstated in relation to electric pumps. In addition, because the data reports the number of "meters" serving pumps, rather than the number of pumps, it may understate the number of pumps where more than one pump is served from the same meter and overstate the amount of energy used where other non-irrigation uses are located downstream of the meter. Natural gas consumption by irrigation pumps was converted from MCF units to BTU units by equating one cubic foot to 975 BTU's (the average used by Kansas-Nebraska Natural Gas for the Colorado High Plains). Data for the years 1969, 1970, and 1971 were not available from Peoples Natural Gas Company and were, therefore, estimated from the average growth rates during the period 1972 to 1978.

The annual number of electric irrigation pumps and kilowatt hours consumed by irrigation was derived from information in the electric utilities' Annual Reports to the Colorado Public Utilities Commission. Electric utilities which served areas inside the "Aquifer Area" were contacted and asked to specify which substations served the study area (if a substation served areas which were both within the area and outside the study area, the utilities were asked to specify the percentage in each area). Substation specific data from each utility's REA Irrigation Study was used to determine what fraction of each utility's irrigation customers and kilowatt hour consumption was in the study area, when data was available. If substation specific

data were not available for a given year, the average growth rate for those years available was used to determine the representative share. Because kilowatt hours were not available in the REA Irrigation Studies, pump horsepower was used as a proxy. Once each utility's annual proportion of service to the "Aquifer Area" was determined, these proportions were applied to each utility's number of irrigation customers and kilowatt hours of electricity consumed by irrigation as noted in the reports to the Colorado PUC. Finally, the data for all utilities was aggregated into annual study area totals.

Data on the total number of irrigation pumps and total BTU's consumed for irrigation pumping were estimated by aggregating the annual totals for natural gas "pumps" (irrigation meters) and electric "pumps" (irrigation customers).

Data concerning the number and energy use by gasoline, diesel, and LP pumps was not examined because of the difficulty of obtaining information about these types and because of their relatively insignificant role in irrigation in the study area--one source[1] has indicated that at most these three types of pumps together constitute only 10 percent, and probably considerably less, of the irrigation pumps in the study area.

Projection Assumptions and Techniques

The projection assumptions and projection techniques are explained as part of the Colorado High Plains A-1 portion of the Six-State Ogallala Aquifer Study.

---

[1]Bernard Sanders, "Availability and Price of Diesel Fuel for Irrigation", 1980 Western Irrigation Forum Proceedings.

TABLE VI - 1

Six-State High Plains-Ogallala Aquifer Area Study
State Research Element A-2
Energy Production Impacts

Colorado
Total Number of Natural Gas and Electric Irrigation Pumps

Historical[1]

Year	Ogallala Region* Actual
1969	1782
1970	2106
1971	2482
1972	2946
1973	3500
1974	3900
1975	4425
1976	4823
1977	5140
1978	5316

Projected[2]

	Ogallala Region		
Year	Low	Most Likely	High
1980	3575	4767	5959
1985	3342	4455	5569
1990	3234	4311	5389
2000	2949	3931	4914
2020	2123	2830	3537

*Aquifer Area

Sources: 1) Colorado Office of Energy Conservation estimates. See Tables VI-2 and VI-3.

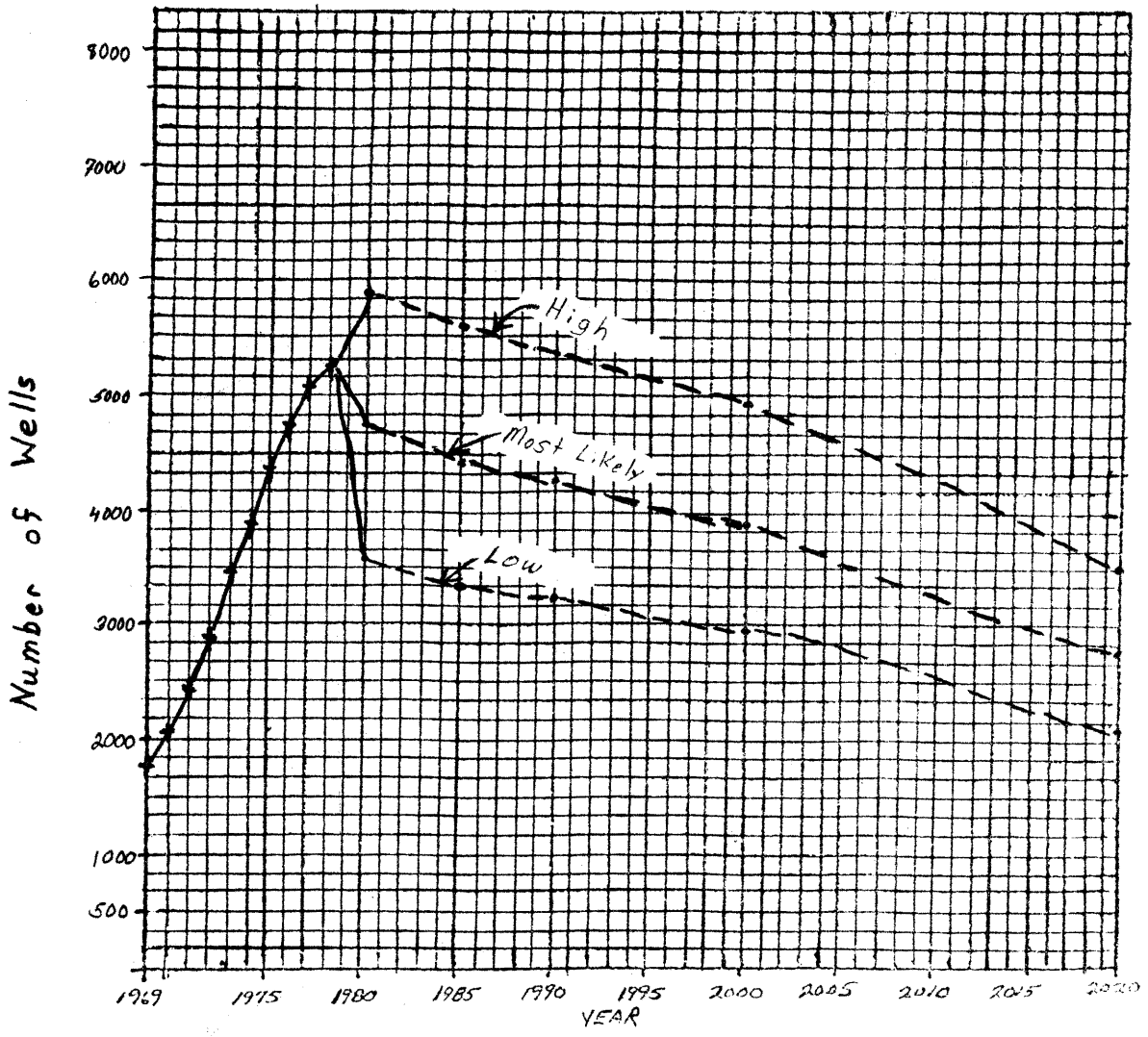
2) Colorado High Plains A-1 Projections of electric and natural gas pumps.

FIGURE VI - 1

Colorado Total Electric and Natural Gas Irrigation Pumps

in the Ogallala Aquifer Area

(Number)



+ denotes historical data

Source: Colorado Office of Energy Conservation estimates, 1969-1978; Colorado High Plains A-1 Projections of electric and natural gas pumps, 1980-2020.

TABLE VI - 2

Six-State High Plains-Ogallala Aquifer Area Study
State Research Element A-2
Energy Production Impacts

Colorado
Number of Natural Gas Powered Irrigation Pumps

Historical[1]

Year	Ogallala Region* Actual
1969	922[a]
1970	1081[a]
1971	1265[a]
1972	1483
1973	1764
1974	1756
1975	1692
1976	1619
1977	1585
1978	1532

a - Estimated by the extension of the 1972-1978 annual growth rates.

Projected[2]

Year	Ogallala Region Low	Most Likely	High
1980	1289	1719	2149
1985	1205	1606	2003
1990	1100	1466	1833
2000	809	1078	1348
2020	349	465	581

*Aquifer Area

Sources: 1) Colorado Office of Energy Conservation estimates based on the natural gas utility company records for service areas which roughly correspond to the study area. Note: the data represents the number of meters--there may be more than one irrigation well connected to a meter as well as uses other than irrigation downstream of a meter.

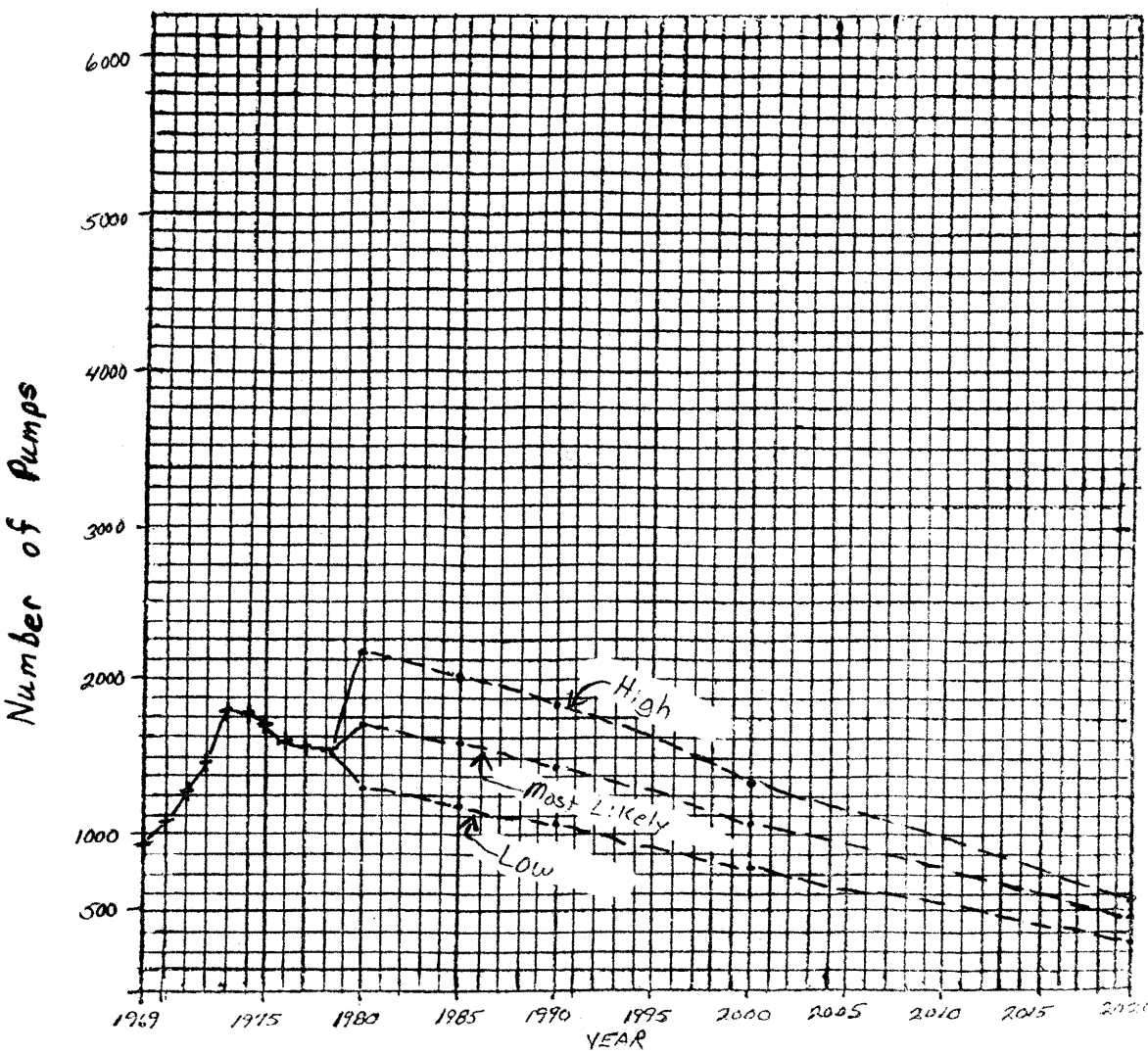
2) Colorado High Plains A-1 Projections.

FIGURE VI - 2

Colorado Natural Gas Powered Irrigation Pumps

in the Ogallala Aquifer Area

(Number)



+ denotes historical data

Source: Natural Gas Utilities' records, 1969-1978; Colorado High Plains A-1 Projections, 1980-2020.

TABLE VI - 3

Six-State High Plains-Ogallala Aquifer Area Study
State Research Element A-2
Energy Production Impacts

Colorado
Number of Electric Powered Irrigation Pumps

Historical[1]

Year	Ogallala Region* Actual
1969	860
1970	1025
1971	1217
1972	1463
1973	1736
1974	2144
1975	2733
1976	3204
1977	3555
1978	3784

Projected[2]

	Ogallala Region		
Year	Low	Most Likely	High
1980	2286	3048	3810
1985	2137	2849	3561
1990	2134	2845	3556
2000	2140	2853	3566
2020	1774	2365	2956

*Aquifer Area

Sources: 1) Colorado Office of Energy Conservation estimates based on data from Colorado Public Utilities Commission Annual Reports modified by individual electric utility High Plains fractions derived from substation specific data from REA Irrigatoin Studies for the years available. Note: REA Irrigation Study data for the "Number of Active Irrigation Pump Installations" (available only for 1973-1976) is 5 to 7 percent higher.

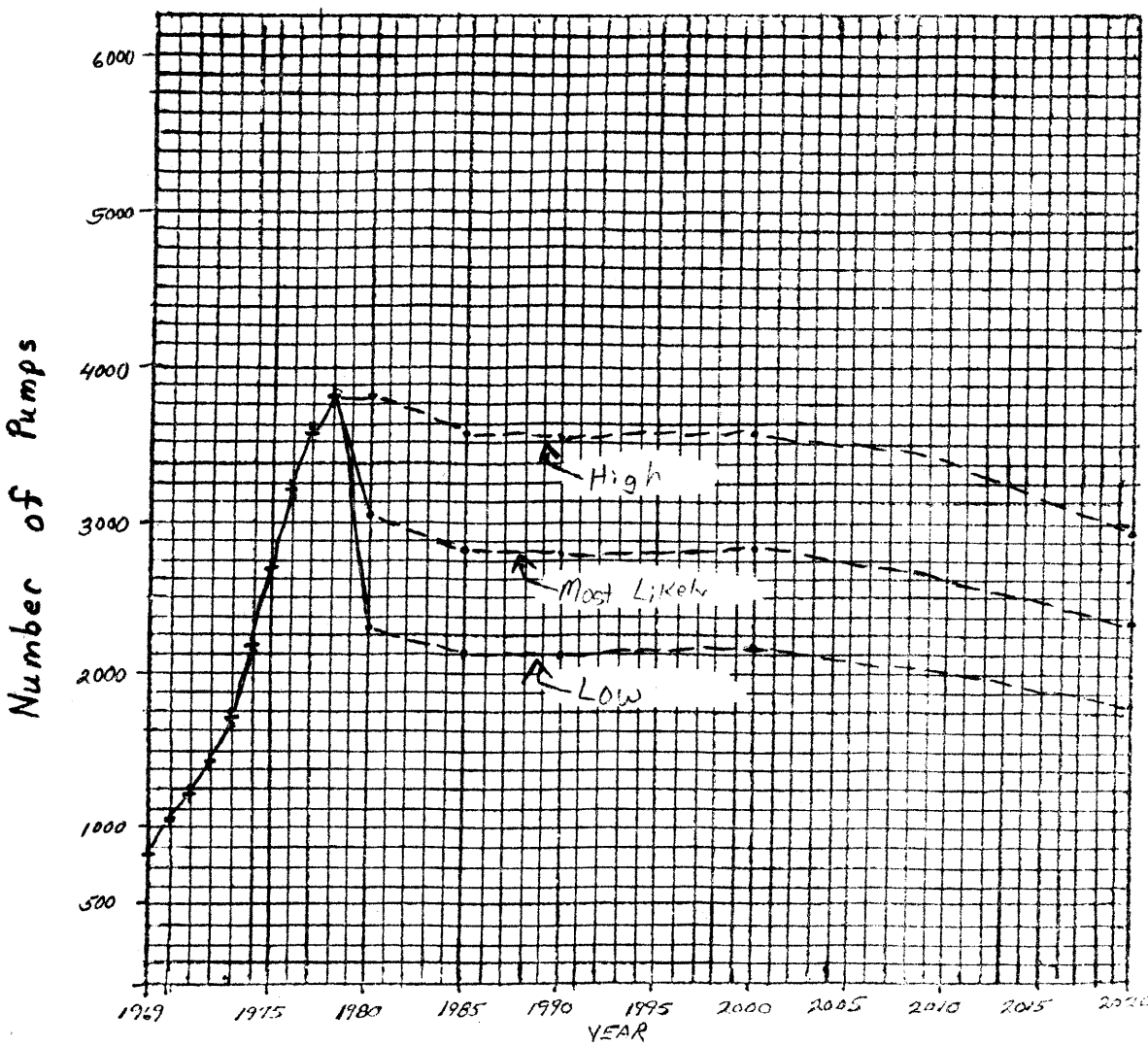
2) Colorado High Plains A-1 Projections.

FIGURE VI - 3

Colorado Electric Powered Irrigation Pumps

in the Ogallala Aquifer Area

(Number)



+ denotes historical data

Source: Colorado Public Utilities Commission Annual Reports and Electric Utilities' REA Irrigation Studies, 1969-1978; Colorado High Plains A-1 Projections, 1980-2020.

TABLE VI - 4

Six-State High Plains-Ogallala Aquifer Area Study
State Research Element A-2
Energy Production Impacts

Colorado
Total Energy (Natural Gas and Electric) Used for Irrigation Pumping
Billions of BTUs (At the Meter)

Historical[1]

Year	Ogallala Region* Actual
1969	2471
1970	2922
1971	3371
1972	3879
1973	3223
1974	5187
1975	5392
1976	6073
1977	4630
1978	4643

Projected[2]

	Ogallala Region		
Year	Low	Most Likely	High
1980	4179	5571	6964
1985	3954	5268	6589
1990	3457	4608	5761
2000	3217	4289	5361
2020	1824	2432	3040

*Aquifer Area

Sources: 1) Colorado Office of Energy Conservation estimates based on utility records, REA Irrigation Studies, and Colorado Public Utility Commission Annual Reports. See notes on Tables VI-2 and VI-3.

2) Colorado High Plains A-1 Projections.

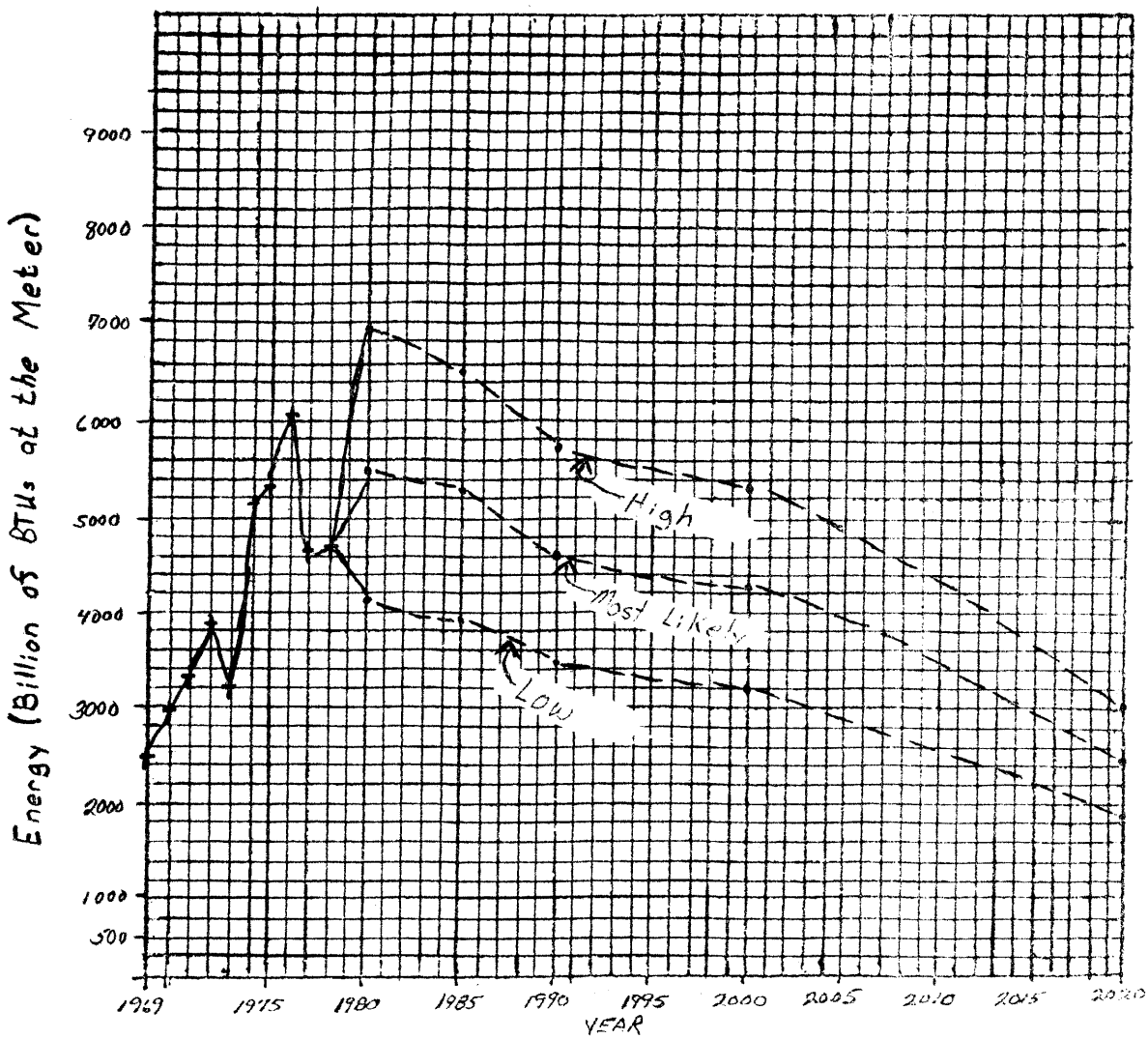
FIGURE VI - 4

Colorado Total Energy (Natural Gas and Electric)

Used for Irrigation Pumping

in the Ogallala Aquifer Area

Billion BTU (At the Meter)



+ denotes historical data

Source: Colorado Public Utilities Commission Reports, and High Plains Electric Utilities' REA Irrigation Studies, 1969-1978; Colorado High Plains Study A-1 Projections, 1980-2020.

TABLE VI - 5

Six-State High Plains-Ogallala Aquifer Area Study
State Research Element A-2
Energy Production Impacts

Colorado
Natural Gas Energy Used for Irrigation Pumping
Billions of BTUs (At the Meter)

Historical[1]

Year	Ogallala Region* Actual
1969	2279
1970	2653
1971	3051
1972	3513
1973	2799
1974	4481
1975	4445
1976	4745
1977	3470
1978	3163

Projected[2]

Year	Ogallala Region		
	Low	Most Likely	High
1980	3050	4066	5083
1985	2848	3797	4746
1990	2312	3082	3853
2000	2001	2668	3335
2020	828	1104	1380

*Aquifer Area

Sources: 1) Colorado Office of Energy Conservation estimates based on utility records and Colorado Public Utility Commission Annual Reports. See notes on Table VI-2.

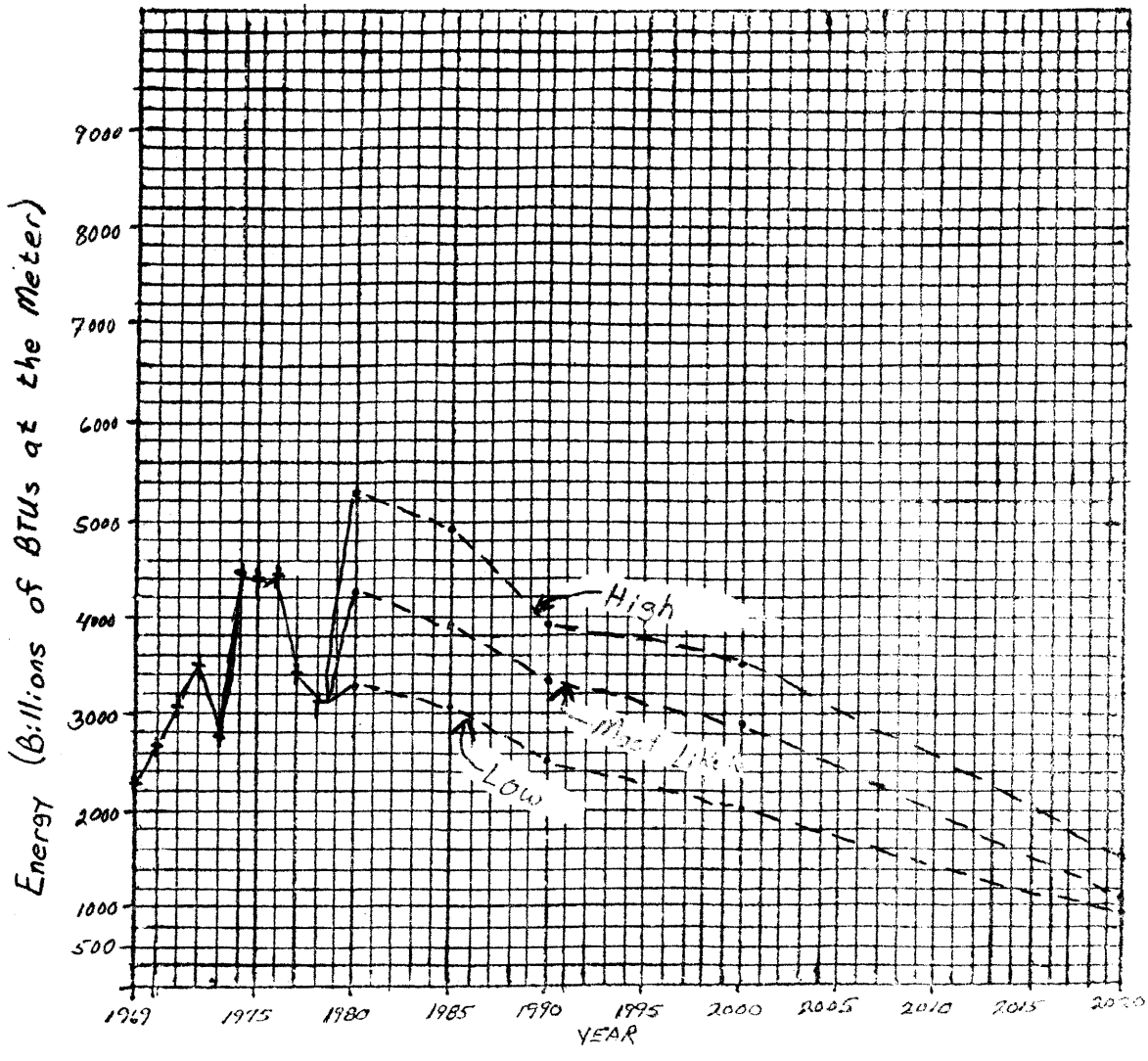
2) Colorado High Plains A-1 Projections.

FIGURE VI - 5

Colorado Natural Gas Energy Used for Irrigation

Pumping in the Ogallala Aquifer Area

Billions of BTUs (At the Meter)



+ denotes historical data

Source: Colorado Public Utilities Commission Annual Reports, and High Plains Electric Utilities' REA Irrigation Studies, 1969-1978; Colorado High Plains Study A-1 Projections, 1980-2020.

TABLE VI - 6

Six-State High Plains-Ogallala Aquifer Area Study
State Research Element A-2
Energy Production Impacts

Colorado
Electric Energy Used for Irrigation Pumping
Billions of BTUs (At the Meter)

Historical[1]

Year	Ogallala Region* Actual
1969	192
1970	270
1971	320
1972	366
1973	424
1974	705
1975	947
1976	1329
1977	1160
1978	1480

Projected[2]

Year	Ogallala Region		
	Low	Most Likely	High
1980	1129	1505	1881
1985	1106	1474	1843
1990	1145	1526	1908
2000	1216	1621	2026
2020	996	1328	1660

*Aquifer Area

Sources: 1) Colorado Office of Energy Conservation estimates based on utility records, REA Irrigation Studies, and Colorado Public Utility Commission Annual Reports. See notes on Table VI-3.

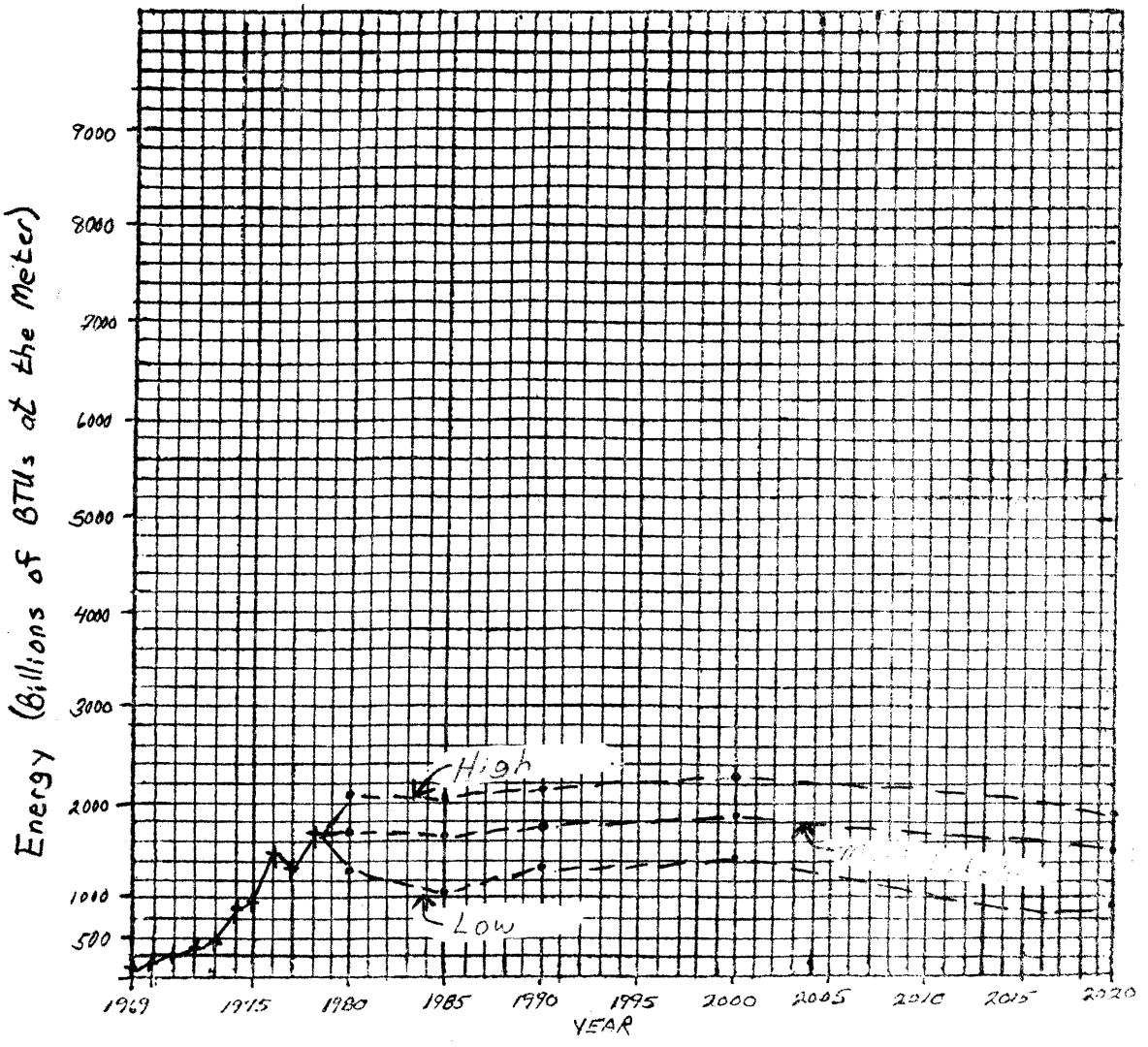
2) Colorado High Plains A-1 Projections.

FIGURE VI - 6

Colorado Electric Energy Used for Irrigation

Pumping in the Ogallala Aquifer Area

Billions of BTUs (At the Meter)



+ denotes historical data

Source: Colorado Public Utilities Commission Annual Reports, and High Plains Electric Utilities' REA Irrigation Studies, 1969-1978; Colorado High Plains Study A-1 Projections, 1980-2020.

COLORADO WATER RESOURCES RESEARCH INSTITUTE

LIST OF PUBLICATIONS AVAILABLE

A. MANAGEMENT OF HYDROLOGIC EXTREMES

		Date	Price
CR 16	Experimental Investigation of Small Watershed Floods	6/68	$ 2.00
CR 18	Experimental Investigation of Small Watershed Floods	6/70	5.00
CR 29	Identification of Urban Watershed Units Using Remote Multispectral Sensing	6/71	5.00
CR 40	Selection of Test Variable for Minimal Time Detection of Basin Response to Natural or Induced Changes	12/72	3.00
CR 42	Theory and Experiments in the Prediction of Small Watershed Response	12/72	5.00
CR 43	Experiments in Small Watershed Response	12/72	5.00
CR 56	Evaluation and Implementation of Urban Drainage and Flood Control Projects	6/74	8.00
CR 65	Urban Drainage and Flood Control Projects: Economic, Legal and Financial Aspects	7/75	10.00
CR 83	Modelling the Dynamic Response of Floodplains to Urbanization in Eastern New England	1/78	6.50
CR 95	Drought-Induced Problems and Responses of Small Towns and Rural Water Entities in Colorado: The 1976-1978 Drought	6/80	4.00
S-GS856	Research Data Assembly for Small Watershed Floods, Part II	1967	.50
IS 13	Flood Plain Management of the Cache La Poudre River near Fort Collins	8/74	2.75
IS 17	Cache La Poudre River near Fort Collins, Colorado - Flood Management Alternatives - Relocations and Levies	8/74	5.00
IS 22	Implementation of the National Flood Insurance Program in Larimer County, Colorado	9/76	4.00
IS 24	Factors Affecting Public Acceptance of Flood Insurance in Larimer and Weld Counties, Colorado	9/77	3.00
IS 27	Proceedings, Colorado Drought Workshops	11/77	Free
IS 44	The National Flood Insurance Program in the Larimer County, Colorado area	8/80	3.00

B. WATER SUPPLY AUGMENTATION AND CONSERVATION

CR 3	Snow Accumulation in Relation to Forest Canopy	6/69	1.50
CR 4	Runoff from Forest and Agricultural Watersheds	6/69	3.00
CR 8	Improving Efficiency in Agricultural Water Use	6/69	1.00
CR 9	Controlled Accumulation of Blowing Snow	6/69	2.50
CR 15	Hydraulic Operating Characteristics of Low Gradient Border Checks in the Management of Irrigation Water	6/68	3.00
CR 16	Experimental Investigation of Small Watershed Floods	6/68	2.00
CR 18	Experimental Investigation of Small Watershed Floods	6/70	5.00
CR 19	Hydraulics of Low Gradient Border Irrigation Systems	6/70	3.00
CR 20	Improving Efficiency in Agricultural Water Use	7/70	3.00
CR 23	A Systematic Treatment of the Problem of Infiltration	6/71	3.00
CR 24	Studies of the Atmospheric Water Balance	8/71	5.00
CR 25	Evaporation of Water as Related to Wind Barriers	6/71	5.00
CR 30	Geohydraulics at the Unconformity between Bedrock and Alluvial Aquifers	6/72	5.00
CR 35	An Application of Multi-Variate Analysis in Hydrology	8/72	5.00
CR 40	Selection of Test Variable for Minimal Time Detection of Basin REsponse to Natural or Induced Changes	12/72	3.00
CR 41	Groundwater Recharge as Affected by Surface Vegetation and Management	12/72	5.00
CR 42	Theory and Experiments in the Prediction of Small Watershed Response	12/72	5.00
CR 43	Experiments in Small Watershed Response	12/72	5.00
CR 49	Improvements in Moving Sprinkler Irrigation Systems for Conservation of Water	6/73	7.50
CR 50	Systematic Treatment of Infiltration with Applications	6/73	5.00

		Date	Price
CR 51	An Experimental Study of Soil Water Flow Systems Involving Hystersis	8/73	$ 7.00
CR 52	Consolidation of Irrigation Systems: Phase 1 - Engineering, Legal and Sociological Constraints and/or Facilitators	6/73	25.00
CR 53	Systematic Design of Legal Regulations for Optimal Surface-Groundwater Usage	8/73	7.00
CR 57	Snow-Air Interactions and Management of Mountain Watershed Snowpack	6/74	3.00
CR 63	Analysis of Colorado Precipitation	6/75	2.00
CR 64	Computer Estimates of Natural Recharge from Soil Moisture Data - High Plains of Colorado	1/76	4.00
CR 68	Systematic Design of Legal Regulations for Optimal Surface-Groundwater Usage, Phase 2	9/75	12.00
CR 69	Engineering and Ecological Evaluation of Antitranspirants for Increasing Runoff in Colorado Watersheds	9/75	2.50
CR 75	Physical and Economic Effects on the Local Agricultural Economy of Water Transfer to Cities	10/76	3.00
CR 76	Determination of Snow Depth and Water EQuivalent by Remote Sensing	6/76	2.00
CR 80	Achieving Urban Water Conservation, A Handbook	9/77	6.00
CR 81	Achieving Urban Water Conservation, Testing Community Acceptance	9/77	5.00
CR 82	Development of a Subsurface Hydrologic Model and Use for Integrated Management of Surface and Subsurface Water Resources	12/77	3.00
CR 87	Development of a Stream-Aquifer Model Suited for Management	8/78	3.00
CR 89	Synthesis and Calibration of a River Basin Water Management Model	10/78	3.00
CR 90	Models for System Water Planning with Special Reference to Water Reuse	6/78	5.00
CR 92	Hydraulic Conductivity of Mountain Soils	10/78	3.00
CR 94	Consolidation of Irrigation Systems: Phase II, Engineering, Economic, Legal and Sociological Requirements	5/80	8.00
CR 97	Water REquirements for Urban Lawns in Colorado	8/80	3.00
CR 99	Applications of Remote Sensing in Hydrology	9/80	3.00
CR 100	A Watershed Information System	9/80	4.00
CR 105	Municipal Water Use in Northern Colorado: Development of Efficiency-of-Use Criterion	9/80	4.00
CR 106	Urban Lawn Irrigation and Management Practices for Water Saving with Minimum Effect on Lawn Quality	9/80	6.00
IS 16	Annotated Bibliography on Trickle Irrigation	6/75	Free
IS 26	Water Use and Management in an Arid Region (Fort Collins, Colorado and Vicinity)	9/77	5.00
IS 31	The Denver Basin: Its Bedrock Aquifers	1/79	Free
IS 32	Snowpack Augmentation by Cloud Seeding in Colorado and Utah	8/79	4.00
IS 33	The Impacts of Improving Efficiency of Irrigation Systems on Water Availability	1/79	Free
IS 35	Federal Water Storage Projects: Pluses and Minuses	6/79	Free
IS 36	Cutting City Water Demand	5/79	Free
IS 37	Water for the South Platte Basin	3/79	Free
IS 39	Administration of the Small Watershed Program, 1955-1978 - An Analysis	8/79	3.00
TR 8	Models Designed to Efficiently Allocate Irrigation Water Use Based on Crop Response to Soil Moisture Stress	5/77	4.00
TR 13	Impact of Irrigation Efficiency Improvements on Water Availability in the South Platte River Basin	1/79	5.00
TR 15	Weekly Crop Consumptive Use and Precipitation in the Lower South Platte River Basin	2/79	Free
TR 16	Water Management Model for Front Range River Basins	4/79	5.00
TR 18	An Interactive River Basin Water Management Model: Synthesis and Application	8/79	4.00
TR 28	An Assessment of Water Use and Policies in Northern Colorado Cities	3/81	5.00
S-TB128	Evaluating Water Distributions of Sprinkler Irrigations Systems	1976	.85
S-TB 76	Introduction of Supplemental Irrigation Water	1965	.50

C. IDENTIFICATION AND CONTROL OF ENTERING POLLUTANTS

		Date	Price
CR 14	Hydrogeology and Water Quality Studies in the Cache La Poudre River Basin, Colorado	6/69	$ 5.00
CR 21	Waterfowl-Water Temperature Relations in Winter	6/70	5.00
CR 26	Water Temperature as a Quality Factor in the Use of Streams and Reservoirs	12/71	3.00
CR 31	Sedimentation and Contaminant Criteria for Watershed Planning and Management	6/72	5.00
CR 54	Geologic Factors in the Evaluation of Water Pollution Potential at Mountain Dwelling Sites	12/73	10.00
CR 59	A System for Geologic Evaluation of Pollution at Mountain Dwelling Sites	1/75	3.50
CR 60	Research Needs as Related to the Development of Sediment Standards in Rivers	3/75	3.00
CR 67	Toxic Heavy Metals in Groundwater of a Portion of the Front Range Mineral Belt	6/75	3.00
CR 71	Salt Transport in Soil Profiles with Application to Irrigation Return Flow - The Dissolution and Transport of Gypsum in Soils	1/76	5.00
CR 72	Toxic Heavy Metals in Groundwater of a Portion of the Front Range Mineral Belt	6/76	4.00
CR 79	Evaluation of the Storage of Diffuse Sources of Salinity in the Upper Colorado River Basin	9/77	4.00
CR 84	Pollutional Characteristics of Urban Stormwater Funoff	9/78	7.00
CR 104	Detection of Water Quality Changes Through Optimal Tests and Reliability of Tests	9/80	4.00

D. EFFECTS OF POLLUTANTS

CR 26	Water Temperature as a Quality Factor in the Use of Streams and Reservoirs	12/71	3.00
CR 67	Toxic Heavy Metals in Groundwater of a Portion of the Front Range Mineral Belt	6/75	3.00
CR 72	Toxic Heavy Metals in Groundwater of a Portion of the Front Range Mineral Belt	6/76	4.00
CR 73	Production of Mutant Plants Conducive to Salt Tolerance	7/76	4.00
CR 96	The Production of Agriculturally Useful Mutant Plants with Characteristics Conducive to Salt Tolerance and Efficient Water Utilization	10/79	3.00
CR 98	The Effect of Algal Inhibitors on Higher Plant Tissues	7/80	2.50
IS 25	Surveillance Data Plains Segment of the Cache La Poudre River, Colorado 1970-1977	1/78	5.00
S-GS870	Chemical Quality of Ground Water in the Prospect Valley Area, Colorado	1968	.25

E. TREATMENT AND DISPOSAL OF WASTES

CR 1	Bacterial Response to the Soil Environment	6/69	3.50
CR 2	Computer Simulation of Waste Transport in Groundwater Aquifers	6/69	2.00
CR 23	A Systematic Treatment of the Problem of Infiltration	6/71	3.00
CR 28	Combined Cooling and Bio-Treatment of Beet Sugar Factory Condenser Water Effluent	6/71	5.00
CR 32	Bacterial Movement Through Fractured Bedrock	7/72	5.00
CR 33	The Mechanism of Waste Treatment at Low Temperature, Part A: Microbiology	8/72	5.00
CR 34	The Mechanism of Waste Treatment at Low Temperature, Part B: Sanitary Engineering	8/72	5.00
CR 50	Systematic Treatment of Infiltration with Applications	6/73	5.00
CR 66	Individual Home Wastewater Characterization and Treatment	7/75	8.00
CR 77	Evaporation of Wastewater from Mountain Cabins	3/77	8.00
IS 4	Proceedings Workshop on Home Sewage Disposal in Colorado	6/72	Free
IS 9	Proceedings of the Symposium on Land Treatment and Secondary Effluent	11/73	3.00
IS 10	Proceedings of a Workshop on Revegatation of High-Altitude Disturbed Lands	7/74	3.00
IS 12	Recreation Benefits of Water Quality: Rocky Mountain National Park, South Platte River Basin, Colorado	5/78	4.00
IS 20	Proceedings, Second Workshop on Home Sewage Disposal in Colorado	9/75	3.00
IS 29	Third Workshop on Home Sewage Disposal in Colorado - Community Systems Management	7/78	4.00

		Date	Price
TR 17	Land Treatment of Municipal Sewage Effluent at Hayden, Colorado	10/77	$ 3.00

F. ECONOMIC EFFECTS

CR 10	Economics and Administration of Water Resources	6/69	2.00
CR 12	Economics and Administration of Water Resources	6/69	3.00
CR 13	Economics of Groundwater Development in the High Plains of Colorado	6/69	1.50
CR 44	Economic, Political, and Legal Aspects of Colorado Water Law	2/73	5.00
CR 46	Evaluation or Urban Water Management Policies in the Denver Metropolitan Area	6/73	7.50
CR 58	Primary Data on Economic Activity and Water Use in Prototype Oil Shale Development Areas of Colorado: An Initial Inquiry	6/74	2.00
CR 61	Economic and Institutional Analysis of Colorado Water Quality Management	6/74	2.00
CR 65	Urban Drainage and Flood Control Projects: Economic, Legal and Financial Aspects	7/75	10.00
CR 70	An Economic Analysis of Water Use in Colorado's Economy	12/75	5.00
CR 75	Physical and Economic Effects on the Local Agricultural Economy of Water Transfer to Cities	10/76	3.00
CR 91	Economic Benefits from Instream Flow in a Colorado Mountain Stream	6/79	5.00
CR 101	An Empirical Application of a Model for Estimating the Recreation Value of Instream Flow	10/80	3.00
CR 102	Measuring Benefits and the Economic Value of Water in Recreation on High Country Reservoirs	9/80	3.00
SR 3	Irrigation Development Potential in Colorado		4.00
IS 2	Economics of Water Quality--Salinity Pollution - Abridged Bibliography	6/71	11.00
IS 35	Federal Water Storage Projects: Pluses and Minuses	6/79	Free
TR 14	Economic Value of Benefits from Recreation at High Mountain Reservoirs	12/78	3.00
TR 19	An Economic Evaluation of the General Management for Yosemite National Park	3/80	4.00
TR 21	The Economy of Albany, Carbon, and Sweetwater Counties,Wyoming-Description & Analysis	1/81	3.00
TR 22	An Input-Output Study of the Upper Colorado Main Stem Region of Western Colorado	1/81	4.00
TR 23	The Economy of Moffat, Routt, & Rio Blanco Counties,Colorado-Description and Analysis	1/81	4.00
TR 24	The Survey-Based Input-Output Model as a Resource Planning Tool	1/81	3.00
TR 25	The Economy of Northwestern Colorado - Description and Analysis	1/81	4.00
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TR 27	An Input-Output Study of the Kremmling Region of Western Colorado	3/81	3.00
S-GS953	Economic Analysis of Water Use in Boulder, Larimer and Weld Counties, with Projections to 1980	1976	1.00
S-543S	Pump Irrigation on the Colorado High Plains	1970	.65
S-545S	Secondary Economic Effects of Irrigation on the Colorado High Plains	1971	.80

G. ECOSYSTEM EFFECTS

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CR 5	Soil Movement in an Alpine Area	6/69	1.00
CR 21	Waterfowl-Water Temperature Relations in Winter	6/70	5.00
CR 55	Water Law in Relation to Environmental Quality	3/74	30.00
CR 69	Engineering and Ecological Evaluation of Antitranspirants for Increasing Runoff in Colorado Watersheds	9/75	2.50
CR 93	Application of Geomorphic Principles to Environmental Management	2/80	3.00
SR 2	Environment and Colorado - A Handbook	1973	4.00
SR 4	Piceance Basin Inventory	12/71	10.00
IS 7	Wildlife and the Environment, Proceedings of Governor's Conference, March 1973	3/73	3.00
IS 10	Proceedings of a Workshop on Revegetation of High-Altitude Distrubed Lands	7/74	3.00
IS 11	Surface Rehabilitation of Land Distrubances Resulting from Oil Shale Development	6/74	Free
IS 14	Bibliography Pertinent to Disturbance and Rehabilitation of Alpine and Subalpine Lands in Southern Rocky Mountains	2/75	3.00
IS 21	Proceedings: High Altitude Revegetation Workshop No. 2	8/76	4.00
IS 25	Surveillance Data - Plains Segment of the Cache La Poudre River, Colorado 1970-77	1/78	5.00
IS 28	Proceedings of a Workshop on Revegetation of High-Altitude Distrubed Lands, No. 3	6/68	4.00
IS 40	Proceedings of the Workshop on Instream Flow Habitat Criteria and Modeling	12/79	5.00
IS 42	Proceedings: High-Altitude Revegetation Workshop No. 4	6/80	4.00
TR 1	Surface Rehabilitation of Land Distrubances Resulting from Oil Shale Development	6/74	10.00
TR 4	Vegetative Stabilization of Spent Oil Shales	12/74	3.00
TR 5	Revegetation of Distrubed Surface Soils in Various Vegetation Ecosystems of the Piceance Basin	12/74	4.25

H. PUBLIC WELFARE (SOCIAL GOALS) EFFECTS

CR 37	Searching the Social Science Literature on Water: A Guide to Selected Information Storage and Retrieval Systems - Preliminary Version	9/72	5.00
CR 38	Water Quality Management Decision in Colorado	6/72	5.00
CR 39	Institutions for Urban-Metropolitan Water Management Essays in Social Theory	11/72	5.00
CR 62	Feasibility and Potential of Enhancing Water Recreation Opportunities on High Country Reservoirs	6/75	4.00
CR 75	Physical and Economic Effects on the Local Agricultural Economy of Water Transfer to Cities	10/76	3.00
CR 78	Selecting and Planning High Country Reservoirs for Recreation Within a Multi-purpose Management Framework	7/77	6.00
CR 81	Achieving Urban Water Conservation: Testing Community Acceptance	9/77	5.00
CR 91	Economic Benefits from Instream Flow in a Colorado Mountain Stream	6/79	5.00
CR 95	Drought-Induced Problems and Responses of Small Towns and Rural Water Entities in Colorado: The 1976-1978 Drought	6/80	4.00
CR 103	Empirical Application of a Model for Estimating the Recreation Value of Water in Reservoirs Compared to Instream Flow	12/80	3.00
CR 106	Urban Lawn Irrigation and Management Practices for Water Saving with Minimum Effect on Lawn Quality	5/81	6.00

			Date	Price
IS	15	Proceedings of the Symposium on Water Policies on U.S. Irrigated Agriculture: Are Increased Acreages Needed to Meet Domestic or World Needs?	3/75	4.00
IS	18	Minimum Stream Flows and Lake Levels in Colorado	8/75	8.00
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IS	38	Public Participation Practices of the U.S. Army Corps of Engineers	7/79	3.00
TR	3	Implementation of the Federal Water Project Recreation Act in Colorado	6/74	Free
TR	11	Federal Water Recreation in Colorado: Comprehensive View and Analysis	1978	4.00
TR	12	Recreation Benefits of Water Quality: Rocky Mountain National Park, South Platte River Basin, Colorado	5/78	4.00

I. INSTITUTIONAL PROBLEMS

CR	11	Organizational Adaptation to Change in Public Objectives for Water Management of Cache La Poudre River System	6/69	3.00
CR	12	Economics and Administration of Water Resources	6/69	3.00
CR	17	An Exploration of Components Affecting and Limiting Policymaking Options in Local Water Agencies	11/68	5.00
CR	36	Urban-Metropolitan Institutions for Water Planning Development and Management	9/72	5.00
CR	39	Institutions for Urban-Metropolitan Water Management Essays in Social Theory	11/72	5.00
CR	44	Economic, Political and Legal Aspects of Colorado Water Law	2/73	5.00
CR	48	Institutional Requirements for Optimal Water Quality Management in Arid Urban Areas	6/73	3.00
CR	52	Consolidation of Irrigation Systems: Phase 1 - Engineering, Legal and Sociological Constraints and/or Facilitators	6/73	25.00
CR	55	Water Law in Relation to Environmental Quality	3/74	30.00
CR	65	Urban Drainage and Flood Control Projects: Economic, Legal and Financial Aspects	7/75	10.00
CR	68	Systematic Design of Legal Regulations for Optimal Surface-Groundwater Usage,Phase 2	9/75	12.00
CR	88	Institutional Arrangements for Effective Water Management in Colorado	11/78	4.00
CR	94	Consolidation of Irrigation Systems: Phase II - Engineering, Economic, Legal and Sociological Requirements	5/80	8.00
CR	95	Drought-Induced Problems and Responses of Small Towns and Rural Water Entities in Colorado: The 1976-1978 Drought	6/80	4.00
CR	105	Municipal Water Use in Northern Colorado: Development of Efficiency of Use Criterion	9/80	4.00
CR	106	Urban Lawn Irrigation and Management Practices for Water Saving with Minimum Effect on Lawn Quality	5/81	6.00
IS	6	Water Law and Its Relationship to Environmental Quality: Bibliography of Source Material	1/73	7.00
IS	12	Water Quality Control and Administration Laws and Regulations	1974	15.00
IS	22	Implementation of the National Flood Insurance Program in Larimer County,Colorado	9/76	4.00
IS	24	Factors Affecting Public Acceptance of Flood Insurance in Larimer and Weld Counties, Colorado	9/77	3.00
IS	34	San Luis Valley Water Problems: A Legal Perspective	1/79	4.00
IS	39	Administration of the Small Watershed Program, 1955-1978 - An Analysis	8/79	3.00
TR	28	An Assessment of Water Use and Policies in Northern Colorado Cities	3/81	5.00

		Date	Price
X-740A	Ground Water Management District Director's Handbook	1970	.25
SR 5	A Guide to Colorado Water Law	9/78	2.50

J. PLANNING AND ANALYSIS METHODOLOGY

CR 11	Organizational Adaptation to Change in Public Objectives for Water Management of Cache La Poudre River System	6/69	3.00
CR 13	Economics of Groundwater Development in the High Plains of Colorado	6/69	1.50
CR 17	An Exploration of Components Affecting and Limiting Policymaking Options in Local Water Agencies	11/68	5.00
CR 22	An Exploration of Components Affecting and Limiting Policymaking Options in Local Water Agencies	6/70	3.00
CR 27	Local Water Agencies, Communication Patterns, and the Planning Process	9/71	5.00
CR 37	Searching the Social Science Literature on Water: A Guide to Selected Information Storage and Retrieval Systems - Preliminary Version	9/72	5.00
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CR 45	Mathematical Modeling of Water Management Strategies in Urbanizing River Basins	6/73	7.50
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CR 61	Economic and Institutional Analysis of Colorado Water Quality Management	3/75	5.00
CR 62	Feasibility and Potential of Enhancing Water Recreation Opportunities on High Country Reservoirs	6/75	4.00
CR 70	An Economic Analysis of Water Use in Colorado's Economy	12/75	5.00
CR 74	The Relevance of Technological Change in Long Term Water Resources Planning	10/76	3.50
CR 75	Physical and Economic Effects on the Local Agricultural Economy of Water Transfer to Cities	10/76	3.00
CR 78	Selecting and Planning High Country Reservoirs for Recreation Within a Multi-purpose Management Framework	7/77	6.00
CR 82	Development of a Subsurface Hydrologic Model and Use for Integrated Management of Surface and Subsurface Water Resources	12/77	3.00
CR 85	Development of a Drainage and Flood Control Management Program for Urbanizing Communities - Part I	9/78	2.00
CR 86	Development of a Drainage and Flood Control Management Program for Urbanizing Communities - Part II	9/78	7.00
CR 87	Development of a Stream-Aquifer Model Suited for Management	9/78	3.00
CR 89	Synthesis and Calibration of a River Basin Water Management Model	10/78	3.00
CR 90	Models for System Water Planning with Special Reference to Water Reuse	6/78	5.00
CR 91	Economic Benefits from Instream Flow in a Colorado Mountain Stream	6/79	5.00
CR 93	Application of Geomorphic Principles to Environmental Management	2/80	3.00
CR 101	An Empirical Application of a Model for Estimating the Recreation Value of Instream Flow	10/80	3.00
CR 102	Measuring Benefits and the Economic Value of Water in Recreation on High Country Reservoirs	9/80	3.00
CR 103	Empirical Application of a Model for Estimating the Recreation Value of Water in Reservoirs Compared to Instream Flow	12/80	3.00
CR 105	Municipal Water Use in Northern Colorado: Development of Efficiency-of-Use Criterion	9/80	4.00
CR 106	Urban Lawn Irrigation and Management Practices for Water Saving with Minimum Effect on Lawn Quality	5/81	6.00
SR 1	Design of Water and Wastewater Systems for Rapid Growth Areas (Boom Towns - Mountain Resorts)	7/76	4.00
SR 3	Irrigation Development Potential in Colorado	5/77	4.00

		Date	Price
IS 19	The Environmental Quality Objective of Principles and Standards for Planning	8/75	7.00
IS 38	Public Participation Practices of the U.S. Army Corps of Engineers	7/79	3.00
IS 40	Proceedings of the Workshop on Instream Flow Habitat Criteria and Modeling	12/79	5.00
IS 43	An Evaluation of the Cache La Poudre Wild and Scenic River Draft Environmental Impact Statement and Study Report	8/80	5.00
TR 6	Colorado Environmental Data Systems (abridged)	10/72	5.00
TR 7	Manual for Training in the Application of Principles and Standards (Water Resources Council)	12/74	10.00
TR 8	Models Designed to Efficiently Allocate Irrigation Water Use Based on Crop Response to Soil Moisture Stress	5/77	4.00
TR 9	The 1972 Federal Water Pollution Control Act's Area-Wide Planning Provision: Has Executive Implementation Met Congressional Intent?	11/77	5.00
TR 10	Efficiency of Wastewater Disposal in Mountain Areas	1/78	5.00
TR 18	An Interactive River Basin Water Management Model: Synthesis and Application	3/80	4.00
TR 20	Development of Methodologies for Determining Optimal Water Storage Strategies	9/80	2.00
TR 26	An Input-Output Analysis of Sportsman Expenditures in Colorado	1/81	4.00
S-TB127	A Simulation Model for Analyzing Timber-Water Joint Production in the Colorado Rockies	1975	1.25

K. WATER CONVEYANCE AND CONTROL WORKS

CR 6	Stabilization of Alluvial Channels	6/69	3.00
CR 7	Stability of Slopes with Seepage	6/69	3.00
SR 1	Design of Water and Wastewater Systems for Rapid Growth Areas (Boom Towns - Mountain Resorts)	6/76	4.00
S-496S	Farm Irrigation Structures	1966	.50
S-TB76	Parshall Measuring Flumes of Small Sizes	1957	.25
X-426A	Parshall Flumes of Large Size	1961	.50
S-TB120	Selection and Installation of Cutthroat Flumes for Measuring Irrigation and Drainage Water	1976	1.25
S-TB126	A Shunt-Line Metering System for Irrigation Wells	1977	.75
S-522S	Weed Seed and Trash Screens for Irrigation Water	1966	.35

L. OTHER

			Date	Price
IS	1	Inventory of Environmental Resources Research in Progress - Colorado State University	1/71	Free
IS	3	Inventory of Environmental Resources Research in Progress - Colorado State University	7/72	Free
IS	5	Directory of Environmental Research Faculty - Colorado State University	12/72	Free
IS	8	Inventory of Current Water Resources Research at Colorado State University	7/73	Free
IS	23	Inventory of Colorado's Front Range Mountain Reservoirs	5/77	5.00
IS	30	The Larimer-Weld Council of Governments 208 Water Quality Plan: An Assessment and Suggestions for Future Directions	8/78	2.00
TR	2	Estimated Average Annual Water Balance for Piceance and Yellow Creek Watersheds	8/74	Free
S-504S		Colorado's Ground Water Problems	1967	.35
S-512S		Ground Water in the Bijou Valley	1961	.25
S-GS757		Public Water Supplies of Colorado 1959-1960	1961	1.25