ECONOMIC IMPACT OF ALTERNATIVE RESOLUTIONS OF NEW MEXICO PUEBLO INDIAN WATER RIGHTS
Volume III

Economic Impacts of Alternative Resolutions of Pueblo Indian Reserved Rights in the Rio Grande Basin

by

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PREFACE

This report represents one of three volumes that contain results of a three-year research project entitled "The Economic Impact of Alternative Resolutions of New Mexico Pueblo Indian Water Rights." The project was funded by the New Mexico Water Resources Research Institute through the U.S. Department of the Interior, Office of Water Research and Technology.

Volume I, Pueblo Indian Water Rights: Struggle for a Precious Resource, discusses the various legal doctrines that may form the basis for ultimately determining the priority and quantification of Pueblo Indian water rights. This volume is available in hardcover from the University of Arizona Press, 1615 E. Speedway, Tucson, AZ 85719.

Volume II, An Economic and Demographic Profile of New Mexico Pueblo Indians: An Historical Perspective, WRRI Report No. 201, provides a reference source for the specific implementation of legal scenarios with respect to the quantification of Pueblo Indian water rights, whether it be a historic use, expanding right or practicably irrigable acreage standard. This volume is available from the New Mexico Water Resources Research Institute, Box 3167, NMSU, Las Cruces, NM 88003. Appendices D.1-D.14, which are listed in the table of contents, profile each pueblo by population, land use, and economy. Each appendix carries a copy charge and is available separately as WRRI Report No. 201-D.1-D.14.

Volume III, Economic Impacts of Alternative Resolutions of Pueblo Indian Reserved Rights in the Rio Grande Basin, WRRI Report No. 202, discusses the economic results of the simulation of several alternative resolutions of Pueblo Indian water rights using an input/output model of the Upper Rio Grande basin. This volume also is available from the New Mexico Water Resources Research Institute. The technical appendix to Volume III carries a copy charge and is published separately as WRRI Report No. 202-TA.

ABSTRACTS

Volume I

Pueblo Indian Water Rights: Struggle for a Precious Resource, explores the richness and diversity of legal theories applicable to the water rights of the New Mexico Pueblo Indian, the original settlers of the Upper Rio Grande. Under each theory the key issues are the priority right in time of the Pueblo Indians and the quantity of the water right. Three separate, but applicable legal doctrines--aboriginal, treaty and Winters--are discussed along with the complications arising from the Pueblo Lands Acts of 1924 and 1933. Aboriginal water rights theory reflects the status of the Pueblo Indians as the original settlers of this region and give the Pueblo Indians a paramount water right priority in time. However, the actual quantity which arises with this oboriginal right remains debatable under either an historic use or expanding right doctrine.

The treaty right theory rests on the applicability of Spanish and Mexican water law to the Pueblo Indians based on their status as Mexican citizens at the time of the Treaty of Guadalupe-Hidalgo. This treaty right theory would provide the Pueblo Indians a priority based upon the principles of the prior appropriation doctrine with quantification based upon an expanding need principal which considers the rights of third parties and community equity. The Winters right rests upon a reservation right as developed in the Winters v. United States and Arizona v. California decisions. Priority of the Pueblo Indian water right would be determined by the date of "reservation" and the quantity by the principle of "practicably irrigable acres."

The Pueblo Lands Act of 1924 and 1933 have complicated the entire issue of Pueblo Indian water rights. The State of New Mexico argues that this law limited the Pueblo Indian water rights by the water rights appurtenant to non-Indian lands. However, the Pueblo Indians argue that this law can be interpreted as giving the Pueblo Indians an aboriginal water right with a practicably irrigable acreage standard for quantifying those rights. Six different new inerpretations of Pueblo Indian water rights are explored as arising from the Pueblo Land Acts.

This volume concludes with a presentation of the historical evidence of the inability to resolve the issue of Pueblo Indian water rights, a discussion of the physical parameters of a judicial resolution, and an outline of the legal and political realities which represent potent obstacles to an eventual resolution. In the concluding chapter a resolution is suggested based upon principles of equity and fairness but which can be accommodated within the basic framework of existing state water laws. Existing water rights can be purchased by the federal government and given to the Pueblo Indians in accordance with their expanding needs as a community.

Volume II

An Economic and Demographic Profile of New Mexico Pueblo Indians: An Historical Perspective, provides a reference for the specific implementation of Pueblo Indian water rights quantification based upon different legal scenarios. As explored in Volume I, quantification can take the form of historic use of water, an expanding use to water based upon an expanding Pueblo economy and/or practicably irrigable acres. In each instance specific data are required concerning each Pueblo for determination of an appropriate quantity of water right.

Volume II, then, presents a comprehensive picture of the Pueblo Indian economy from earliest recorded history to the present day. Historical data series are included for population, irrigated acres, and where possible, crop values and livestock inventory. A thorough search of all available literature on the Pueblo Indians from the history, political science, anthropology and economics fields was made. The data are sometimes conflicting and many gaps in the historical series occur. The quality of data on the New Mexico Pueblo Indians is quite inadequate. One expects this of their earliest recorded history, but it is true even of data from the 1980 Census. Substantial revisions of the 1980 population estimates were made in 1982, and there is much confusion in the data between Pueblo Indians living on and off the reservation. Recent federal welfare assistance programs have provided incentives for distortions in Pueblo Indian data. The Pueblo Indians themselves measure labor force and unemployment data which are used in the allocation of federal assistance funds. There is a great incentive to overstate unemployment in order to receive a geater share of federal assistance. Thus, you observe great discrepancy between data reported by the Pueblo Indians through the Bureau of Indian Affairs and data reported by the New Mexico Employment Security Commission and the U.S. Department of Labor.

Volume III

Economic Impacts of Alternative Resolutions, discusses the specific economic consequences of different legal outcomes of Pueblo Indian water rights in the Upper Rio Grande basin. These impacts, although expressed in different economic forms according to the scenario modeled, describe the social opportunities precluded by specific alternative quantifications of Pueblo Indian water rights. The specific impacts are described using solutions of an input/output linear programming model of five regions in New Mexico, with each region consisting of 24 economic sectors. The model is specified for three regions in the Upper Rio Grande basin (i.e., above Elephant Butte Reservoir), with constraint on the model solution provided by available water resources.

The analysis projects economic growth and other changes affecting the region to the year 2000, with the model originally calibrated to reflect observed economic conditions in 1975. Naturally available water supplies in the Upper Rio Grande are augmented in the 2000 projection by the San Juan-Chama transmountain diversion. The baseline solution (before change in Pueblo Indian water rights over 1975 levels) describes output in the sectors of each Upper Basin region and concludes that no absolute water scarcity condition will exist in the Upper Rio Grande Region which would constrain this economic development projection. Alternative scenarios from these baseline conditions asociated with increased Pueblo Indian agriculture generally describe increases in output and water scarcity. An alternative scenario, describing the leasing of water by the Pueblo Indians, shows specific economic impacts which are dependent on the lease price charged. In general, the model describes changes in the geographic distribution and use of available water resources in the Upper Rio Grande basin. On the whole, the economic impacts associated with the specific quantifications of Pueblo Indian water rights appear at worst neutral, with the potential for positive net economic benefits in the Upper Basin associated with specific resolution scenarios. These economic impacts are described as changes in output and water utilization by Upper Basin society (both Indian and non-Indian), but are unable to assess the cultural impacts associated with the specific Pueblo Indian water right scenario modeled.

THE ECONOMIC IMPACTS OF

ALTERNATIVE PUEBLO INDIAN WATER

RIGHT RESOLUTIONS IN NEW MEXICO

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The economic analysis of alternative Pueblo Indian water right resolutions relies on a 120 sector input-output linear programming model depicting five geographic regions in New Mexico. The model is constrained by water availability in each region and the linear program algorithm maximizes the value-added by economic activities required to satisfy the specified final demand scenarios.

Alternative Pueblo Indian water right resolutions were incorporated in the model by modifications to the available water resource constraints, and allowances for source of supply and inter-regional water supply transfer activities in the model. Specification of resolution scenarios in the model required analysis of the legal foundations and likely forms of actual implementation provided by the possible claims to Pueblo Indian water rights.

The results of the modeling activities demonstrate that all resolutions of Pueblo Indian water right claims provide favorable

economic consequences to the Upper Rio Grande and New Mexico economies. The rigorous statement of the resultant positive economic impacts provided by alternative resolution scenarios interpreted in an inter-regional input-output linear programming model is supported by economic theory and intuitive reasoning with respect to uncertainty and resource constraints imposed by failure to resolve Pueblo Indian water right claims.

ACKNOWLEDGMENTS

Funding for the research described herein was provided under contract by the New Mexico Water Resources Research Institute and the United States Department of Interior. These research funds were administered through the Bureau of Business and Economic Research at the University of New Mexico. I must express a special thanks to Dr. F. Lee Brown and Dr. M. Brian McDonald, as Directors of the Bureau of Business and Economic Research during the proposal and administration of this research, for their cooperation, assistance and guidance which has allowed this dissertation to be completed.

I must also express a great appreciation for the valuable and dedicated assistance of Dr. Shaul Ben-David of the Department of Economics, University of New Mexico, and Dr. Fredrick Roach of Los Alamos National Laboratories. Their participation in the project made possible the updating and revision of the input-output linear programming model which serves as the foundation of the analysis contained herein, and their timely criticism added significantly to the model's implementation and interpretation.

The assistance and cooperation of the staff of the New Mexico State Engineers Office must also be acknowledged, and particularly the aid provided by Mr. Earl F. Sorenson and Mr. Brian Wilson of the Data Acquisition and Assessment Bureau. In addition, Mr. Peter White of the State Engineers Legal Services Division was of valuable assistance in providing details of the pending Aamodt litigation.

Others who must be acknowledged for their assistance in this research include numerous staff members of the U.S. Geological Survey, and in particular, Mr. Doug Makado, Mr. Robert White, and Mr. Glenn A. Hearn. From the Bureau of Reclamation I am grateful to Mr. Ralph E. Hauke and Mr. Gary Roe. The City of Albuquerque Water Resources Department must also be recognized for their assistance, and in particular, Mr. Paul Noland, Mr. James Gill, and Mr. Greg Duty. I am sincerely indebted to these individuals and administrative agencies for their cooperation and assistance in this research endeavor.

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CHAPTER I

AN INTRODUCTION TO THE ECONOMIC PROBLEMS OF PUEBLO INDIAN WATER RIGHTS IN THE UPPER RIO GRANDE BASIN

A. Background

Water has been the source of life and prosperity in the Upper Rio Grande Basin since the time of the Pueblo Indians' prehistoric ancestors. The necessity of the water resource to these aboriginal cultures has expression in the religious ceremonies of these people, and has served as the vital link in the consecutive centuries of the region's inhabitance by the agriculturally sustained Pueblo Indians.

However, in recent years the competition for the water resources of the Upper Rio Grande Basin has become increasingly intense and has forced specific quantification of property rights to the resource. Current use of the basin's water resources is thought to be (generally) equal to the annually renewed supplies. The Pueblo Indians of the region now assert claims to water rights greater than their current uses. If resolution of these Pueblo Indian water right claims results in the assignment of additional rights to the Pueblos, then some existing users of water will likely be forced to curtail their current appropriations. Thus, the assertion of additional Pueblo Indian water rights poses the question of economic impacts which may be associated with resolution of these claimed rights. The research described herein addresses the specific possible resolutions of these competing water right claims, and provides a methodology by which the economic impacts of the alternative Pueblo Indian water right claims may be assessed.

An illustration of the Upper Rio Grande Basin in New Mexico is provided by Map 1.1. Ever since the region's first exploration by non-Indians in the 16th century there have been claims to the water resources which competed with the aboriginal culture's claims. Jurisdictional claims over all the water resources of the region by the external sovereigns of Spain, Mexico and the United States have resulted in the neglect of the rights to the water resource upon which the native Indian culture is historically dependent.

This neglect is well illustrated by the following passage from the 1911 Annual Report of the Pueblo Day School to the Commissioner of Indian Affairs:

> The Indian's title to water is not yet perfected, but preliminary steps have been taken to have their rights adjudicated by the Courts of New Mexico in all the Pueblos and it is expected that their rights will be finally settled in all cases at as early a date as they can be presented and reached by the Courts.[1]

Nearly three-quarters of a century later the Pueblo Indians remain a protected people with unperfected title to the water which has nurtured their civilizations over the centuries.

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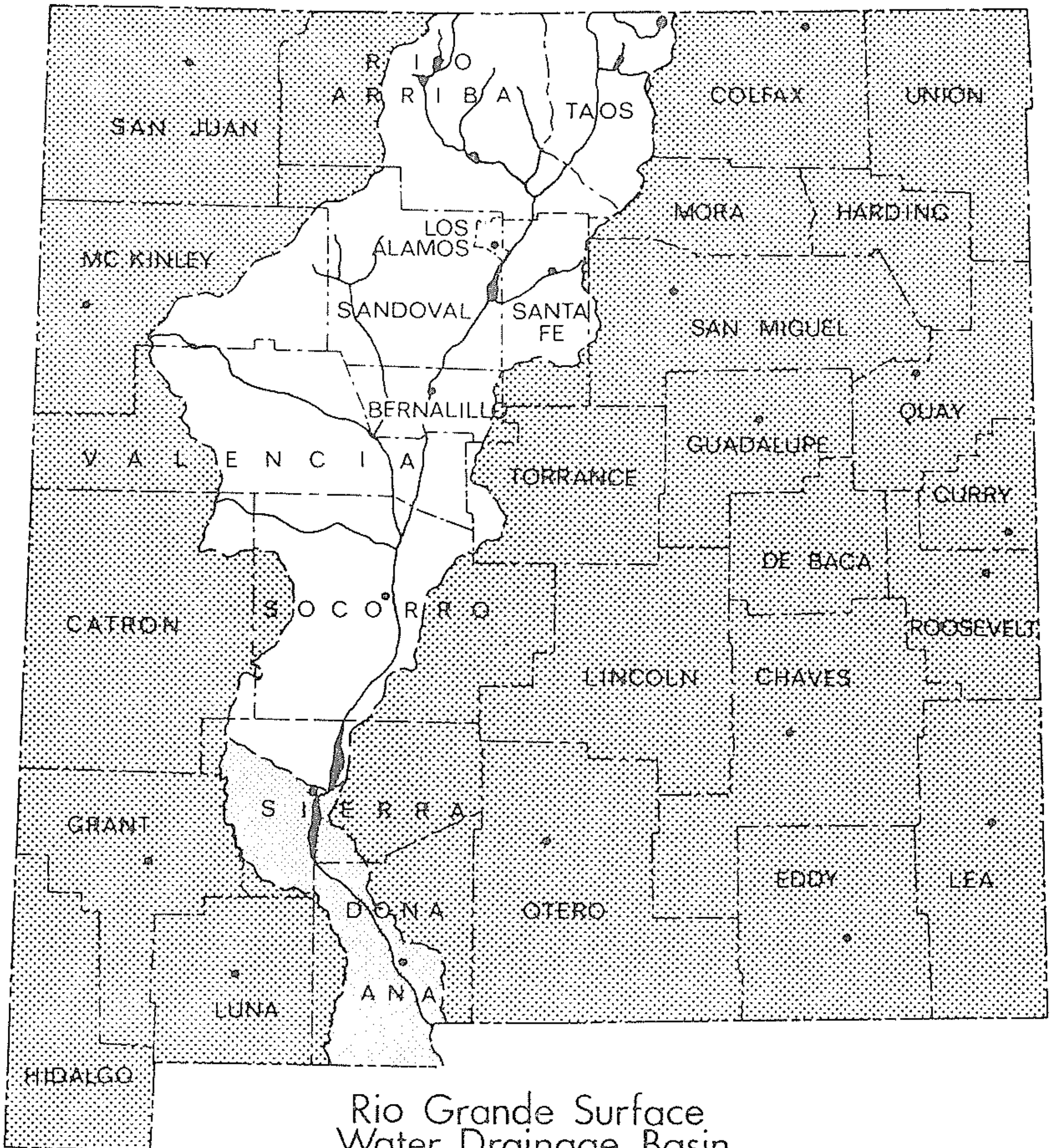
1 Bureau of Indian Affairs, "Annual Report of the Pueblo Day School to the Commissioner of Indian Affairs," Albuquerque: U.S. Department of the Interior, 1911, p. 11.



Rio Grande Surface
Water Drainage Basin

Legend

☐ Upper Rio Grande Basin

☐ Lower Rio Grande Basin

☐ Other

Prior to 1960 the water right claims of the Upper Rio Grande Pueblos were affected by three major actions of their trustee, the United States government. The first of these, the Pueblo Lands Act of 1924,[2] was designed to compensate the Pueblos for the encroachment and adverse possession by non-Indian settlers on the protected Pueblo lands. This Act provided insufficient compensation, and was followed by the Pueblo Lands Act of 1933[3] which provided additional compensation to the Pueblos for the lands lost by the non-Indian encroachment. The relinquishing of these Pueblo lands also resulted in the forfeiture of potential water rights which could be made appurtenant to the irrigable land lost. The Pueblo water rights have been negatively impacted by other non-Indian development; however, it must also be pointed out that the Pueblos have benefited from the development provided by non-Indian society as well. Most prominent of these benefits has been the participation of six Pueblos in the Middle Rio Grande Conservancy District, a reclamation project started in the late 1920s which provides water to some 8,847 acres of irrigable Pueblo land.

Clearly the neglect of the Pueblo Indian water rights by the trustee has not been absolute, but for the most part the concern for protection of Pueblo water rights has been ancillary to the general

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2 Act of June 7, 1924, Ch. 331, 43 Stat. 636.

3 Act of May 31, 1933, Ch. 45, 48 Stat. 108.

development of the region's water resources. In recent years the Pueblo Indians have become impatient and have filed several law suits asserting their claims to the waters of the Upper Rio Grande. The first of these suits, commonly referred to as the Aamodt case,[4] was filed in 1966 by four northern Pueblos seeking adjudication of water rights in the Pojoaque River basin, a tributary of the Rio Grande above Santa Fe. At the present time this case remains only partially resolved. Water right claims have recently been filed by Pueblos on the Jemez River and Rio San Jose, both of which are tributary to the Rio Grande.[5] Clarification has also been recently sought by the Pueblos included within the Middle Rio Grande Conservancy District regarding first priority releases of their water rights from the District's storage reservoirs.[6]

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4 New Mexico v. Aamodt, 537 F.2d 1102 (10th Cir. 1976).

5 United States v. Abiysleman, U.S. District Court CIV No. 83-1041BB, filed by the United States on behalf of Santa Ana and Zia Pueblos to adjudicate water rights on the Jemez River. United States v. Bluewater-Toltec Irrigation District, U.S. District Court CIV No. 83-1466 BB, filed by the United States on behalf of itself and Laguna and Acoma Pueblos relating to the adjudication of water rights in the Rio San Jose stream system. The later case, filed December 22, 11982, has already had a complex history of removal and remand between federal and state courts.

6 In early 1981, six Pueblos took steps to assure the proper storage and release of water for Pueblo lands served by the Middle Rio Grande Conservancy District, particularly recognizing the Pueblo's paramount rights to the water. It seems an amicable understanding has been reached by the parties without litigation.

B. Water Supply Conditions

The water resource has served all cultures which have settled in the region, and under the laws of all the independent sovereigns (including the Pueblo Indians) the right to use of the resource is protected. Although the specific protection provided is not the same under each of the four possible jurisdictions (i.e., Indian, Spanish, Mexican and American), there is common to all an acceptance of a limited water resource supply. In the period between the 1848 Treaty of Guadalupe Hildago,[7] under which the jurisdictional claim of the United States arose, and the mid-1920s, the water resources of the Upper Basin became fully utilized and subject to downstream obligation. Indeed, the river itself responded to a condition of overdevelopment during this period by making much previously irrigable land unproductive as the result of a rising water table.[8]

During this time water scarcity conditions caused institutional constraints to be imposed on the water available in the Upper Basin. The 1906 Treaty between the United States and Mexico[9] guarantees the

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7 Treaty of Guadalupe Hildago, February 2, 1848, United States-Mexico, 9 Stat. 922, T.S. No. 207.

8 This is particularly true of the region of the Upper Basin south of Santa Fe. For further discussion of this problem and its remedy, see M. Brian McDonald, John Tysseling, Michael Browde, and Lee Brown, Case Studies in the Development of New Mexico Water Resources Institutions: The Middle Rio Grande Conservancy District and Urban Water Pricing, Report No. 131, Las Cruces, New Mexico: New Mexico Water Resources Research Institute, 1981.

9 Convention between the United States of America and Mexico, May 21, 1906, 34 Stat. 785, T.S. No. 455.

annual delivery of 60,000 acre-feet in the Rio Grande at the head of the Mexican Canal near El Paso. The Rio Grande Compact,[10] ratified in 1939, provides for an equitable apportionment of the available surface waters of the Rio Grande among Colorado, New Mexico and Texas. Finally, the New Mexico State Engineer's declaration of the Rio Grande Underground Water Basin in 1956 rigidly controls the use of groundwater within the Upper Basin and has necessarily constrained groundwater development in this region to protect existing surface water users.

Two major water resource projects were undertaken in response to water scarcity condition in the Upper Basin. The Middle Rio Grande project in the 1930s resulted in extensive control of the river's seasonal flows and allowed for the development of significant additional lands by drainage and flood control measures. The San Juan-Chama transbasin diversion project, authorized in 1962, has augmented the water supplies of the Upper Rio Grande by some 30 percent. However, based upon growth anticipated for this region at some future time water scarcity will again prevail.

C. Research Overview

The research undertaken and described herein models interrelated economic activity throughout the state with particular focus on the

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10 Rio Grande Compact (1938), N.M. Stat. Ann. §5-34-3 (1953), Act of May 31, 1939, ch. 155, 53 Stat. 785.

Upper Rio Grande basin. The model depicts the available water resource constraint, the required use of water in economic activity, and the potential that economic growth in the Upper Basin could be limited by the water resource. Incorporated in this model are mechanisms for the transfer of water entitlements and allocated resources among competing users. Most important, though, is the model's analytical application for identification and expression of the economic impacts associated with alternative resolutions of Pueblo Indian water rights.

The model depicts New Mexico as an independent economic entity which seeks to maximize the (value-added) benefits of economic activity without exceeding the available water supply constraint, and so as to produce output sufficient to satisfy both the intermediate and final demands for all goods and services modeled. This equilibrium model allocates the available water to successively less efficient users of the resource, and allows for the projection of future economic conditions in the Upper Basin. In describing the impacts of alternative Pueblo water right resolutions the model allows interpretation of the effects in a "qualitative" manner.

That is, the model is not intended for specific economic forecasting, projection of output from specific sectors, or for predicting the specific quantitative outcomes. Rather, it is merely designed for comparing <u>relative</u> effects of the alternative possible resolutions of Pueblo water right claims in the Upper Rio Grande

Basin. The impacts identified are associated with specific regions of the Upper Basin, major economic sectors and different levels of Pueblo Indian water right quantification. However, the "best use" of the results are to provide qualitative information indicating both the directions (i.e., positive or negative) and general magnitude of the impacts anticipated.

The model provides significant information regarding the economic impacts which can be anticipated; but, as will be described, also provides significant additional information of both economic and noneconomic content.

Economic analysis has seen an increasing role in the quantification and perfection of Indian water rights throughout the West in recent years. The conceptual form of analysis described herein contrasts dramatically, though, with the previous forms of economic analysis employed.

The previous analyses have investigated and debated the microeconomic "feasibility" of specific Indian water projects as elements of the adjudication of these water right entitlements.[11]

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11 The continuing resolution of the Aamodt case has investigated extensively the benefit/cost feasibility of the specific irrigation projects discussed. The methodology used in Aamodt is largely derivative of the "practicably irrigable acreage" standards defined in Arizona v. California, (373 U.S. 546 (1963)), most recently clarified by the report of Elbert P. Tuttle, Special Master filed with the U.S. Supreme Court February 22, 1982. Numerous other Indian water right cases throughout the West also rely on similar tests of feasibility with regard to quantification of asserted rights.

Economists performing these analyses are necessarily advocates of their specific quantification and feasibility methodologies.[12] The method relied upon herein is properly characterized as a macro-economic resource constrained model designed for regional analysis of alternative forms of Indian water rights resolution. The analysis adopts no specific advocacy, except in its specification of alternative Pueblo Indian water right resolutions. The analysis is of the economic effects on the regions' society -- both Indian and non-Indian -- associated with specific alternative resolutions of Pueblo Indian water rights.

The goal of this economic analysis is to investigate the interaction between economic agents in the New Mexico economy with particular focus on the Upper Rio Grande basin. The specific (possible) resolutions of Pueblo Indian water right claims are imposed on this system of economic actors, and the analysis provides a description of how these agents would react based on a specific pattern of rational behavior. In this model the prescribed behavior maximizes the net benefits to society from use of the water resource. Indeed,

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12 The most extensive discussion of alternative methodologies for determination of benefit/cost feasibility regarding Indian water rights is found in the Report of Teno Ronocalio, Special Master, In Re: The General Adjudication of All Rights to Use Water in the Big Horn River System and All Other Sources, State of Wyoming (Concerning Reserve Water Right Claims By and On Behalf of the Tribes of the Wind River Indian Reservation, Wyoming), Civil No. 4993 (Wyoming District Court, 5th District, December 15, 1982).

other social goals should ideally be allowed expression as well; but, within the limitations of the economic models available, this maximizing behavior seemed the most pertinent in addressing the questions posed.

It is important to reiterate that this investigation is unique in the historic application of economic analysis to Indian water right questions.[13] This contrasts with previous economic analyses, specifically, in its expression of both the questions posed by Indian water rights and the social consequences of the implementation of these water rights. This research adopts a broader, macro perspective in discussing the resolution of Indian water rights claims. Whereas previous studies have been largely micro analyses of projected benefits and costs as evidence of "feasibility," this regional analyses assumes feasibility (over a broad range of definitions) and investigates the economic effects of alternative resolution scenarios.

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13 To the author's knowledge no previous economic investigation of Indian water rights has addressed questions of regional economic impacts associated with alternative resolution. The only other application of the analytical technique (i.e., linear programming) to Indian water right questions described maximization of economic benefits within a single reservation from alternative irrigation facilities and cropping patterns, and must be characterized as a microeconomic feasibility analysis and contrasted dramatically with our application of the analytical technique (see James P. Merchant and David M. Dornbusch, The Importance of Water Supply to Indian Economic Development, prepared for the Office of Water Research and Technology, U.S. Department of Interior, San Francisco: David M. Dornbusch and Company, Inc., 1977).

D. The Dimension of Pueblo Indian Water Right Problems

The water resources of the Upper Rio Grande are derived principally from the annual melting of snowpacks in the southern Rocky Mountains. The spring runoff is supplemented by very limited, but occasionally intense, summer showers. This relatively assured source of water supply first lured the Pueblo Indians to establish settlements along the river's banks and initiate the first irrigated agricultural enterprises found in the North American continent. Economic historians have concluded that it is the water resource which has limited the economic development of these people, and have asserted that it was the lack of water which forced the relocation of these ancient cultures from the high and dry plains of the present-day Four Corners region to the valleys of the Upper Rio Grande.[14] The monuments and homes of the long abandoned ancient civilizations can today be visited at Mesa Verde, Chaco Canyon and other less protected archeological sites.

Very impressed by the extent of the Pueblo Indians' civilization and development, the Spanish conquest of the region in the Seventeenth Century resulted in Spanish colonization sustained by the same water resource and agricultural enterprises. Through the centuries of

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14 Shaul Ben-David, F. Lee Brown, William D. Schulze, and Jenifer Zamora, Water as the Limiting Factor in Indian Economic Development, Report No. 36, New Mexico Water Resources Research Institute, Las Cruces, New Mexico; New Mexico State University, 1974.

development the Hispanic communities of the Upper Basin developed formal social structures based on the needs of the community acequia. Indeed, in several small communities of the Upper Rio Grande Basin these social structures persist, with annual community ditch cleaning and preparation of individual family plots under the direction of the acequia's Mayordomo.[15]

All cultures of the region have been highly dependent upon irrigated agriculture for survival through the many years of inhabitance, and the rural communities have been the foundation upon which nearly all development of the water resource has been based. On the many small tributary streams which carry water from the high mountains numerous rural communities remain; although in many of these communities it is the familia and rural life-style which perpetuates continued inhabitance, as yields from agriculture in the region are no longer able to provide for even the subsistence requirements of the present day residents. With the relocation of the Anglo cultures from other regions of the United States the economy of the Upper Basin has become less dependent on irrigated agriculture. Yet even today in the center of the Albuquerque metropolitan area there remains a substantial community of "agriculturalists" who, at a minimum, are attempting

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15 An interesting discussion of the Acequias of Northern New Mexico is provided in Phil Lavato, Las Acequias Del Norte, Technical Report Number 1, Four Corners Regional Commission, Taos, New Mexico, 1974.

to preserve the rural life-style. In some cases these irrigation enterprises are viable in an economic sense. However, the majority of the individuals who continue to irrigate in this increasingly urban area are only part-time or "gentlemen" farmers.[16]

The slow economic diversification of the Upper Basin has left agriculture in a position of significant political power, a power in the middle Rio Grande valley perpetuated by the Middle Rio Grande Conservancy District. The shift from the rural life-style to an urban life-style in particular counties of the Upper Rio Grande Basin is clearly illustrated in Table 1.1. What is most evident in this data is the relative stability of Taos County, Rio Arriba County, and Socorro County, as well as the dramatic growth in the population of Santa Fe and Bernalillo Counties, particularly in the past 30 years. In the basin as a whole, population has grown during the past 60 years at a remarkable 3.07 percent (compound) annual rate, yet during this same period agriculture has remained at approximately the same acreage. Thus, the pattern of increasing urbanization and economic diversification is clear. The simplicity of this description belies many of the changing water use patterns and water scarcity conditions which has largely shaped the present use of the Upper Basin's water resources.

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16 M. Brian McDonald, et al., supra, note 8.

TABLE 1.1

UPPER RIO GRANDE BASIN POPULATION
1920, 1950 AND 1980

County	1920	1950	1980
Taos	12,773	17,146	19,456
Rio Arriba	19,552	24,997	29,282
Los Alamos	N/A	10,476	17,599
Santa Fe	15,030[1]	38,153	75,360
Sandoval	8,863[1]	12,438	34,799
Bernalillo	29,855	145,673	420,164
Valencia	13,795	22,481	61,115
Socorro	9,611[2]	9,670	12,566
TOTALS	109,479	281,034	670,341

N/A Not Available

1 Includes a portion of what would become Los Alamos County.
2 This is the 1930 population of Socorro County. The 1920 population is reported as 14,061, but includes a portion of what would become Catron County.

Source: Bureau of the Census, U.S. Department of Commerce, Washington, D.C.

The Upper Rio Grande Basin is diverse in many respects. The climate changes dramatically from north to south, with an average frost-free period in agricultural regions of Rio Arriba County of 106 days (Chama), to an average frost-free period in Socorro County (the southernmost of the Upper Basin) of 197 days. Over this same north-south range reported average annual precipitation varies from nearly

20 inches to less than 9 inches, although in the high mountains there is substantially more than reported here.[17]

The Upper Rio Grande Basin within New Mexico comprises some 26,505 square miles north of Elephant Butte Reservoir.[18] The original Pueblo Grants comprise nearly 847 square miles. If there is inclusion of lands acquired by the Pueblos outside these grants and reservations, the area of Pueblo land in the Upper Basin is more than 2,469 square miles.[19] A summary of these Pueblo lands is provided in Table 1.2.

The Pueblos chose not to reveal the specific lands which are presently irrigated by the Indian residents of the Pueblos. But, relying on a survey and mapping of irrigable lands prepared by the U.S. Geological Survey and the New Mexico State Engineers Office in 1979, it was determined that within the exterior boundaries of the

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17 Data from County Profile series of New Mexico Interstate Stream Commissions and New Mexico State Engineer Office, Water Resource Assessment for Planning Purposes (specific citation, for example, N.M. Interstate Stream Commission and N.M. State Engineer Office, Socorro County, Water Resource Assessment for Planning Purposes, Santa Fe, New Mexico, 1974).

18 Reported surface water drainage area above the dam at Elephant Butte Reservoir (U.S.G.S. Station Number 08360500). U.S. Department of Interior, Geological Survey, Water Resources Data, New Mexico, Water Year, 1981, National Technical Information Service, Springfield, Virginia, 1982, p. 299.

19 See details of Pueblo Lands in Phillip Farah and Brian McDonald, An Economic and Demographic Profile of New Mexico Pueblo Indians: An Historical Perspective, Water Resources Research Institute, Las Cruces, New Mexico (forthcoming).

TABLE 1.2

SUMMARY OF PUEBLO INDIAN LANDS
IN THE UPPER RIO GRANDE BASIN
(acres)

	Original Spanish Grant-Official Gross Area	Net Indian Area of Original Spanish Grant	Net Indian Area of Reservations Created by Executive Order or Acts of Congress	Net Acres of Indian Grants, Reserved, and Acquired Lands
Acoma	94,169.00	93,910.20	56,241.01	249,115.75
Cochiti	23,218.22	22,754.36		28,778.85
Isleta	130,879.48	130,472.27		211,026.32
Jemez	17,331.00	17,313.85	15,831.42	89,616.28
Laguna	17,456.39	17,456.39	141,777.87	441,149.42
Nambe	13,711.67	12,481.17	6,463.36	19,104.53
Picuris	17,468.15	14,948.09		14,948.09
Pojoaque	13,438.15	11,600.53		11,606.12
Sandia	24,034.42	22,870.49		22,870.49
San Felipe	30,601.05	28,197.93	11,972.90	47,758.57
San Ildefonso	16,199.61	15,413.40	4,430.72	26,191.05
San Juan	16,174.15	12,234.55		12,234.55
Santa Ana	15,405.63	15,405.63		60,868.23
Santa Clara	16,781.19	12,699.22	33,044.30	45,743.52
Santo Domingo	65,931.20	65,427.22		68,450.09
Santo Domingo-San Felipe Joint Grant	1,055.94	1,055.94		1,055.94
Santo Domingo-Cochiti Conflict		149.88		149.88
Taos	17,390.13	14,781.67		95,334.22
Tesuque	16,960.37	16,492.62		16,810.67
Zia	16,282.28	16,281.67	368.85	117,358.64
TOTAL	564,488.03	541,947.08	270,148.43	1,580,171.21

Source: U.S. Bureau of Indian Affairs, New Mexico Indian Pueblos Land Status Report-1979, Branch of Real Estate Services, Albuquerque Area Office, Albuquerque, New Mexico: Bureau of Indian Affairs, U.S. Department of Interior, February 1, 1979.

Pueblo lands that approximately 35,632 acres are irrigable.[20] This estimate is unable to distinguish between the lands which the Pueblos lost title to under the Pueblo Land Acts and those which were retained, nor is there an ability to describe which of these lands are actually irrigated. The estimate is of lands which could be served by existing irrigation works. This leads to an estimate that within the exterior boundaries of the Upper Basin Pueblos there are located up to 24 percent of the 1975 irrigated acres.[21] It can be said that the irrigation of Pueblo lands adds significantly to the agricultural output of the Upper Rio Grande Basin, but unfortunately it is impossible to be more specific in describing this contribution to the region's economy.

E. Summary Perspective on Pueblo Indian Water Rights Quantification

It is appropriate to conclude this overview of the research with a description of the general extent to which quantification of Pueblo

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20 New Mexico State Engineer Office and U.S. Geological Survey Joint Study, "Regional Aquifer Systems Analysis," preliminary data provided by New Mexico State Engineer Office, 1979.

21 That is, if all 35,632 acres of irrigable land within the Pueblo Indian Reservation boundaries were irrigated in 1975, and total irrigated lands in the Upper Rio Grande Basin in 1975 was 150,470 acres (as reported by New Mexico State Engineer Office, see Technical Appendix TA-A for specific data), then irrigated acreage within boundaries of Pueblos in Upper Basin could have been as much as 23.68 percent of the total irrigated acres in 1975 (within the Upper Basin). This is admitted to be an overestimate of lands within reservation boundaries actually irrigated in 1975, but no better data was available to base the calculation upon.

Indian water rights will impact on these activities. There are essentially only two types of water right entitlements which the Pueblos are likely to have assigned under the resolution scenarios considered, with a brief statement of the alternative legal theories provided in an appendix at the end of this chapter.[22]

In one case it is asserted that the Pueblo rights might be assigned as fee title without actual utilization of these rights by the individual Pueblos. That is, establish a "leasable" water right entitlement. The effect on the non-Indian economic activities would simply be the loss of perpetual title to the right in whatever quantity was determined by the courts. Certainly the Pueblos would not chose to force total curtailment of all the economic activities which had been dependent upon the rights; but may, by lease mechanism, force the curtailment of some of these historic uses. More specifically, the Pueblos might assign a lease price which is sufficiently high to force some of the marginal economic activity dependent on the water resource out of business simply because they cannot afford to purchase the water. This, of course, might also force the relocation of some economic activity onto Pueblo lands if the Pueblo Indians chose to practice some form of price discrimination so as to encourage the relocation.

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22 Charles T. DuMars, Marilyn O'Leary and Albert E. Utton, Pueblo Indian Water Rights, Struggle for a Precious Resource, The University of Arizona Press, Tucson, Arizona: 1984.

It should be noted that such relocation is _not_ damaging to the region's economy as a whole, except to the extent that the relocated firms incur costs in the move. As has been stated before, this analysis attempts no discrimination between Indian and non-Indian economic activity. The model utilized simply describes dollar values of output and corresponding water use requirements. $100 of bread produced by an Indian baker in Taos has the same general affect in the model as that same output by a non-Indian in Socorro. This general principal does not necessarily apply to agricultural output in different subregions of the Upper Basin simply due to significant differences in water use requirements for specific crops in the Basin's subregions.

The alternative resolution scenario considered postulates Pueblo Indian water right assignments based on actual agricultural use within the boundaries of the reservations. Thus, quantification of Pueblo Indian water rights based on planned _actual_ agricultural use may have significantly different effects than in the previously described transfer of fee title without specific use servitude (e.g., agricultural use servitude).

It was beyond the scope and limitations of this research to undertake estimation of "practicably irrigable acres" within the boundaries of Pueblo Indian lands of the Upper Basin. As an alternative to this, it was felt appropriate to assign to each Pueblo water right quantities in proportion to each Pueblo's currently irrigable acres, as estimated from the survey and mapping of irrigable lands done by the United States Geological Survey (U.S.G.S.) and the New Mexico State Engineer's Office (SEO) in 1979. This procedure may be made more clear by example. If adjudication of the water rights resulted in the assignment to the Pueblos an additional 10,000 acre-feet of water, and Pueblo X's share of total irrigable Pueblo land was 15 percent (in 1979), then Pueblo X's allocation under this hypothetical allocation scheme would be 1,500 acre-feet, plus or minus an estimated difference in the consumptive use requirements between the transfer from and the transfer to locations.

It is possible to assert under the previously described legal theories that the maximum quantification of Pueblo Indian water rights could result in the elimination of <u>all</u> non-Indian irrigation water entitlements -- <u>if</u> sufficient "practicably irrigable" lands exist within the boundaries of the Pueblos. Can one defensibly assert (or deny) that this extreme scenario is indeed a "possible" outcome <u>in fact</u>? Again, I was forced to rely on limited factual information in addressing an answer to this question.

Presently there exists no judicial resolution of whether the quantification of Pueblo rights based on practicably irrigable acres standards should be limited to irrigable lands within the original grant and reservation boundaries, or whether this standard should be applied to all lands under the ownership of the Pueblo Indians.[23] The more limiting case (i.e., original lands) would allow consideration of the irrigation potential for some 564,488 acres, while the alternative (i.e., all Pueblo lands) would allow estimation of the irrigable lands within the boundaries of some 1,580,171 acres of the Upper Basin.

In 1975 there were a total 150,470 irrigated acres in the Upper Basin, with 116,210 acres of this total irrigated by surface water exclusively.[24] If one assumes that Pueblo Indian water rights quantification is limited to irrigable lands within the boundaries of the original Spanish grants, then to displace all 1975 irrigation in the Upper Basin 26.65 percent of these original Pueblo lands must be

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23 On June 10, 1983 U.S. District Judge Edwin Mechem ruled in the Aamodt suit that the Winters Doctrine does not apply to Pueblo lands which have a history different from explicit congressional reservation of Indian lands. The recognition of Pueblo Indian lands by the 1848 Treaty of Guadalupe Hildago was held not to be a reservation of land by Congress which conveyed Winters rights. No alternative legal theories were rejected or adopted by this ruling. The ruling suggests that the "practicably irrigable acres" claimed by the Pueblos under the Winters Doctrine on the land comprising the original Spanish Grants and other "non-reserved" Pueblo lands may be dismissed, but provides no alternative basis for resolution of water right claims appurtenant to these lands. It must also be noted that 270,148.32 acres of Pueblo land in the Upper Rio Grande Basin was set aside by Executive Order or by Acts of Congress, and may yet be eligible for protection of water rights under the Winters Doctrine. I do not attempt to specifically correct this statement (originally drafted prior to Judge Mechem's ruling), and admonish the reader to account for this recent development in the Aamodt case in interpretation of this analysis.

24 Earl F. Sorensen, Water Use by Category in New Mexico Counties and River Basins, and Irrigated and Dry Cropland Acreage in 1975, Technical Report 41, Santa Fe: New Mexico State Engineer, 1977.

found to be "irrigable." If one employs the additional assumption that only surface water rights may be affected by the specific resolution, then only 20.58 percent of the original land grants must be found "irrigable" to displace all surface water irrigation in 1975.

The alternative basis for quantification, where irrigation potential is considered for all lands owned and possessed by the Pueblo Indians in the Upper Basin, provides much greater potential for displacement of all non-Indian irrigation. That is, it would be required that 11.28 percent of these Pueblo Indian lands be deemed "irrigable" to supplant all 1975 irrigation in the Upper Basin with irrigation of these Pueblo lands. If the effects are limited to existing surface rights only (as described by 1975 use), then it is required that only 8.72 percent of these Pueblo Indian lands be found to be "irrigable" to eliminate all non-Indian surface water irrigation in 1975.

Of course critical to determination of "irrigable" lands are many physical and economic criteria not investigated. Probably most important of these considerations are the source of development capital and the nature of the repayment obligation associated with this funding. Indeed, if "money were no object", there could be easily proven "irrigable" Pueblo Indian lands sufficient to eliminate all non-Indian agriculture in the Upper Basin -- the state of irrigation agronomy and engineering is such as to allow production on all but the most extreme climatic and topographic conditions found on these Pueblo Indian lands. Yet it is also clear that these economic considerations may in fact significantly impact the determination of "irrigable" lands.[25]

The approach adopted here is not to ignore these questions, but rather to assume some specific determination of irrigable lands is possible, and to investigate a broad range of these possible outcomes. This, again, is the fundamental difference between this research and all previous economic investigations of Indian water rights. The goal is not to describe a "most likely" resolution, but rather to compare alternative possible resolutions. Feasibility is not investigated, but rather conclusions are drawn regarding the economic activities impacted and the efficacy of the alternative resolutions. It is hoped that this analysis will allow specific (judicial) identification of desired results prior to the finalization of the resolution process. The conclusions relate to regional economic impacts on the society of the Upper Rio Grande Basin as a whole, and are specific to groups of similar industries in three subregions of the Upper Basin area. The next chapter describes the economic model employed in this analysis in greater detail.

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25 For extensive discussion of the "state" of economic analysis in Indian water right adjudication see report of Teno Ronocalio, special master, in re: The General Adjudication of All Rights to Use Water in the Big Horn River System and All Other Sources, State of Wyoming (concerning reserved water right claims by and on behalf of the Tribes of the Wind River Reservation, Wyoming), Civil No. 4993 (Wyoming District Court, 5th District, December 15, 1982).

CHAPTER I - APPENDIX

PUEBLO INDIAN WATER RIGHTS LEGAL THEORIES

Alternative legal bases upon which Pueblo Indian water rights can be asserted can be condensed into essentially three distinct types of water right claims. The first is the assertion of an aboriginal claim, whereby the water rights are thought to have survived the Spanish, Mexican and American sovereigns, and are a first priority and paramount claim to the water resources of the region. The claim derives from the Pueblo Indians' prehistoric settlement and irrigated agricultural development of the Upper Basin prior to European colonization.

The second type of water right claim asserted can be generally described as Spanish/Mexican treaty rights. Water rights claimed under this authority were created and defined by the laws of the prior sovereigns which the United States is bound to honor under the Treaty of Guadalupe Hildago.

Finally, Pueblo Indian water right claims are thought by some to have been created directly by Acts of Congress. The actions of Congress designating Pueblo Indian reservations are thought, under this doctrine, to have created a reserved water right which is defined by the Winters doctrine.[26]

The specific use(s) to which Pueblo Indian water rights are made appurtenant is largely dependent upon the particular legal theory asserted, while the specific quantification of water rights is dependent on the relative priority date assigned the particular water rights. Under the three basic legal doctrines there can be variously claimed: a) quantities of water limited to the historic use of the water resource by the Pueblos, b) water right quantities sufficient to irrigate all acreage of the Pueblos which can be determined to be practicably irrigable, or c) undefined quantities adequate to satisfy the expanding water needs and changing uses of the Pueblos in the future. However, the summary of the asserted legal positions provided below ignores much of the subtle interpretation and character which these various legal theories embody. The reader interested in these details is directed to the work of DuMars, O'Leary and Utton.[27] There is acknowledged here a broad generalization of their legal analyses regarding asserted Pueblo Indian water rights; this generalization necessary for interpretation in the economic model projecting impacts associated with the possible alternative resolutions of these claims.

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26 Winters v. United States, 207 U.S. 564, 285 Ct. 207, 52 L. Ed. 340 (1908) (hereinafter Winters).

27 DuMars, et al., supra Note 22.

1. Aboriginal Water Right Claims

The prehistoric settlement of the Upper Rio Grande Basin by the Pueblo Indians forms the basis for assertion of Pueblo water rights of aboriginal origin. Indeed, Pueblo society until relatively recently was totally dependent upon irrigated agriculture for survival; however, in both Pueblo culture and religion there is clear expression of a desire not to control the resource but to utilize it as it is available. As the original people of the region, the rights to the water resource sought under this legal theory predate any non-Indian sovereign and have survived without dimunition through the centuries. It is asserted that this paramount right does not require any historic diversion of water or application to beneficial use. Further, all non-Indian development which presently relies on this resource has no perpetual usufructuary right, and the present non-Indian "rights" can at any time be extinguished by "activation" of these dormant aboriginal claims.[28]

Quantification of water rights under the aboriginal rights doctrine can be asserted based on two basic quantification schemes. The first simply limits the Pueblos to the rights which they have

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28 Several cases have established basis for aboriginal rights which may extinguish non-aboriginal claims; see Cramer v. United States, 373 U.S. 546 (1963); and United States v. Shoshone Tribes, (304 U.S. 111 (1938)), interpreted in Washington v. Washington State Commercial Passenger Fishing Vessel Ass'n, (443 U.S. 658 (1979) at 686. See also DuMars, et al. (supra Note 22), Chapter 3.

established by historic application of the water to beneficial use. The second is derivitive of the Winters[29] dicta, and would allow the Pueblos to expand their use of water in accord with their needs. Proponents of the historic use limit to Pueblo rights point to the early case law which protected Indian rights appurtenant to lands which were actually occuppied and used. Proponents of the expanding rights under Winters rely on a paramount claim and turn to the recognition of aboriginal rights provided under Spanish, Mexican and American law for specific language upon which to base their asserted claims.

2. Treaty Rights

In 1848 the United States entered into the Treaty of Guadalupe Hildago with Mexico,[30] and thereby became obligated to continue to protect the Pueblo Indians in accord with Spanish and Mexican law. Thus, it is asserted, Pueblo Indian water rights were created and defined at that time by the laws of these antecedent sovereigns as binding rights against all non-Indian claimants otherwise governed by the water laws of the United States. Pueblo water rights asserted as treaty rights rely not only on the protection provided aboriginal claimants under Spanish/Mexican law, but also as citizens of these

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29 Supra note 26.

30 Treaty of Guadalupe Hildago, February 2, 1848, United States--Mexico, 9 Stat. 922, T.S. No. 207.

colonial powers. It is important to note that the Treaty of Guadalupe Hildago was between non-Indian sovereigns and that the Pueblos did not, and have not, entered into explicit treaty agreement with the United States. It is also important that if treaty rights are valid as the basis for assertion of Pueblo Indian water rights, then non-Indians residents of the New Mexico territory in 1848 are accorded, arguendo, the same protection as that provided Indian rights.

The assertion of Treaty rights is dependent on the "clarification" of the limits to these rights provided by Winters. Although clarification may be too strong a statement of that which is provided by Winters, it is clear from that decision that the Indians are to be provided sufficient water to assure their future livelihood as a "civilized people." This has been interpreted as an expanding right to all the water needed for future populations and sufficient quantities to maximize the development of tribal resources. The interpretation of the limits to Indian water rights provided by Winters has been the subject of much litigation since the decision in 1908.

DuMars, et al., conclude that under Spanish and Mexican law Indian water right grants cannot be seen in isolation from the total system of users. Historians are, unfortunately, not in agreement as to the extent to which these competing rights should be considered; but clearly equity and flexibility was the touchstone of Spanish water allocations. Interpretation of this doctrine as a treaty right of a specific quantity is difficult. A favorable interpretation for proponents of Pueblo Indian water rights would certainly recognize additional and expanded uses over the historic levels of use. At the extreme, advocates of Pueblo rights would interpret the protection provided by the prior sovereigns to allow any new use which contributed to the livelihood of the Pueblo Indians. Opponents of Pueblo water rights strongly assert the claim of "equities" which limit the Pueblo rights to historic use only.

3. Winters Rights

The final legal theory upon which Pueblo Indian water rights can be asserted interprets the Acts of Congress as "reserving" an Indian water right sufficient to sustain the Indian communities' livelihood. Although Pueblo Indian water rights claimed under the *Winters* doctrine are in many ways similar to those claimed under the treaty right doctrine, many subtle and important differences exist. Most important of these differences is the priority date which would be assigned the water rights.

Under the treaty right doctrine the date would certainly be prior to the 1848 date when the Treaty of Guadalupe Hildago was signed, and could possibly be interpreted as aboriginal in origin and senior to all other rights. Under the *Winters* doctrine the priority of Pueblo water rights is dependent on whether the case was indeed an aboriginal water rights case. If Pueblo rights under the *Winters* doctrine are aboriginal, then the priority date is interpreted as time immemorial.

If, alternatively, Winters is interpreted as "creating" the Indian water right as of the date when Congress reserved the Indian lands, then the priority date is thought to be established by the congressional action. This priority date is important in that it could result in Pueblo Indian water rights junior to those of many rights claimed by non-Indian settlers in the Upper Rio Grande basin which have been subject to continuous appropriation for several centuries.

Ignoring the problem of specific priority date assignment for the time being, the significance of the United States having explicitly established "reservations" provides for linkage to a recognized methodology for adjudication of quantitative rights. Under the Arizona v. California decision there was established the "practicably irrigable acreage" standard for quantification of Indian reserved rights. Assertion of the practicably irrigable acreage standard, juxtaposed with interpretation of the Winters decision as recognizing the aboriginal origin of Pueblo Indian water rights, achieves both paramount priority status and a definitive quantification standard for these rights. Although the methodology for determination of practicably irrigable acres under Arizona v. California continues to be refined,[31] it remains as the most explicit standard for

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31 It is clear the final decision in Arizona v. California (373 U.S. 546 (1963)) (as supplemented by additional decrees) has not been found yet. The most recent special master's report to the court (February 22, 1982) was in part rejected by the court, particularly in regard to reclassification of "irrigable

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quantification of Indian water rights available presently. It is alternatively asserted that no "reservation" of Pueblo lands was made by the 1851 Act. Rather, that the confirmance of fee title to Pueblo lands provided by the Joseph decision and 1858 Congressional Confirmation Act[32] recognized the Pueblos' existing ownership of the lands, and that both the quantity and priority of these rights under the Winters doctrine must be determined by the laws of prior sovereigns.

Polar to the preceding statements of Pueblo Indian water rights under Winters is the argument that there has never been reservation of Pueblo lands by the United States. Under this theory interpretation of either Winters or Arizona v. California is moot, for there exists no reserved water rights for the Pueblos, nor did any law of prior sovereigns ever recognize any concept similar to practicably irrigable acreage. Indeed, the point made by opponents of Pueblo Indian water rights who forward this position is simply that the Winters decision is silent with respect to rights granted by prior sovereigns, and is thus totally irrelevant to adjudication of these water rights.

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31 [continued from previous page]

lands." It is expected that this case, as well as others pending, will further define this basis for quantification of Indian water rights in the future.

32 United States v. Joseph, 94 U.S. 614 (1876); and Act of December 22, 1858, Ch. 5, 11 Stat. 374.

4. New Mexico v. Aamodt

The complexity of the legal theories and their interpretation is nowhere more clearly illustrated than in the pending Aamodt litigation. It may be recalled that this suit seeks the adjudication of four Upper Basin Pueblos' water right entitlements on the Pojoaque River. The suit was originally filed in 1966, and to date the only substantive rulings which have resulted provide that "...the water rights of the Pueblos are not subject to the laws of New Mexico...,"[33] and that "...the water rights of the Pueblos are prior to all non-Indians whose land ownership was recognized pursuant to the 1924 and 1933 Acts."[34] No clear statement has been provided of the relationship between the Pueblo Indian water rights and the other non-Indian water rights of the Upper Basin, and no ruling to date regarding a specific basis for quantification of the Pueblo rights or their priority date.

It is clear that with the more than 15 years of litigation in this case there has been little progress in final resolution of the competing claims. Indeed, much of the testimony presented (e.g., practicably irrigable acres) has been without resolution of the fundamental legal theories upon which the specific testimony is based. It is also apparent to the litigants that final resolution of

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33 New Mexico v. Aamodt, 537 F. 20 1102 (10th Cir. 1976) at 1112.

34 Ibid. at 1113.

these water right claims is not imminent, nor have all the questions of Pueblo Indian water rights been addressed as yet. One of the most significant of these questions is the transferability of Pueblo Indian water rights.

5. The Transferability of Pueblo Indian Water Rights

The transferability of water rights qua property rights is clearly provided for by the water laws of New Mexico, yet it has been determined that the laws of New Mexico do not apply to Pueblo Indian water rights. The prior appropriation doctrine as applied throughout the West generally allows for the transfer of water right entitlements to the extent that no demonstrative impairment occurs; yet it is unclear whether the doctrine has application under any of the previously described Pueblo Indian water right theories, with the possible exception of the Winters doctrine. If there exists reserved Pueblo Indian water right entitlements, then there must be answered prior to discussion of transfer the explicit purposes for which the reservation was established. Non-Indian reserved rights have been interpreted to serve only the narrow purposes for which the reservation was established in United States v. New Mexico,[35] and the language of the Winters decision refers only to the pastoral life-styles which were to

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35 United States v. New Mexico, 438 U.S. 696 (1978), although it must be noted this was a non-Indian federal reserved rights case possessing somewhat distinct character from Pueblo Indian reserved right questions.

be provided for by the reserved water right entitlements. Yet interpretation of Indian reserved rights as a fee simple property right would leave open the question of transferability.

The question of transferability requires consideration beyond a pure legal question, for in the West generally, and the Upper Rio Grande Basin specifically, the circumstances of water scarcity could be significantly exacerbated by adjudication of significant additional Indian water right entitlements with agricultural servitude and no possible transfer from the agricultural use. Should the adjudication of the Indian water rights, regardless of the specific legal foundation employed, reflect a broader social policy which attempts to allow for the maximization of benefits from the resources' use? Should there be sought a policy which mitigates the uncertainty of unquantified future Indian water right uses by assuring -- regardless of the specific uses to which new quantifications of Indian rights are tied in the adjudication processes -- that at such future time as water scarcity requires the acquisition of additional rights, these Indian water rights will be available to non-Indian users? Is it possible that the "preferred status" of Pueblo Indian water rights under Spanish law contemplated their emergence as regional "water brokers" with significant control over non-Indian economic development? Again, there are no clear answers to these questions at this time.

The argument in favor of allowing Pueblo Indian water right transfers to off-reservation non-Indian users can rely in part on the changing needs of the Indian people, recognizing that the potential profitability of irrigated agriculture in the Upper Basin is extremely limited. If it is the goal of the United States to provide the Indian people with rights of self-determination, then forcing the agricultural servitude of their reserved water rights dooms these people to continued dependance on the support of the government. If the rights are held to have an agricultural servitude, then actual use of the entitlements would require significant capital investment in irrigation works, and depending on repayment obligations, potential operational support to ensure project profitability. In light of these circumstance can a nontransferable Pueblo Indian water right entitlement be justified?

An alternative view can be taken which asserts that Pueblo culture is abhorrent to the notion of water's treatment as a commodity subject to sale and purchase. At the present time the only specific language which can be relied on to clarify the nature of these reserved rights is provided by the 1979 Supplemental Decree in the Arizona v. California litigation.[36] It was there held that the quantification of reserved rights was to be determined by the practicably irrigable acreage standard, but that the means of determining quantity did not

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36 Arizona v. California, 439 U.S. 419 (1979).

restrict the use to which the rights could be assigned. This decision unfortunately did not address the off-reservation use issue; thus the question remains largely undecided at this time.

6. Summary of Legal Theories

Throughout the preceding there have been clear grounds for the assertion of Pueblo Indian water beyond the quantities of water which are currently appropriated to beneficial use. Under none of the legal circumstances does it appear likely that the Pueblo Indians of the Upper Rio Grande Basin will be forced to relinquish any of the present water right entitlements. However, there is significant question as to which, if any, of the assorted legal theories will be adopted by the courts in resolution of the claims. Table 1.3 summarizes in tabular form the alternative quantification schemes, priority date assignments, and corresponding legal theories upon which the alternative quantifications and priority assignments can be based. It is freely admitted that this tabular presentation grossly oversimplifies the problems of Pueblo Indian water rights, yet serves as a convenient distillation of the legal question for the analysis which follows.

The water right claims of the Pueblo Indians can be asserted to be limited in quantity to actual historic use under all three of the major legal theories asserted (i.e., aboriginal rights, treaty rights,

TABLE 1.3

LEGAL THEORY SUMMARY OF ALTERNATIVE PUEBLO INDIAN WATER RIGHTS
ALTERNATIVE QUANTIFICATION SCENARIOS AND PRIORITY ASSIGNMENTS

QUANTIFICATION SCHEME * Priority Assignment	ALTERNATIVE LEGAL THEORIES Aboriginal Water Rights	Treaty Water Rights	Winters Rights: Based on Treaty Obligations	Winters Rights: Based on "Reserved Rights" Doctrine
ACTUAL HISTORIC USE LIMIT				
* First Priority Rights	Yes	Yes	Yes	No
* Indefinite Priority Rights: priority relative to other non-Indian "natives" and users in region uncertain	No	Yes	Yes	No
* Priority Based On Date "Reservation Created"	No	No	No	Yes
EXPANDING USE BASED ON "NEED"				
* First Priority Rights	Yes	Yes	Yes	No
* Indefinite Priority Rights: priority relative to other non-Indian "natives" and users in region uncertain	No	Yes	Yes	No
* Priority Based On Date "Reservation Created"	No	No	No	Yes
"PRACTICABLY IRRIGABLE ACREAGE" STANDARD				
* First Priority Rights	No	No	Yes	No
* Indefinite Priority Rights: priority relative to other non-Indian "natives" and users in region uncertain	No	No	Yes	No
* Priority Based On Date "Reservation Created"	No	No	No	Yes

and Winters rights),[37] and may be considered as aboriginal first priority rights if specific resolution were based on any of three theories. It is also possible that the historic use limit could be imposed with these rights being assigned an indefinite priority relative to the other non-Indian "natives" of the region and other specific uses of the water resource, with this group of resolutions supported by the legal theories of treaty rights and Winters rights. Finally, under only the Winters right doctrine could the historic use limit be imposed with a priority date as of the time of the "reservations were created."

The quantification of Pueblo Indian water rights could be based on the expanding "needs" of the aboriginal people, with first priority assigned to these rights under any of the three legal doctrines as well. This expanding needs quantification could alternatively be assigned an indefinite priority relative to the other "native" users of the region, and relative to other specific uses under either the treaty right or Winters rights doctrines. These expanding rights could, by other judicial interpretation, be assigned a priority date

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37 It should be noted that Table 1.3 defines two separate types of Winters rights, one dependent upon the obligations of the U.S. under the Treaty of Guadalupe Hildago, and the other derived from explicit "reservation" of Pueblo lands by Acts of Congress. In many respects these types of Winters rights are quite similar, yet at the same (as is shown by the table) there are fundamental differences. The reader interested in these differences is directed to DuMars, O'Leary and Utton (supra Note 22).

as of the date the reservation was "created" under the Winters rights doctrine.

Quantification could be based on the "practicably irrigable acreage" standard with assignment of aboriginal first priority rights to the Pueblo Indians, or as rights with indefinite priority relative to other "native" users and specific uses, under the Winters doctrine interpreted as recognizing the treaty right obligations of the United States. The same practicably irrigable acreage standard could be used in quantifying these reserved rights under the Winters doctrine, with the specific priority date interpreted to be based on the date when the reservations was created by Congress.

Under all of the quantification theories it is possible to assert that the water rights could be applied to any beneficial use, although the assertion of this position appear strongest under claims of either aboriginal water rights or water rights created by treaty. The potential for transfer of Pueblo Indian water rights to off-reservation uses and users seems to have its strongest foundation in interpretations of Winters rights, although treaty rights may also allow for this possibility. A settlement which considers the "historic equities" created by adverse possession of Pueblo rights by non-Indians seems to have basis in Spanish and Mexican law as imposed under the treaty right doctrine. It also appears that the Pueblo Lands Acts may have spoken to these "equities" as well, with the resolution of Pueblo claims under either of these interpretations of vested equities resulting in compensation to the Pueblo Indians from rights lost by this form of adverse possession. It is clear that the specific use, transferability, and historical equities questions step beyond the confines of strict legal theory.

CHAPTER II

MODEL ORGANIZATION, STRUCTURE, DEVELOPMENT AND SOLUTION METHODOLOGY

A. Introduction

The modeling of economic behavior by firms and individuals can be traced to mid-eighteenth century inquires.[38] Critical to all models of economic behavior are rules by which resource use decisions are made. In the analysis of Pueblo Indian water rights the allocation behavior is specified so as to maximize the economic benefits of water resource use; in more formal economic rhetoric, a linear programming model with a value-added objective function which is maximized by an optimal solution.

The input-output matrix which forms the sectoral basis for analysis of impacts in this present research is derivative of work done by others since the late 1950s at the University of New Mexico.[39] This

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38 Francois Quesnay's Tableau Economique prepared in 1758.

39 The input/output table was first specified (by survey technique methods) as a 50 sector model in research conducted at the Bureau of Business Research (forerunner to BBER) in the early 1960s and is summarized in "A Preview of the Input-Output Study," New Mexico Business 18(10), October 1965; and Carolyn G. Lindberg, A Technical Supplement to the Input-Output Study for New Mexico, Bureau of Business Research, University of New Mexico, September 1966. This model was then modified by Fred Roach and other to a 24 sector input/output water constrained

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analytical technique accounts for the economic transactions between and among the agents of an economic system, summarizing these economic activities with sectoral output data.

With the current state of the art in computer modeling and with the financial commitments which have been made it has been possible on a national level to develop input-output relationships for as many as 500 separate economic sectors.[40] With the resources available in New Mexico it has been possible to develop these input-output relationships in several separate models.[41] This research has relied

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linear programming optimization model, with the most extensive discussion of the model's modification in James Fredric Roach, "An Economic Model for the Rio Grande Drainage Basin, New Mexico," (unpublished Ph.D. dissertation) University of New Mexico, 1977. (The dissertation was prepared in conjunction with WRRI Research cited later herein.)

40 There are many national input/output tables with some derivative of others. Two common references include the Bureau of Economic Analysis, The Detailed Input-Output Structure of the U.S. Economy: 1972, BEA, Washington: U.S. Department of Commerce, Volumes I and II, 1979; and the most recent published version of the Clopper Almon Model in Clopper Almon, Jr., et al., 1985: Interindustry Forecasts of the American Economy, Lexington, Maryland: Lexington Books, 1974.

41 There have been (at least) two separate input/output models developed at the University of New Mexico, including the model which is the basis for the present research (citations provided later); and a model which also continues to be used and modified, which was first discussed in R.J. Lievano, et al., An Energy Management System for the State of New Mexico Phase I, Bureau of Business and Economic Research, University of New Mexico, Albuquerque: New Mexico Energy Institute Report No. 78-1130, 1979, with subsequent publication of several reports directly related to this project.

upon an interregional input-output matrix for 24 economic sectors in the state, with each of these 24 sectors specified in five different regions of the state. The most recent use of this model was the result of previous research funded by the New Mexico Water Resources Research Institute, which produced a series of reports generally entitled An Analytical Interdisciplinary Evaluation of the Utilization of the Water Resources of the Rio Grande in New Mexico.[42]

In the later analysis there was a general investigation of the economic and environmental consequences of alternative economic growth and development patterns in the Rio Grande Basin. In the present research the same input-output matrix, appropriately updated and modified, is used to analyze the economic impacts of different legal resolutions of Pueblo Indian water rights. However, before further

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42 R. R. Lansford, et al., An Analytical Interdisciplinary Evaluation of the Utilization of the Water Resources of the Rio Grande in New Mexico, Technical Report 20, New Mexico Water Resources Research Institute, Las Cruces, New Mexico: New Mexico State University, 1973; R. R. Lansford, et al., An Analytical Interdisciplinary Evaluation of the Utilization of the Water Resources of the Rio Grande in New Mexico: Upper Rio Grande Region, Technical Report 21, New Mexico Water Resources Research Institute, Las Cruces, New Mexico: New Mexico State University, 1973; R. R. Lansford, et al., An Analytical Interdisciplinary Evaluation of the Utilization of the Water Resources of the Rio Grande in New Mexico: Middle Rio Grande Region, Technical Report 22, New Mexico Water Resources Research Institute, Las Cruces, New Mexico: New Mexico State University, 1973; R. R. Lansford, et al., An Analytical Interdisciplinary Evaluation of the Water Resources of the Socorro Region in New Mexico, Technical Report 23, New Mexico Water Resource Research Institute, Las Cruces, New Mexico: New Mexico State University, 1974; see also Roach, supra note 39.

discussion of the specific model implemented in the present analysis, it is appropriate to describe in some greater detail the significance, limitations and applicability of the general theoretic tools employed in this analysis.

B. Input-Output and Linear Programming Analysis

As was mentioned, the attempt to model economic interactions and equilibrium conditions on a fairly broad scale has had a significant history. It can be said that empirical input-output modeling is largely derived from the work of Leontief[43] published in 1936 which provided a system of input-output interrelationships describing the United States economy. The input-output modeling process attempts to characterize all the purchases of inputs and sales of outputs (even as intermediate factors of production) which actually occur among the economic agents of the economy. It explicitly recognizes the interaction between industries via the intermediate demand for output. That is, production in one sector requires the output of another sector as an input. Expansion (or contraction) in one industry thus requires the simultaneous expansion (or contraction) in all industries which provide intermediate products as inputs.

In order to simplify such a modeling, it is frequently asserted that many different firms in an economy have similar production

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43 Wassily W. Leontief, "Quantitative Input and Output Relations in the Economic System of the United States," The Review of Economic Statistics 18 (August 1936): 105-125.

processes, requiring similar types and quantities of specific inputs, and generating outputs which serve as similar products for either final consumption or intermediate inputs into other production processes. As a more technical consideration, input-output modeling frequently specifies these economic interdependencies (i.e., production functions) as linear relationships. Specific levels of production inputs are related to the level of output of other sectors. That is, by example, a 10 percent increase in the output of one sector modeled requires that all inputs used in the production process by that sector must also increase by 10 percent.

Without specific allocation rules an I/O table is unable to determine to which specific sector a resource (or intermediate product) should be allocated if there is insufficient supplies of that resource input to meet the full demands of the competing sectors. In "free market" society such a case typically defers to the "price mechanism" to accomplish the allocation of this scarce resource. In general, it can be said that a resource is allocated to its highest valued use in this manner, and that such an allocation is the optimal allocation of that resource.[44]

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44 The optimality of the price mechanism in perfectly competitive markets is a concept commonly accepted by economists. A simplified explanation of this principal describes market participants as maximizing the value they receive from all market commodities by equating marginal products of a commodity used and the price of that commodity, including all alternative market commodities. (For technical explanation see any microeconomics

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A sector's production function -- characterized by the elements of the I/O "row vector" for a particular sector -- describes only the specific pattern of inputs required per unit of output by that sector. Therefore, a feasible allocation of scarce resources inputs must be consistent with each production sector's resource needs, without exceeding the available resource constraint. However, it may also be desired that the specific allocations to each sector in some manner reflect the "optimal" use of those resources by society.

The first question which must be addressed is what value society wishes to optimize by the allocation of its resources. Clearly one candidate for this optimization problem is to allocate the available resources in a manner which maximizes the value added to the economy by their use. In actual social economic activity it is thought that the price mechanism largely accomplishes this allocation, for those who are able to make more productive use of a resource are thought able to purchase that scarce resource away from someone who is making a lesser use of it.

In a similar manner, the mathematical modeling technique of linear programming results in the allocation a limited set of resource inputs so as to optimize the value obtained by society from the use of those

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textbook, for example, James M. Henderson and Richard E. Quandt, Micro-economic Theory, 3rd ed., New York: McGraw-Hill Book Company, 1980).

resources. Linear programming modeling techniques allow for the establishment of a social objective to which scarce resources (e.g., labor, water, etc.) can be allocated so as to maximize the benefits from the various economic activities which society undertakes.

For many sectors this input-output linear programming (IOLP) modeling technique is able to adequately reflect a particular sector's responses to changes in economic conditions affecting its activity over time. In other sectors this simplicity must be more closely scrutinized. This is particularly true in agricultural, trade and service sectors, where there can be anticipated a broad spectrum of responses, substitutions, or complimentary activities which might be affected in a "nonlinear manner" as a result of other changes in economic activities throughout the economy. However, the linear programming optimal solution technique requires linear "production technologies". It must be acknowledged that modeling specific economic activity in this restrictive and simplistic manner constrains the "reality" of the empirical analysis. But, with recognition of this limitation, it can be asserted that the analytical tool is both implementable and empirically testable, and may therefore be highly useful in economic analysis.

Stated more succinctly, over a <u>broad</u> spectrum of hypothetically possible economic outcomes, a IOLP model may be overly simplistic and unrealistic; but within a relatively <u>narrow</u> spectrum of possible outcomes (defined as slight deviations from the status quo) an input-output structure can adequately describe much of the activity and interactions which can be anticipated. This is particularly true when the analysis is intended to describe a qualitative response rather than the specific quantitative outcomes in the problem investigated.

Development of a state or region-specific input-output tables can be accomplished by several common techniques. The original input-output (I/O) table used here is a survey-based table which relied upon questionnaire responses to establish interindustry trading patterns for 50 separate sectors in the New Mexico state's economy. A similar table could have been derived based on national I/O tables made state-specific and/or region specific based on a variety of non-survey techniques which are available.[45]

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45 There have been many input/output models developed since Leontief's original work. Survey based input/output models are based on empirical interindustry transactions data obtained by survey of firms within the economy investigated. Due to survey costs this technique is rarely observed, with non-survey techniques more commonly observed in derivation of regional input/output models (e.g., from national input/output tables). A comprehensive survey of the literature is provided by Harry W. Richardson, Input-Output and Regional Economics, New York: John Wiley and Son, Inc., 1972. Non-survey techniques are described and appraised in William A. Schaffer and Kong Chu, "Non-survey Techniques for Constructing Regional Interindustry Models," Papers, Regional Science Association, Volume 23 (1969): 65-77; Stanislaw Czmanski and E.E. Malizia, "Applicability and Limitations in the Use of National Input-Output Tables for Regional Studies," Papers, Regional Science Association Volume 23 (1969): 65-77; W. I. Morrison and P. Smith, "Non-survey Input-Output Techniques at the Small Area Level: An Evaluation," Journal of Regional Science, Volume 14, No. 1 (April, 1974):

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The 1960 survey-based I/O table for New Mexico required updating with its reuse in the late 1960s. Additionally, due to the specific research requirements addressed then, it was felt desirable at that time to reduce the 50 sector model to a 24 sector model. This basic updating and simplification of the New Mexico model was done by Lansford, et al., for their research published in 1973.[46] In addition, this 1973 modification of the model attempted to describe the trade interrelationships among five separate regions in the state at this 24-sector level of specificity. The particulars of this I/O table's modification are presented in their research, and therefore are not further summarized here.

It was determined that a further updating of this 24 sector model should be attempted so as to more accurately depict the 1975 starting point for the analysis of Pueblo Indian water rights. The specifics of this most recent updating are presented subsequently and will be left at this time in favor of discussion of the model's objective function (i.e., resource allocation rules).

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1-14; David G. McMenamin and Joseph E. Harding, "An Appraisal of Non-survey Techniques for Estimating Regional Input-Output Models," Journal of Regional Science, Volume 14, No. 2 (August, 1974): 191-205. For an overview of interregional input-output modeling using the national BEA model as a base, see Karen R. Polenske, The U.S. Multi-regional Input-Output Accounts and Model, Lexington, Maryland: Lexington Books, 1980.

46 The input/output table's modification is described in Technical Report 20 (see supra note 5 for full citation).

C. Description of the Model and the "Objective Function"

The model in its final form is described by an I/O matrix which is 168 rows by 201 columns. The main body of the model is comprised of 120 rows and columns, previously described as the production functions for each of the 24 sectors in each of the five regions. The remainder of the rows and columns comprise the constraints, imports and various mechanisms (e.g., surface to groundwater transfer mechanism) which implement the specific analyses desired. For linear programming solution of the model it was necessary to specify an objective function. In the case of this model the objective function for optimization is defined to be the value added[47] to the economy which results from output by a specific sector. As used in this model, value-added describes the value of output minus the cost of all inputs to the production process.

The concept of value-added is significant in that it describes the value to society of output by a sector. This value-added measure of output describes the "price" which society is willing to pay so that the output might be produced. The more common use of "price" is simply the <u>consumer's</u> willingness to pay for the output, <u>not</u> the

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47 The objective function for linear programming maximization is the value added within the state by output production from each of the economic sectors. Value-added, as defined in this model, generally describes (per unit of output) the payment to households as wages, payment to governments as taxes, and payments to businesses as profits. The objective function goal, thus, maximizes this "net addition" to the state's economy.

"social value" of output from a particular sector. In the linear programming solution to a water resource constrained model, a value-added objective function allocates available water resources to successively less "socially valuable" sectors until either all demand for output is satisfied, or the available supplies of water are exhausted. The other rows and columns of the IOLP model are used to implement the specific analyses desired, and are described in detail later.

With a value-added objective function, the solutions obtained from the linear programming maximization problem describe specific levels of economic activity within the state which maximizes the social value of output. In a pure theoretical setting it is thought that value-added maximization would describe a social welfare maximum.[48] However, within the limitations of this present research it can only be asserted that this programming solution describes relative changes in social benefits derived by different levels of specific economic activities within the state.[49]

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48 Depending on interpretation of the definition assigned "social welfare," this statement can be subject to dispute. If social welfare describes only a strict interpretation of economic well-being defined as personal income, business profits and government income, then there is achieved a social welfare maximum by the optimal linear programming solution. If other cultural values are also included in the social welfare definition, problems with the model solution's identity to a social welfare maximum must be considered.

49 Further explanation of the qualifications corresponding to the social benefits incorporated in the specific model solutions will follow with the interpretation of the results obtained.

With the model's objective function specified in this manner the "pricing" of certain activities which are desired in the model, such as the ability to transfer a surface water right to a groundwater right, requires careful introduction and interpretation. The "value-added pricing" of these activities might be more clearly stated as the "social cost" of the activity described. This value-added price/social cost relationship exists in the same sense that the price of a product represents its cost to the individual. Continuing with the surface to groundwater transfer example, the social cost to the state of this transfer is the full administrative cost of approving such a water right transfer in compliance with the rules and regulations of the State Engineer,[50] <u>plus</u> the lost value-added in the transfer from sector which must now forego production. This value-added pricing <u>does</u> <u>not</u> lend itself to precise interpretation as an "observable water rights market price", and this must be clearly understood in the interpretation of the results obtained.

In one resolution scenario the model was required to reflect Pueblo Indian water rights which are acquired by actual use. Since the greatest quantitive use of water in economic activities also

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50 The model by this mechanism interpretes the State Engineer's administration and management of the Upper Rio Grande Basin as a hydrologically interconnected surface water and groundwater resource which is fully appropriated.

considered to be a "beneficial use"[51] of water occurs in irrigated agriculture, one must naturally conclude that one model scenario would require a specific minimum level of agricultural output (i.e., Pueblo Indian agriculture), even at times when that agricultural commodity would otherwise have been imported as a result of regional water scarcity.

It is commonly thought that the use of water by irrigated agriculture is among the lowest valued alternative uses of the resource.[52] It is also commonly asserted, in part because of this low valued use, that as water resources become increasingly scarce in New Mexico (and throughout the Southwest) agricultural water rights will be transferred to other uses. In short, the model must allow for transfer of existing water rights.

Thus, for this Pueblo agriculture scenario there was required mechanisms for both market reallocation of agricultural water rights

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51 "Beneficial use shall be the basis, the measure and the limit of the right to use water." (NM Const., Art. XVI, §3). Although other specific uses may be deemed beneficial with greater water depletion per unit of output, in 1975 agriculture in New Mexico accounted for 77.63 percent of statewide water use (depletions) in producing 5.60 percent of the state's total economic output.

52 Our water depletion coefficients, derived from actual water use data provided by the State Engineer's Office, clearly reflect this high quantitative use relative to the economic values generated by the production activities of the agricultural sectors in the Upper Rio Grande Basin. The specific water coefficients for all model sectors are presented in Technical Appendix TA-C.

associated with increasing water scarcity, and at the same time production of (Pueblo) agricultural output <u>regardless</u> of water scarcity conditions.

Another possible resolution of the Pueblo Indian water right claims allows the Indians to sell (or lease) all or some portion of the water rights to which they are entitled. Thus, there was need to include a mechanism in the model which would allow the sale of water by the Pueblos to sectors of the economy willing to purchase that water. This required an objective function "pricing" of the water at a level which reflected (to some extent) society's willingness to pay for the resource. The specific technique used to establish such a price is described later.

The first of the "water market" transfer mechanisms modeled the commonly observed practice of transferring a surface water right into a groundwater right.[53] The actual process of these transfers was somewhat simplified, with the model possessing a mechanism whereby a

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53 In <u>Templeton v. Pecos Valley Artesian Conservancy District</u> (65 N.M. 59, 332 P.2d 465 (1958)) the ability to change a surface water appropriation to a groundwater appropriation was recognized in regard to the interconnection of surface water and groundwater aquifers. In <u>City of Albuquerque v. Reynolds</u> (71 N.M. 428, 379 P.2d 73 (1963)) the court made explicit the quantitative relationship (according to Darcy's Law) between the two interconnected resources, and thereby provided a specific mechanism in the Rio Grande by which impairment could be assessed in the transfer of surface water rights to groundwater rights.

surface right is transferred (quantitively) one-for-one to a groundwater right[54] at a specific (objective function) cost.

Corollary to this first transfer process, which occurs within a particular model region, is the possible transfer of water right entitlement from one region of the model to another (See Chapter III for specific definition of the geographic regions modeled). It is possible to transfer water rights across the boundaries of all the regions which are described in the model; however, there are also restrictions to interregional transfers imposed reflecting the legal and institutional conditions which exist in the basin and state.[55]

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54 Specifically, there is a time lagged effect associated with the required retirement of a surface right to offset the associated new groundwater appropriation's effect on available supply. Thus, under the present administration of New Mexico water law, the transfer of a surface right to a groundwater right may have a short-term net effect of increasing <u>total</u> (combined surface and groundwater) available supply. The one-to-one relationship therefore describes accurately the long-run relationship between surface and groundwater sources of supply, but may understate the actual short run effect on available supplies resulting from such transfers.

55 The correspondence of the boundary between Region One and Two in the model (on the Rio Grande mainstream) and the Otowi Bridge gauging station, which is used to determine New Mexico's delivery obligation to Texas under the Rio Grande Compact, significantly constrains the ability of private parties to transfer water rights across the boundaries of these two model regions. These transfers are not impossible, though, with this demonstrated by the successful renegotiation of the Compact provisions in conjunction with increased water flows at the gauge resulting from deliveries of San Juan-Chama water. Thus, it is asserted that transfers are possible in (legal) theory, but that the practical reality of costly Compact renegotiation makes such transfer highly unlikely.

For all practical purposes no water right can be transferred upstream or downstream of Elephant Butte Reservoir since this is New Mexico's point of delivery of water to Texas under the Rio Grande Compact.[56] The geographic location of Elephant Butte and the northern boundary of Region Four correspond closely. Therefore, the interregional water right transfer mechanism incorporated in the model did not include any possible transfer of water into or out of Region Four.

A transfer across the shared boundaries of Regions One and Two would be difficult (if not practically impossible) since this geographic boundary corresponds closely with the Otowi Bridge Gauging Station on the Rio Grande. It is this gauging station which determines New Mexico's delivery requirement to Texas under the Rio Grande Compact, and it is probable that any sizable transfer would also require renegotiation of the Compact, a renegotiation which would be strongly resisted by many of the required parties.[57]

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56 The reasoning for this assertion relies on the general principle described in note 55, with the additional condition that upstream transfers (i.e., from below the Elephant Butte gauge to above the gauge) would most likely be protested by the Elephant Butte Irrigation District as a transfer outside the taxable boundaries of the District, while downstream transfers would likely be opposed by Texas as an effective reduction in reported Compact deliveries (i.e., increased flow at the gauge which is diverted prior to reaching Texas).

57 Included in a partial listing of effected parties likely to be given some standing in a major renegotiation of the Compact are the City of Albuquerque, the Middle Rio Grande Conservancy

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The only probable interregional transfer of water rights are those which might occur between Regions Two and Three. Agriculture in these two regions is largely served under the administration of the Middle Rio Grande Conservancy District which would not likely restrict such a transfer unless it were to damage the District in some material way. To accomplish the inclusion of all possible transfers (and leaving the potential problems of transfers between Regions One and Two for later resolution) a mechanism was included in the model to allow a one-to-one transfer of water right entitlements between Regions One, Two and Three.[58]

The final mechanism which was included in the model can be best described as allowing the purchase of additional labor by all sectors. The reason for inclusion of such a mechanism is relatively

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District, the Bureau of Reclamation, the Bureau of Indian Affairs as well as other smaller groups and individual water users. It must also be noted that any resolution of Pueblo Indian water right claims which results in transfers of water entitlements across Otowi Bridge gauge, and necessary Compact renegotiation, are assumed dealt with by the specific judicial resolution in our modeling. The discussion here pertains only to the transfer of non-Indian water rights which remain within the modeled scenario.

58 It is recognized that upstream or downstream transfers in most cases would not be quantitatively one-to-one due to consideration of impairment, return flow, and evaporative losses/gains to the available water supply. This problem is acknowledged, but must be ignored due to the unavailability of basin-wide hydrologic effect water right transfer models which would allow more precise specification of these transfer mechanisms.

straightforward. Although the state's labor force can be anticipated to grow at approximately the same rate as population, this rate of labor force growth may be insufficient to allow the growth anticipated in the state's economy. It was therefore necessary, if this model were to be strictly water availability constrained, to allow the purchase of additional labor if the otherwise available labor is fully employed. It was necessary (by a technique detailed later) to establish a price for this purchased labor which was near the "threshold" of the economy's willingness to pay, and at the same time it was necessary to include a water coefficient for this purchased labor which reflected that water requirement of this addition to the state's population.

This completes a general "structural" description of the IOLP model employed in this analysis. The next section of this chapter provides the specific details of this model's mathematic and analytic specifications. For the less technically concerned reader the next section could be skipped without loss of continuity. Many of the terms and techniques described in this next section assume a familiarity with IOLP, data construction and analysis, and some fundamental economic theory.

D. Specific IOLP Model Structure.

The base Pueblo model consists of 24 economic sectors in five regions of New Mexico. Associated with this basic I/O model are rows and columns which describe population, labor and water requirements for output in each sector, as well as columns to allow explicit imports, transfers and purchases of water within the economic system modeled. The economic sectors "drive" the solution to the model by describing the interindustry trade patterns required for output in any particular sector. The import, labor, population, water, and water transfer vectors of the model define the possible alternatives and constraints to be found in the model solutions. The value-added objective function establishes a criterion for evaluations and selecting among differing possible solutions. But, most importantly, the vector of final demands (for the 120 sectors) determines the set of feasible solutions to the model. It is appropriate to more formally specify the economic relationships described by the model, and in particular, the economic system defined by the interindustry transactions which forms the basis for the model.

To accomplish this description we must return to the form of the basic information upon which the technical coefficients matrix is based. It may be recalled that the I/O structure is derived from the actual dollar transactions observed between the sectors comprising the economic system modeled. The transactions information, although interesting in its own right, can be transformed into an analytical model of an economic system by making certain assumptions. The most significant of these assumptions is regarding the nature of the sectoral production functions (i.e., linear production functions). By looking at only the interindustry transactions matrix, and by assuming that amount of one sector's output purchased by other industries is a stable function of those industries' outputs, the direct input coefficients are derived as:

$$a_{ij} = \frac{X_{ij}}{X_i} \qquad (2.1)$$

where X_{ij} is the transaction amount for sector i with sector j, and X_i is the gross output of sector i. From this it can be asserted that:

$$X_i - a_{i1}X_1 - \ldots - a_{ij}X_j - \ldots - a_{in}X_n = Y_i \qquad (2.2)$$

or that output by a sector (X_i) minus all intermediate demand for that sector's output ($a_{ij}X_j$)is equal to the final demand for that sector (Y_i). If these linear input relationships remain constant over time there can be asserted a direct linkage between final demand and gross output. In this form I/O analysis describes the interaction of final demands, input requirements for each sector, and gross outputs by all sectors for the entire economic system modeled.

As an analytical tool I/O modeling is principally a device which allows the determination of the effects of specific changes in final demand upon gross output, given the technical coefficient matrix. Such effects include both the direct and indirect impacts on input requirements. The indirect impacts are simply the input/output requirements for all sectors connected by interindustry trading. The equilibrium equation for final demand can be expressed in matrix form as:

$$X - AX = Y \qquad (2.3)$$

where X and Y are column vectors of gross output and final demand, respectively, and A is a (n x n) matrix of direct input coefficients, a_{ij}. Using an (n x n) identity matrix (I) this equation can be rewritten as:

$$(I-A)X = Y \qquad (2.4)$$

Under the condition that (I - A) has an inverse (i.e., is non-singular), there can be expression of gross output as a function of (exogenous) final demand:

$$X = (I-A)^{-1}Y \qquad (2.5)$$

The $(I - A)^{-1}$ matrix is known as the Leontief inverse matrix with the elements of this technical coefficients matrix (commonly referred to as b_{ij}) representing the direct and indirect requirements of sector i per unit of final demand for the output of sector j. This inverse matrix allows analysis by projection of exogenous changes in final demand (Y), with impacts expressed by the level of total output for each model sector (X).

The IOLP model can be extended to perform interregional analysis in much the same theoretical manner; first by construction of the intersectoral and interregional trade coefficients, then developing direct input coefficients, through the identity matrix and inversion routine, etc.

The inclusion of resource constraints can be easily accommodated in the IOLP structure if technical coefficients of necessary resource use (per unit of output) can be obtained. For example, if one can find a coefficient which reflects the number of employees required to produce a million dollars of output for each sector modeled, then one can add a row of these labor coefficients to the IOLP structure and constrain the sum of labor used in the production of output to be less than or equal to the (exogenously determined) total available labor force.

Whereas the equilibrium condition in the I/O structure <u>without</u> resource constraints requires equality between the gross output and the sum of the intermediate and final demand, the resource constrained IOLP structure requires (in equilibrium) that the productive sectors maintain this previously described equality between output and demand, <u>and</u> at the same time not exceed the specific resource constraints modeled.

In more technical terms, a <u>feasible</u> <u>solution</u> of the resource constrained IOLP problem is one which achieves this equilibrium condition without exceeding the resource constraints. An <u>optimal</u> <u>feasible</u> <u>solution</u> to this same problem is one in which the value of the objective function cannot be increased by any alternative combination of resource inputs allocated to the specific sectors. With this short introduction to the techniques it is appropriate to return to discussion of the general model structure as implemented in the Pueblo Indian water rights analysis.

E. General Model Implementation

The basic model employed in the research of Lansford, et al., analyzed the probable effects of differing growth patterns in specific economic sectors throughout the state, and described conditions of water scarcity, water quality, and recreation demand which can be associated with these alternative growth scenarios. Many of the specific mechanisms included in the Lansford, et al., model were felt to be either unnecessary or irrelevant to the "qualitative" modeling of alternative Pueblo Indian water right scenarios. This group of unnecessary model characteristics included the recreation coefficients, the winter/summer water demand requirements, water quality considerations, and the diversion versus depletion requirements.

It should be noted that although these are interesting analytical characteristics when incorporated in a water constrained IOLP model, the specific objectives of the Pueblo Indian water rights analysis undertaken required only a constraint which described the water supply available for depletion in each of the regions. The concern in the modification of the Lansford, et al., model was not with all hydrologic and/or social conditions effecting the actual allocation of water, but rather with an attempt to describe in a qualitative manner the sectors and regions which can be anticipated to be effected by specific quantifications of Pueblo Indian water rights.

Thus, the Lansford model was first "stripped-down" so as to include only depletion coefficients (i.e., acre-feet of water depleted per million dollars of output) for both surface and groundwater use in each of the 120 economic sectors, plus water requirements per capita for both urban and rural[59] populations. Reduction to depletion coefficients greatly simplified many of the calculations and implementation steps for use of the Lansford model in the Pueblo Indian water right analysis. It can be said that loss of the diversion-to-depletion relationship is the most damaging to the "reality" of the model; but at the same time, the depletion constrained model can be asserted with substantial authority. Under New Mexico water law it is the allowed depletion of water which constrains both water rights and economic activity ultimately.[60] This is not to say that return flows or diversionary patterns would be ignored in actual quantification of a water right or in its application to beneficial

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59 Rural populations are defined throughout this report to be all settlements of 2,500 people or less.

60 The transfer of water rights under the water laws of New Mexico are much more complex than depicted by the mechanisms employed in this model. Yet it is clear that the fundamental limit to a water right is the consumptive use, or depletion right, conveyed by a specific water right entitlement. Much litigation has pursued the nuances of transferable quantities associated with specific water rights, but the fundamental depletion right limit to transfers has been consistently supported throughout western prior appropriation states in such cases, as <u>Coffin v. Left Hand Ditch Co.</u> (6 Colo. 443 (1882)) and <u>W.S. Ranch Co. v. Kaiser Steel Co.</u> (79 N.M. 65, 439 P.2d 714 (1968)).

use. Alternatively, it is asserted that a qualitative analysis of the impact of alternative Pueblo Indian water right scenarios can be adequately described by consideration of depletion requirements only.

The new model which resulted from modifications to the Lansford model, hereinafter to be referred to as the Pueblo model, relied on the square matrix of technical coefficients (i.e., intersectoral trade coefficients) from that original model. The derivation of this 120 by 120 element square matrix by Lansford, et al., relied primarily upon 1967 data. This technical coefficients matrix was found in our updating to be very similar structurally to the pattern of economic activity observed in the 1972, 1975, and 1977 data which were available in the preparation of the Pueblo model.

Several major structural changes were noted to have occurred in the interim, including the emergence of large energy transport and production sectors (particularly electricity, oil and gas), the sudden expansion of the uranium mining sector in Region Two,[61] and to a much lesser extent, the general filling-in of several small economic sectors throughout the state. There was also reliance on the surface and groundwater depletion coefficients included in the original model, although there was required modification of these coefficients so as

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61 This expansion was very rapid and significant both as an economic and water using sector, but the expansion was followed by an equally rapid contraction in the late 1970s and early 1980s as demand for uranium ore declined dramatically.

to update the model to the New Mexico State Engineer's Office reporting of water depletions in 1975. Finally, there was also dependence on the labor coefficients used in the original model (i.e., labor required per million dollar output), but these too required modification so as to be updated to the 1972, 1975, and 1977 employment data (and trends) reported for each sector by the New Mexico State Employment Security Department (ESD).

The Pueblo model at this stage consisted of a matrix of technical coefficients, including trade coefficients, surface and groundwater coefficients, and labor coefficients. To set up a linear programming problem several other characteristics were required. There was need to establish a right-hand-side (RHS) for the model which a linear programming solution must satisfy. For the purposes of this model this RHS is defined to be the final demand for output of a sector. As used in this model this final demand includes private consumption purchases, government purchases, and gross exports from the region (or state). By definition, the sum of all intermediate purchases and final demand purchases of a sector's output must be equal to the output of that sector in this equilibrium model.[62] This was previously stated in equation 2.3 as:

$$X - AX = Y \qquad (2.3)$$

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62 The model is considered to be an equilibrium model in the sense that inventory stocks are assumed constant and all demands for output must be satisfied.

or, output (X) minus intermediate demand (AX) equal final demand (Y). This equation can be rewritten as:

$$(I - A)X = Y \tag{2.4}$$

The (I-A) matrix is the inverse of the technical coefficient matrix which was extracted from the Lansford, et al., model.

The technique for derivation of the final demand RHS in the Pueblo model was clear. First, there must be a calculation of the 1975 level of output for each of the 120 sectors of the state's economy, then the technical coefficients matrix from the Lansford, et al., model must be inverted (mathematically) and multiplied by the vector of outputs for the 120 sectors, with the product vector then equal to the 1975 final demand (or RHS) vector in the Pueblo model.[63]

The most difficult aspect of this simple computational manipulation is the derivation of output levels for the 120 sectors modeled. In the case of agricultural output sectors (Sectors 1 thru 4 in each region) there was output data available for 1975 at the county level which made derivation of regional output in each of these sectors simply a matter of data collection.[64] In the case of the remaining

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63 The reader interested in a thorough description of the specific output estimation techniques utilized for each sector is directed to Technical Appendix TA-B. The description provided in the following portion of the text is a general expression of the technique, and is in some cases not a precise description of the estimation technique employed.

64 Data principally provided by United States Department of Agriculture and New Mexico Crop and Livestock Reporting Service,

[continued on next page]

sectors the derivation of 1975 output estimates was not nearly so simple.

For most of these nonagricultural sectors the best, consistent set of output estimates is provided by the 1972 and 1977 Census of Business from the Department of Commerce.[65] Employment data for 1972, 1975, and 1977 were obtained for each of the sectors modeled at the county level. For most (nonagricultural) sectors the 1975 state output estimates were derived from the 1977 output reported by the U.S. Department of Commerce by the following general technique: a) multiplication by the ratio of 1975 employment (emp_{75}) to 1977

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64 [continued from previous page]

New Mexico Agricultural Statistics, 1977 (includes 1975 revised data) New Mexico Department of Agriculture, Las Cruces, New Mexico: New Mexico State University, 1978.

65 Bureau of Census, 1977 Census of Mineral Industries, Mountain Division, U.S. Government Printing Office, Washington, D.C.: U.S. Department of Commerce, March 1981; Bureau of Census, 1977 Census of Manufacturers, New Mexico, U.S. Government Printing Office, Washington, D.C.: U.S. Department of Commerce, October 1981; Bureau of Census, 1977 Census of Retail Trade, New Mexico, U.S. Government Printing Office, Washington, D.C.: U.S. Department of Commerce, July 1979; Bureau of Census, 1977 Census of Wholesale Trade, New Mexico, U.S. Government Printing Office, Washington, D.C.: U.S. Department of Commerce, April 1980; Bureau of Census, 1977 Census of Service Industries, New Mexico, U.S. Government Printing Office, Washington, D.C.: U.S. Department of Commerce, October 1979; and Bureau of Census, 1977 Census of Construction Industries, Mountain States, U.S. Government Printing Office, Washington, D.C.: U.S. Department of Commerce, August 1980.

employment (emp_{77})in that sector (emp_{75}/emp_{77}),[66] b) multiplication by change in productivity for sector (productivity per emp_{75}/productivity per emp_{77}),[67] and c) multiplication by a general price deflator index ratio for expression of 1975 output in 1975 dollars in each of the sectors.[68]

$$\text{(1975 Output)} = \text{(1977 Output)} \bullet \left(\frac{emp_{75}}{emp_{77}}\right) \bullet \left(\frac{\text{productivity}_{75}}{\text{productivity}_{77}}\right) \bullet \left(\frac{\text{price index}_{75}}{\text{price index}_{77}}\right) \qquad (2.6)$$

This provided a statewide estimate of 1975 output in each of the 24 model sectors. Then this statewide output was allocated to each of

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66 Employment data was provided by the New Mexico State Employment Security Department at the 4-digit SIC level for covered employment, at the 9-sector level for covered and noncovered employment. This data allowed derivation of covered and noncovered employment estimates for each of the 120 sectors and on a 24-sector state total level.

67 Productivity data is provided by the Bureau of Labor Statistics at a national level for selected two, three, and four-digit SIC industries. In some sectors there were numerous industries for which data was provided, and in other sectors there was no data available. Thus, the 1975 output estimates made full use of the data which was available, but in some sectors the 1975 output estimate reflects 1977 labor productivity since no more precise estimate could be derived.

68 Depending on the nature of output in each sector, there were derived price deflator estimates for each sector relying on Department of Commerce wholesale or retail price data weighted according to relative dollar output levels of the industries which comprise each of the 24 sectors.

the five model regions. Here the county level ESD employment data was relied upon. Output was allocation to each region based on the percentage of a region's employment to total state employment in that sector.

There are many assumptions both implicit and explicit in the derivation of these 1975 output estimates for each region. The most important of these assumptions include: 1) the Census of Business (and other sources relied upon) reporting of output for each sector is definitionally equivalent to the output measure utilized in the previous uses of the basic I/O transaction table, 2) the designation of employment according to SIC category provided by ESD correctly classifies and accurately reports employment in each of the model sectors, 3) national productivity data accurately describes productivity changes in New Mexico economic activities, 4) national commodity price data reflects price changes in New Mexico, and 5) output per employee in each of the state's 24 sectors is equal in all regions of the state.

Clearly there is reliance on data which does not reflect the precise economic circumstances in New Mexico. But at the same time, no better data are available to provide a more accurate estimation of 1975 output for each of the sectors. For a model of the qualitative economic impacts of alternative resolutions of Pueblo Indian water right claims these estimated output levels are entirely adequate for the analysis undertaken. On the other hand, estimates such as these are far too imprecise to serve in a quantitative economic model for predictive application -- and no pretention is suggested that this is the purpose or application of the Pueblo model here described.

Having estimates of output for each of the 120 sectors in 1975, the matrix of technical coefficients from the Lansford, et al., model was inverted and multiplied by the vector of outputs. Nineteen seventy-five final demand was thereby derived, and the model was now "calibrated" to the 1975 level of output estimates for each of the 120 sectors.

Next, the labor and water constraints in the model required updating so that the solution to the model reflected the actual 1975 employment (ESD) and water use (SEO) data which were available.[69] In the case of employment this calibration was such as to match total employment in each region modeled to the employment reported in that region by ESD. The updating of the model to the 1975 water use data provided by the SEO for each region was more precise. The final run of the 1975 Base Year model results in water use in each region which reflects the SEO's reporting of water use in: a) agricultural sectors (Sectors 1 through 5), b) mining sectors (Sectors 6 and 7), c) municipal and industrial uses (Sectors 8 through 24, plus Urban), and

69 Water use data from Earl F. Sorensen, supra Note 24; also there was reliance on the SEO data files which supported the preparation of this technical report. Employment data from New Mexico Employment Security Department, supra note 66.

d) rural population uses (Rural).[70] This, then, represents the model's general updating and modification so as to reflect economic conditions in 1975. The model solution reflects all the information available regarding the use of labor and water in these economic activities in New Mexico.

There are several possible summary representations of the model and its specific elements. Figure 2.1 is a "picture" of the Pueblo model which shows the row and column names, and details either positive (+), negative (-), one (1), or minus one (T) the values in the specific rows and columns of the matrix. It may be recalled that

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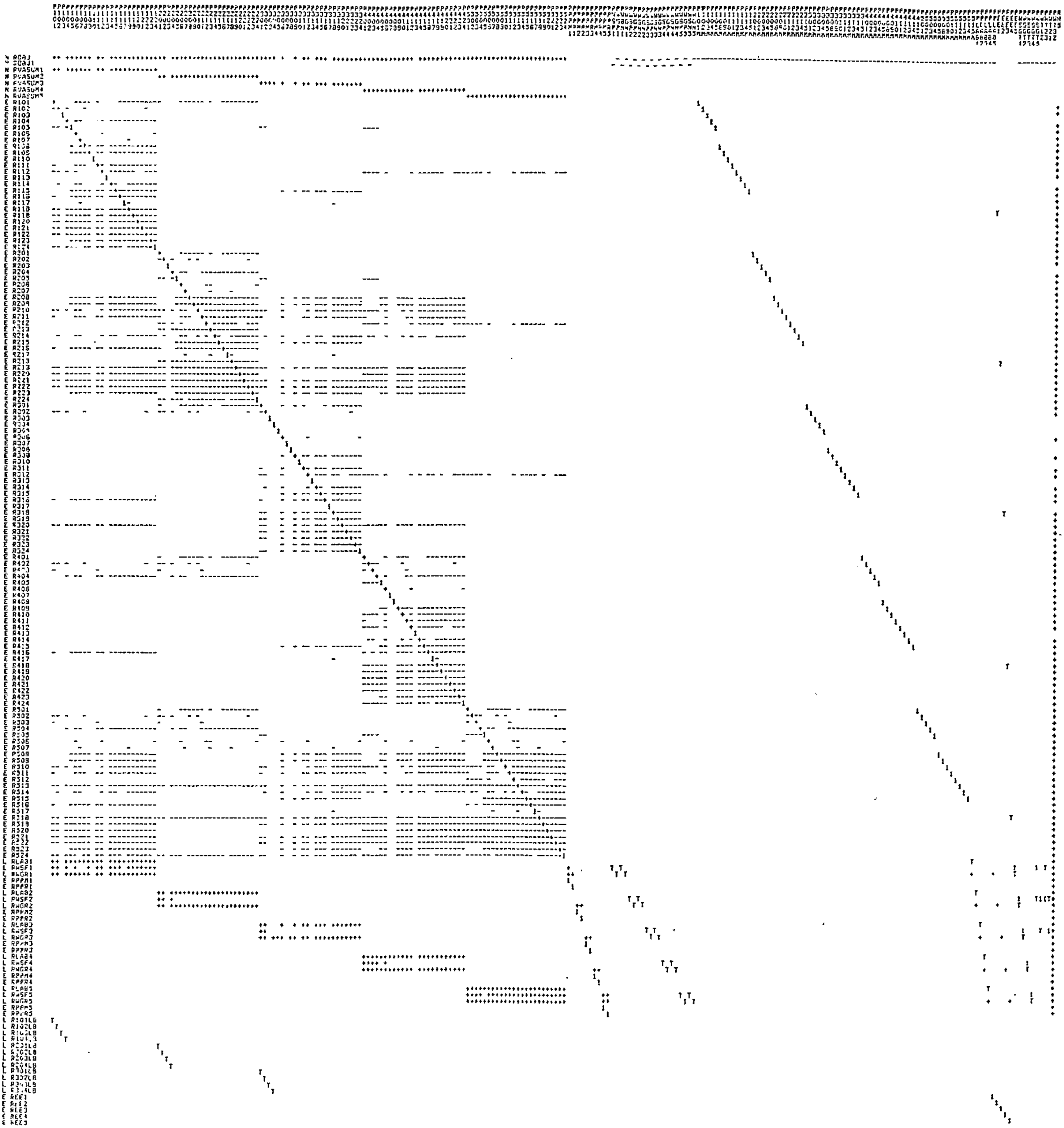
70 Definitionally the categories of water use in the model and the SEO's data report are not identical. The two data sets correspond as follows:

SEO Data	Model Sectors
Irrigated Agriculture Livestock Stockpond Evaporation	Sectors 1 through 5
Minerals	Sectors 6 and 7
Self-supplied Manufacturing Power Recreation Military Urban	Sectors 8 through 24, plus Urban
Rural	Rural

In addition, the SEO data reported surface water use in Regions One and Five for Sectors which the Lansford, et al., model had no surface water coefficients. This necessitated the derivation of these surface water coefficients, and the derivation was based on the patterns of groundwater use in the corresponding sectors.

FIGURE 2.1

PUEBLO MODEL
INPUT-OUTPUT LINEAR PROGRAMMING MATRIX



reading Figure 2.1 across a sector's row describes the sales of output produced by a sector to the other sectors in the model; and reading down a sector's column describes the purchases of output from other (row) sectors required for production in that sector. It is also clear from this picture that several other rows and columns are included in the Pueblo model which have not previously been described. By way of defining the mnemonics used in this picture there will also be provided a brief description of the additional rows and columns included in the basic Pueblo model.

ROBJ and ROBJ1--these two rows describe the value-added objective function which the model is to optimize, with ROBJ1 used to augment (increase or decrease) specific values which enter into the objective function (e.g., ROBJ1 allows parametric increase in the price of water which is an element of ROBJ),

RVASUM1-5 -- these rows act as accounting rows and describe the value-added for each of the five regions, and in no way effect the solution to the model.

R101 through R524 -- these rows represent the 120 economic sectors in the state, with the first numeral describing the region (One through Five) and the second and third numerals describing the sector (1 through 24) in that region.

RLAB1-5 -- these rows describe the labor coefficients (per million dollars of output) for each sector in Regions One through Five.

RWSF1-5 -- these rows describe the surface water depletion coefficients (per million dollars of output) for each sector in Regions One through Five.

RWGR1-5 -- these rows describe the groundwater depletion coefficients (per million dollars of output) for each sector in Regions One through Five.

R101LB through R304LB -- these rows define minimum or maximum output levels for agricultural sectors in Regions One through Three, and are utilized in Pueblo agriculture scenarios.

RPPM1-5 -- these rows define the urban population for each region.

RPPR1-5 -- these rows define the rural population for each region.

REE1-5 -- these rows define a energy export sector in Regions One through Five which appeared as possibly required for projections of future economic activity because the pattern of water use in large coal-fired electrical generation facilities (for energy export) was thought to be significantly different from that observed in small scale generation for in-state demand.

P101 through P524 -- these columns represent the 120 economic sectors in the state, with the first numeral describing the region and the second and third numerals describing the sector in that region.

PPPM1-5 -- municipal (Urban) population columns for Regions One through Five, which are required for allocating urban water use per capita.

PPPR1-5 -- rural population columns for Regions One through Five, which are required for allocating rural water use per capita.

PWSP1-5 -- columns describing the surface water available for sale from the Pueblos in Regions One through Five.

PWGP1-5 -- columns describing the groundwater available for sale from the Pueblos in Regions One through Five.

PWSN1-5 -- columns describing the surface water available for sale from non-Indians (e.g., City of Albuquerque) in Regions One through Five.

PWGN1-5 -- columns describing the groundwater available for sale from non-Indians in Regions One through Five.

P101M through P515M -- columns describing sectors (1 through 5 and 8 through 15) in which imports are allowed in Regions One through Five.

PPLAB1-5 -- columns allowing the purchase of labor from outside the model (i.e., necessary growth in the labor force greater than anticipated by model labor force growth assumption), and serves to prevent model from being absolutely constrained by labor availability.

PEE1-5 -- columns allowing energy export sector in Regions One through Five.

PMSGT1-5 -- column allowing the transfer of surface water depletion right to a groundwater depletion right.

PWT12 -- column allowing the transfer of surface water depletion right from Region One to Region Two.

PMT23 -- column allowing the transfer of surface water depletion from right Region Two to Region Three.

PWT21 -- column allowing the transfer of surface water depletion right from Region Two to Region One.

PWT32 -- column allowing the transfer of surface water depletion right from Region Three to Region Two.

RHS and RHS1 -- columns describing the final demand and constraint variable values (e.g., surface water availability), with the RHS1 used to augment (increase or decrease) specific values in the RHS (e.g., RHS1 allows parametric increase in the level of Pueblo agriculture in Regions One and Two).

F. Summary

This chapter has detailed the formal structure of the Pueblo model and its derivation. It is appropriate to condense this discussion and provide a concise statement of the model's features and application as a summary to this detailed description. By way of this summary there will also be introduction of the functional constraints which are further specified in the next chapter.

Each column of the model's 120 sectors describes a "production function" for that sector, including labor and water requirements. Expressed in the objective function for these 120 sectors is an estimation of the social benefits (i.e., value-added) by output in that sector. In addition to the basic 120 sectors there is also expressed as columns the population water requirements in each region, bounded in the linear programming solution to the model to be greater/less than a minimum/maximum value. For example, the sale of Pueblo water must be less than or equal to x-number of acre-feet. The optimal solution to model attempts to maximize the value of the objective function without exceeding the column bounds (if any), but also subject to the feasibility constraints imposed by the row functions of the model (i.e., both final demand satisfaction and resource use constraints).

The rows which describe the 120 economic sectors of the model are specified so as to describe an equilibrium condition between the output of a sector and the demand for that output. Thus the equality condition requires a feasible solution to satisfy all output demand, although a portion of this demand may be satisfied by commodity imports. The solution to the model is therefore dependant upon specification of the final demand for determination of sectoral output, this due to the fixed intermediate demand relationship for trade between sectors described by the basic I/O trade matrix.

There are also rows specified which describe regional water and labor requirements for output. The labor and water rows are specified in the model to be less than or equal to the RHS expression of their constraining values.[72] That is, for example, a feasible solution

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72 Only in the water rows are there expressed (potentially) binding constraints. This is due to the ability to "import" or purchase" labor from outside the model. Although the price of this

[continued on next page]

requires that total water depletions in Region One not exceed x-number of acre-feet. There are also population rows which function as to define the urban and rural population in each region, and which are specified so as to force the water requirements of each region's population to be met first.

The basic elements of the model have now been explained in a general form. The optimal IOLP solution to a particular specification of the model requires compliance with the equalities and binding constraints, while at the same time achieving the maximum possible value for the objective function. This IOLP solution thus must choose successively less valuable (in the social welfare value-added sense of the objective function) utilization of the constraining resources. Viewed from another perspective, the constraining resources will be allocated to decreasingly valuable uses until the available supplies of that resource are fully consumed, or up to the level where all intermediate and final demands for output can be satisfied without exceeding the resource constraints of the model.

It is now appropriate to turn to a brief economic and demographic profile of the Upper Rio Grande Basin. This is followed by a specific description of the empirical structure and specification of the

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72 [continued from previous page]

imported labor can constrain the "economic feasible" level of purchase, the model is asserted to the strictly constrained by only these water rows.

constrained regional IOLP model utilized for analysis of impacts associated with Pueblo Indian water right resolution.

CHAPTER III

AN ECONOMIC, DEMOGRAPHIC AND WATER SUPPLY PROFILE OF THE UPPER RIO GRANDE BASIN

A. Overview

The Upper Rio Grande Basin must be considered to be the heart and soul of New Mexico. This is not to diminish the contributions to New Mexican history and society provided by the other regions of the state; however, it is the Upper Rio Grande region which has sustained the greatest population, and served as the center of multi-cultural and economic development for New Mexico since the prehistoric settlement of the region. To a very large extent it is the water resources of the Rio Grande which have nurtured the development of the region.

According to the 1980 Census 51.8 percent of the New Mexico population lives within the boundaries of the Upper Rio Grande Basin, and this population is expected to nearly double by the year 2000. Approximately 59 percent of all state economic activity, as measured by 1980 employment levels, takes place within the Upper Basin; and this region is expected to be one of the top economic growth areas in the United States over the next several decades. An expanding regional economy and population will give rise to increased demand for water.

Physical parameters limit the geographic distribution of impacts associated with specific future resolution of the Pueblo Indian water right claims to the Upper Basin region of New Mexico. Of the 19

Indian Pueblos which were described by the Treaty of Guadalupe Hildago, 18 are located in the Upper Rio Grande surface drainage basin. The specific locations of these Pueblos relative to the boundaries of the Upper Basin are depicted in Map 3.1. It is apparent that the Pueblo lands constitute a significant portion of the total Upper Basin land area, with a 1979 estimation of total Pueblo lands representing more than 9.3 percent of total Upper Basin surface drainage basin.[73]

Outside of Albuquerque, the nearest metropolitan areas of similar size are located at El Paso 250 miles downstream on the Rio Grande, Phoenix 350 miles to the west and Denver 350 miles to the north. The extensive economic development found in the Upper Basin is unique to New Mexico. The degree of the Upper Basin's economic isolation from the other centers of activity in the Southwest it important to its regional IOLP modeling. The Upper Basin operates as an interconnected economic unit largely separated from these other Southwestern centers of economic activity. The geographic regions which define the

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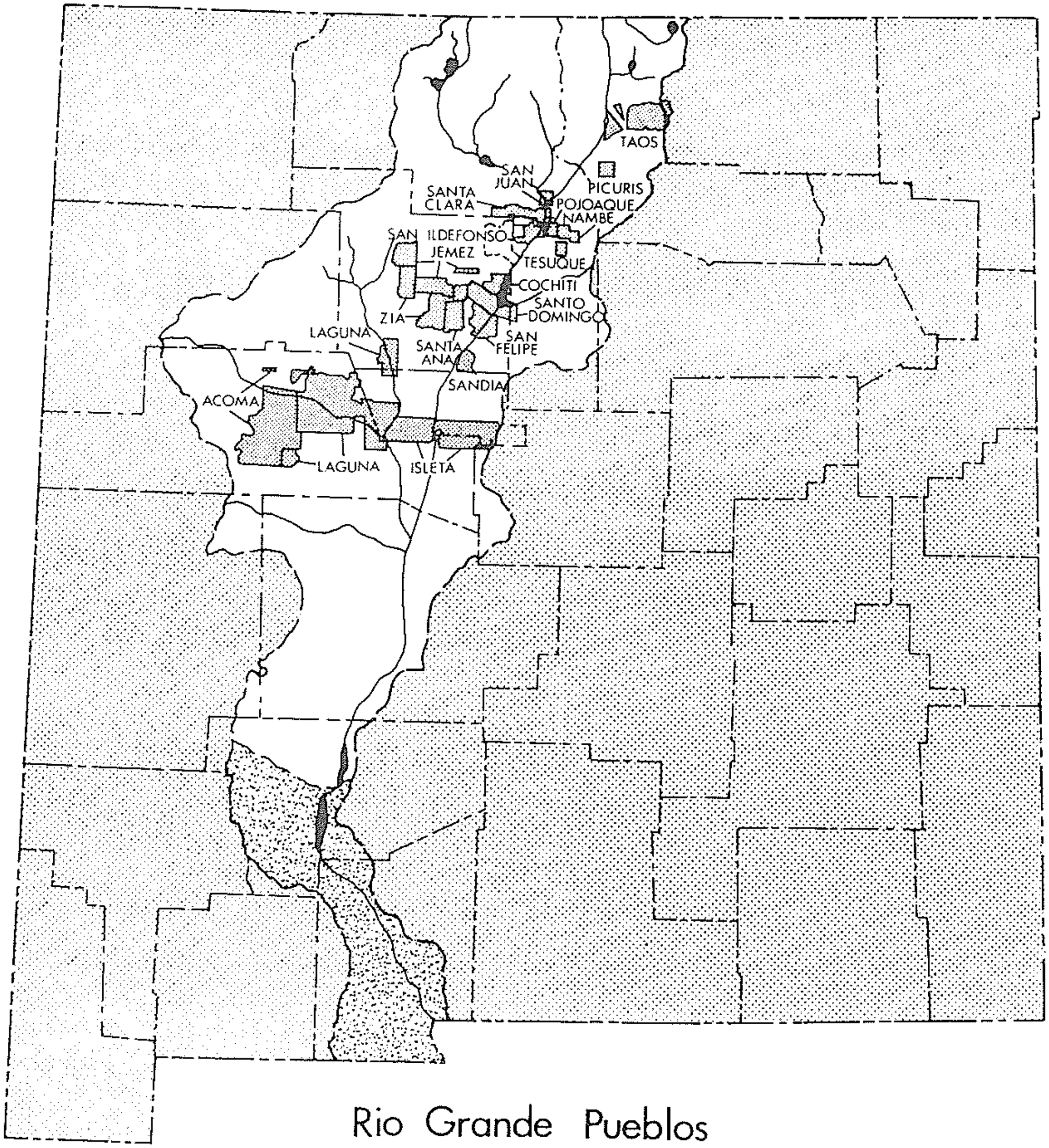
73 That is, original Pueblo grants, reservation lands, and acquired Pueblo lands outside the grants and reservations are reported in 1979 to be 1,580,171.21 acres (2,469.02 square miles) and the Upper Rio Grande surface water drainage above Elephant Butte Dam is reported as 26,510 square miles. Bureau of Indian Affairs, New Mexico Indian Pueblos Land Status Report 1979, Albuquerque, New Mexico: Branch of Real Estate Services, Albuquerque Area Office, Bureau of Indian Affairs, U.S. Department of the Interior, 1979. Water Resources Data for New Mexico, Water Year 1981, U.S. Geologic Survey Water Data Report NM-81-1, p. 300.



Rio Grande Pueblos

Legend

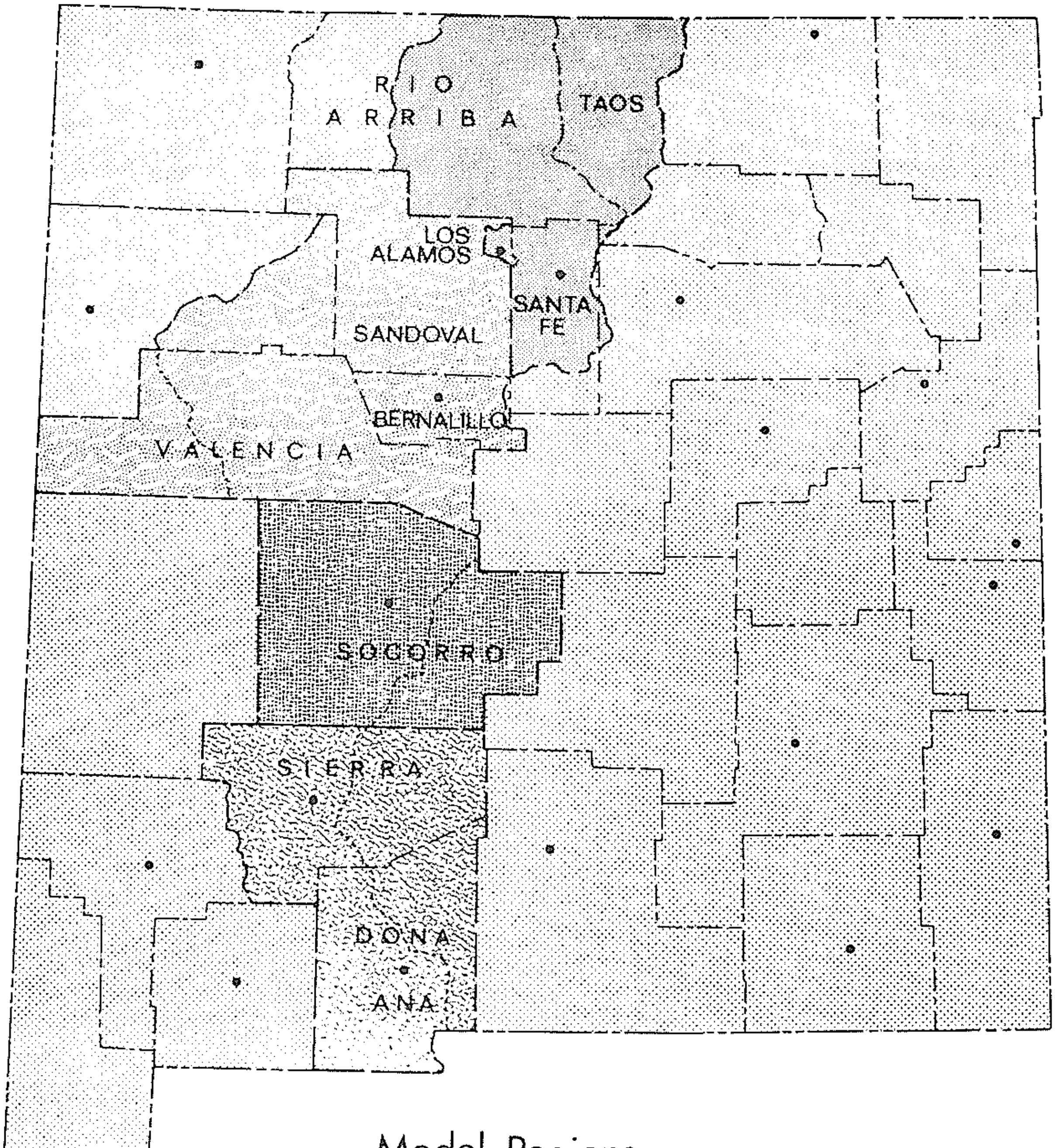
- Upper Rio Grande Basin
- Lower Rio Grande Basin
- Other

interregional IOLP model must be further detailed before turning to an expanded profile of economic and demographic conditions in the Upper Basin.

B. Definition of Regions Modeled

As has already been mentioned, the definition of the model according to five separate regions of New Mexico was first done by Lansford, et al., in their specification of the IOLP model. A mapping of the counties included in each of the regions is shown in Map 3.2, with these county boundaries for the most part closely approximating the surface drainage basin of the Rio Grande. Only in the cases of the relatively large portion of Santa Fe and McKinley Counties which lie outside the hydrologic boundaries were there required any adjustments of the regional sector outputs to reflect more closely the specific economic activity which occurs in the Rio Grande Basin portion of those counties.

In reviewing the original version of the model (Lansford, et al.), it was determined that the regionally significant mining activity in the Rio Grande portion of McKinley County was not included within the basin. Since this is the only major economic activity which occurs in the Rio Grande portion of McKinley County, the sector was added to the Region Two economy. This "structural" change was the only modification of the Region Two economy not included in the original Lansford model. The Lansford model also did not recognize that nearly two-thirds of the irrigated agriculture in Santa Fe County is located



Model Regions

Legend

- Region 1
- Region 2
- Region 3
- Region 4
- Region 5

outside the Rio Grande surface drainage basin, and so it was felt necessary to remove a percentage of the agricultural output for Region One which had previously been included in the model. These two changes reflect the only two geographic modifications of the original model, and for all subsequent discussion the counties included in the five regions of the model are as follows:

Region One: Rio Arriba County, Taos County, Los Alamos County, and Santa Fe County (portion).

Region Two: Sandoval County, McKinley County (portion), Valencia County (including Cibola County), and Bernalillo County.

Region Three: Socorro County.

Region Four: Sierra County, and Dona Ana County.

Region Five: The remainder of the state.

It should also be noted (for clarity) that the Rio Grande Basin described in this model does not include the Pecos River Basin, which is eventually tributary to the Rio Grande. Since the confluence of the two stream systems is outside the state's boundaries, it is reasonable to allow their treatment as two separate basins in this analysis. Additionally, the closed basins in central New Mexico are excluded from the analysis, as they are not tributary to the Rio Grande's surface flows and would therefore be unaffected by the resolution of Pueblo Indian water right claims on the mainstream of the Rio Grande.

The reasons for designation of the three subregions of the Upper Basin are twofold. For many purposes the Upper Basin can logically be divided at Otowi Bridge, located near to the point where the Rio Grande mainstream leaves Santa Fe County. Above this point most irrigation must be characterized as occurring in narrow valleys of mountain stream tributaries to the Rio Grande. Below this point agricultural lands open up and are more commonly served directly from mainstream diversions. The region below Otowi Bridge has greater economic and geographic diversity than is found in the counties which comprise Region One, although Socorro County in the far southern reaches of the Upper Basin does not display the diversity of the remainder of these counties below Otowi. Region Two, therefore, consists of Sandoval, Bernalillo, Valencia, and (the southeastern portion of) McKinley Counties. Region Three is limited exclusively to Socorro County, and thus completes the Upper Basin. This division of the Basin into three subregions plays a central role in the economic analysis of alternative Pueblo Indian water right resolutions.

C. <u>Agriculture in the Upper Rio Grande Basin</u>

The development of agriculture in the Upper Rio Grande Basin has been largely based on surface water irrigation techniques, contrary to the practices found in the majority of the rest of the state. Prior to the development of flood control reservoirs and other flood control improvements these agricultural enterprises were periodically ravaged by spring flooding, resulting in dramatic swings in both the number of irrigated acres and agricultural yields from these irrigation enterprises. The last of these devastating floods struck the middle valley region in the late 1920s.[74] With the subsequent completion of the Middle Rio Grande Project, the emergence of the Middle Rio Grande Conservancy District (MRGCD) as a viable water resource management institution, and the protections provided by the Bureau of Reclamation and Army Corps of Engineers, most of the threat from large scale flooding of the irrigated lands has been eliminated.

Some small areas of the Upper Basin must still contend with unseasonably high flows with occasional damage incurred, but for the most part the number of irrigated acres in the Basin has remained essentially constant since the mid-1940s. There have been significant shifts in the specific cropping patterns found in the Upper Basin, although specific agricultural data prior to 1960 is limited in both accuracy and completeness. Therefore, discussion of the specific patterns of irrigation found in the Upper Basin will focus on the period from 1960 through 1980. Likewise, data for livestock and poultry production is spotty and inaccurate prior to 1960. What is

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74 The last of the floods which devastated large areas of irrigable land in the Middle Valley came in the spring of 1929, prior to completion of many of the flood control projects associated with the MRGCD. High flows, with some damage, were also seen in the spring of 1941 and 1942, and the district received $500,000 in federal emergency flood relief funds for damages. The flood damage in the early 1940s was substantially limited due to the existence of MRGCD flood control works.

consistent throughout the specific data described here is a general pattern of stability -- or slight decline -- in the role of Upper Basin agriculture, a trend which has been observed by other authors as well.[75]

A note on the analytical technique employed here and the specific data available is appropriate. First, trends in specific data are identified by regression techniques. If there is a reported rate of change for any identified trend, this is a compound annual rate of change, and may be either positive or negative depending on the increasing or declining trend identified. The main sources of data for this section are the statistical publications of the U.S. Department of Commerce's Census of Agriculture. It was not possible to obtain consistent data for certain crops or crop categories. For example, New Mexico Agricultural Statistics did not provide sufficient data to study vegetables and fruit trends in the Upper Basin over the 20-year period previously described. The Census of Agriculture crop data proved insufficient for the purposes of this investigation, with much data either unavailable or withheld under disclosure rules.

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75 Mark C. Resta and Lee B. Zink, The New Mexico Economy: Change in the 1980's, Albuquerque: Institute for Applied Research Services, University of New Mexico, 1978; and Robert R. Lansford and Charles H. Greene, "New Mexico Agriculture, 1970 and 1971," New Mexico Business, Volume 25 (10), Bureau of Business Research, University of New Mexico, October, 1972.

In the Upper Rio Grande, as in the rest of the state, animal husbandry generates a considerably larger proportion of farm income than does crop raising. For the years 1959, 1964, 1969 and 1974, the cash value of all crops sold ranged between 12 and 20 percent of the cash value of all farm products sold in the Upper Basin. Hay has been the most important crop in the Upper Basin, accounting for over 40 percent of the cash receipts from all crops in the year 1980. Vegetables and grains (mainly corn and wheat) compete for second place as sources of farm income below Otowi, while in Region One the second most important crops are fruits and grains. The value of the cotton crop exceeded that of hay in Socorro County at the beginning of the period investigated; however, the output of cotton has declined steadily until, by the seventies, no cotton production is reported anywhere in the Upper Basin.

Farming in Regions One and Two is probably quite vulnerable to competition due to generally low crop yields, including the yields from cattle feed crops.[76] Furthermore, the development of agriculture in these subregions of the Upper Basin is severely hampered by structural factors:

> There is only one bulk fertilizer dealer (in Belen) north of Hatch in the San Juan and Rio Grande Basins. There is only one Production Credit Association and one Federal Land Bank

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76 Ben Mason and Tom Clevenger, "Achieving the Potential for Irrigated Agriculture in New Mexico," New Mexico Business, Volume 32 (2), Bureau of Business and Economic Research, University of New Mexico, March, 1979.

Association (both in Albuquerque) north of Las Cruces in the two basins. There is only one tractor dealership north of Albuquerque in the Rio Grande Valley; Dona Ana County farmers use more farm machinery than all other Rio Grande Basin farmers combined. Maricopa County, Arizona, has 17 farm machinery dealerships.[77]

Crop marketing is also extremely underdeveloped in the Upper Basin.

Region Three's crop yields generally compare favorably with statewide averages, often exceeding the latter. Region Two's hay crop yields are also comparable to the state average, although in general crop yields throughout Regions One and Two are very poor. The value of crops produced per acre in all three regions is also low, because of low physical productivity and the predominance of minimum-value crops. Cattle feed crops accounted for nearly 80 percent of the Upper Rio Grande Basin irrigated acreage throughout the 1970s. By comparison, cattle feed crops accounted for less than 20 percent of irrigated acreage in Dona Ana County during the same period.[78] Low productivity and other structural market disadvantages are therefore likely to cause a continued decline in farming in the Upper Basin as a whole.

Irrigable cropland, defined as lands which could be served by existing irrigation facilities, is described for each of the counties of the Upper Rio Grande Basin Table 3.1. In the Upper Basin as a

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77 Ibid., p. 8.

78 R. R. Lansford, et al., Sources of Irrigation Water and Dry Cropland Acreages in New Mexico, by County, 1972-1977, New Mexico Agricultural Experiment Station Report 377, Las Cruces, New Mexico: New Mexico State University, July, 1978.

TABLE 3.1

ACRES OF IRRIGATED CROPLAND, INCLUDING IDLE, FALLOW, AND DIVERTED ACREAGE IN UPPER RIO GRANDE BASIN 1950-1980

County	1950	1955	1960	1965	1970	1975	1980	Annual Growth Rate (%)
Rio Arriba	40,330	40,330	40,330	40,330	41,110	41,110	41,110	0.08
Taos	37,580	39,810	41,900	41,900	41,900	41,900	41,900	0.31
Los Alamos	0	0	0	0	0	0	0	
Santa Fe[1]	4,005	4,236	4,621	4,999	6,100	6,304	6,870	1.94
Region I	81,915	84,376	86,851	87,229	89,110	89,314	89,880	0.30
Sandoval	16,240	16,240	16,240	16,270	16,270	16,270	16,960	0.10
Bernalillo	18,000	17,000	16,000	15,460	13,240	11,290	10,730	-1.18
Valencia	39,580	40,860	42,140	43,420	43,690	43,590	39,250	0.10
McKinley[2]	165	165	170	170	170	170	170	0.11
Region II	73,985	74,265	74,550	75,320	73,370	71,320	67,110	-0.28
Socorro/Region III	14,500	15,600	16,700	17,820	17,820	19,810	20,630	1.15
Upper Rio Grande Basin	170,400	174,241	178,101	180,369	180,300	180,444	177,620	0.15

1 Estimates irrigable acres within Rio Grande Basin, based on 38.51 percent of county total located within basin in 1980.

2 Estimated irrigable acres within Rio Grande Basin, based on 2.64 percent of county total located within basin in 1980.

Source: R. R. Lansford, et al., Sources of Irrigation Water and Irrigated and Dry Cropland Acreages in New Mexico, by County, 1975-1980, Agricultural Experiment Station Research Report 454, Las Cruces: New Mexico State University, 1981.

whole there was no significant change in the total irrigable acreage during the 30-year period between 1950 and 1980. This is somewhat misleading in that the acreage shown in Table 3.1 includes idle and fallow cropland that may (or may not) be rotated into production status during any particular year. Yet Table 3.1 does show that there has been almost no investment in "new" irrigation facilities which would bring new cropland into production during the 30-year period. Santa Fe County in Region One shows the highest rate of (compound) annual growth, although this is likely due to the estimation technique employed.[79] In fact, the irrigable acres in Santa Fe County served by the Rio Grande and its tributaries has likely remained as stable as the other counties included within Region One. Bernalillo County's 1.18 percent annual decline in irrigable acreage reflects largely the dramatic growth of the Albuquerque urban area. The overall decline in Region Two acreage must be noted to offset the increasing acreage trend observed in Region One. The growth in Region Three's irrigable acreage serves as a relatively insignificant trend in relation to the

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79 The allocation of Santa Fe County historical data based on observations made in 1975 of economic activity inside and outside the boundaries of the hydrologic basin infers to both subregions of the county identical relative changes in patterns of economic activity. If the county's actual economic development (over the historic period observed) cannot be so uniformly characterized, then the described economic growth rates manifested in data so allocated must admit to an imprecise methodology. The imprecision must also be noted as inconsequential to the accuracy of the fundamental research herein described.

overall stability of the irrigable acreage of the Upper Rio Grande Basin.

Complementing the trends observed in irrigable acreage, Table 3.2 indicates that there has been a decline in the number of farms in the Upper Basin at a 2.61 percent annual rate during the last 20 years. Region Three alone exhibited an increase in number of farms, but the more significant declines in Regions One and Two resulted in the overall declining trend in the Basin as a whole. The loss of 1,473 farms in the period between 1959 and 1978 represents a more than 35 percent decline in the number of farming enterprises (from 1959 levels) in the Upper Rio Grande Basin. For there to have remained stable irrigable acreage with declining farm numbers there must have been some consolidation of irrigation systems and increased average farm size.

TABLE 3.2

THE NUMBER OF FARMS IN THE UPPER RIO GRANDE BASIN
1959-1978

Region	1959	1964	1969	1974	1978	Growth Rate %
One[1]	1,888	1,945	728	921	1,050	-3.77
Two[2]	2,024	1,435	1,089	1,106	1,325	-2.19
Three	242	288	255	321	307	1.18
Total URGB	4,154	3,668	2,072	2,348	2,681	-2.61

1 Using 0.3815 of Santa Fe County in URGB.
2 Using 0.0264 of McKinley County in URGB.

Source: U.S. Department of Commerce, Bureau of the Census, Census of Agriculture, 1978, 1974, 1969, 1964 and 1959, Vol. I, State and County Data, Washington, D.C.

D. Demographic and Nonagricultural Economic Profile

The 1980 Census data shows that 674,508 people live within the boundaries of the Upper Rio Grande Basin, or 51.8 percent of the total state population. This population is highly concentrated within the Albuquerque metropolitan area comprised principally of Bernalillo County, although the city has expanded so that portions of Sandoval County are now significantly affected by the City's growth. Other significant population centers include the City of Santa Fe in Santa

Fe County, Grants and Belen in Valencia County,[80] Socorro in Socorro County, and Espanola in Rio Arriba County. Table 3.3 presents the population of the Upper Rio Grande Basin by county.

TABLE 3.3

1980 STATE AND UPPER RIO GRANDE BASIN POPULATION

County	Population	County as % of Basin
Bernalillo	420,164	62.29
Los Alamos	17,599	2.61
McKinley	4,658	0.69
Rio Arriba	29,282	4.34
Sandoval	34,799	5.16
Santa Fe	74,869	11.10
Socorro	12,566	1.86
Taos	19,456	2.88
Valencia	61,116	9.06
Total Upper Rio Grande	675,508	
NEW MEXICO	1,303,445	
Upper Basin Population as a % of Total State	51.75%	

Source: 1980 Census of Population, Bureau of Census, U.S. Department of Commerce.

Employment by major sector identifies much of the Upper Basin's economic profile, and Table 3.4 presents this data for 1980. Figures

80 Valencia County was split into two counties, Valencia and Cibola, by the 1981 New Mexico State Legislature. Grants is now a part of Cibola County.

TABLE 3.4

1980 EMPLOYMENT BY MAJOR SECTOR

County	Agr.	Mfg.	Mining	Constr.	TCU	Trade	FIRE	Services	Govt.	Total
Albuquerque SMSA[1]	398	17,900	*	13,100	11,600	46,900	10,900	43,600	43,000	187,298
Los Alamos	0	56	0	210	67	1,043	246	2,344	8,949	12,915
McKinley	101	899	4,685	778	982	4,024	387	3,106	4,785	19,746
Rio Arriba	118	203	21	346	283	1,006	189	1,436	2,386	5,988
Santa Fe	140	1,321	370	1,871	909	5,983	1,284	7,226	9,725	28,829
Socorro	158	62	*	153	112	580	96	691	1,959	3,810
Taos	34	390	737	357	177	1,244	191	1,553	1,510	6,193
Valencia	279	288	3,201	1,139	1,001	2,568	468	1,768	3,251	13,963
Upper Rio Grande Basin	1,228	21,119	9,014	17,954	15,131	63,348	13,761	61,724	75,565	278,742
NEW MEXICO TOTAL	9,196	34,400	29,400	32,100	28,300	103,400	21,100	91,800	125,000	474,596

* Employment data whithedl under disclosure policy and is included in services employment sector.
1 Standard Metropolitan Statistical Area (SMSA) includes all employment in Sandoval and Bernalillo Counties.
Soruce: New Mexico Employment Security Commission and U.S. Department of Commerce, Bureau of Economic Analysis (agricultural employment).

FIGURE 3.1
UPPER RIO GRANDE BASIN AND STATE EMPLOYMENT
BY MAJOR SECTOR — 1980

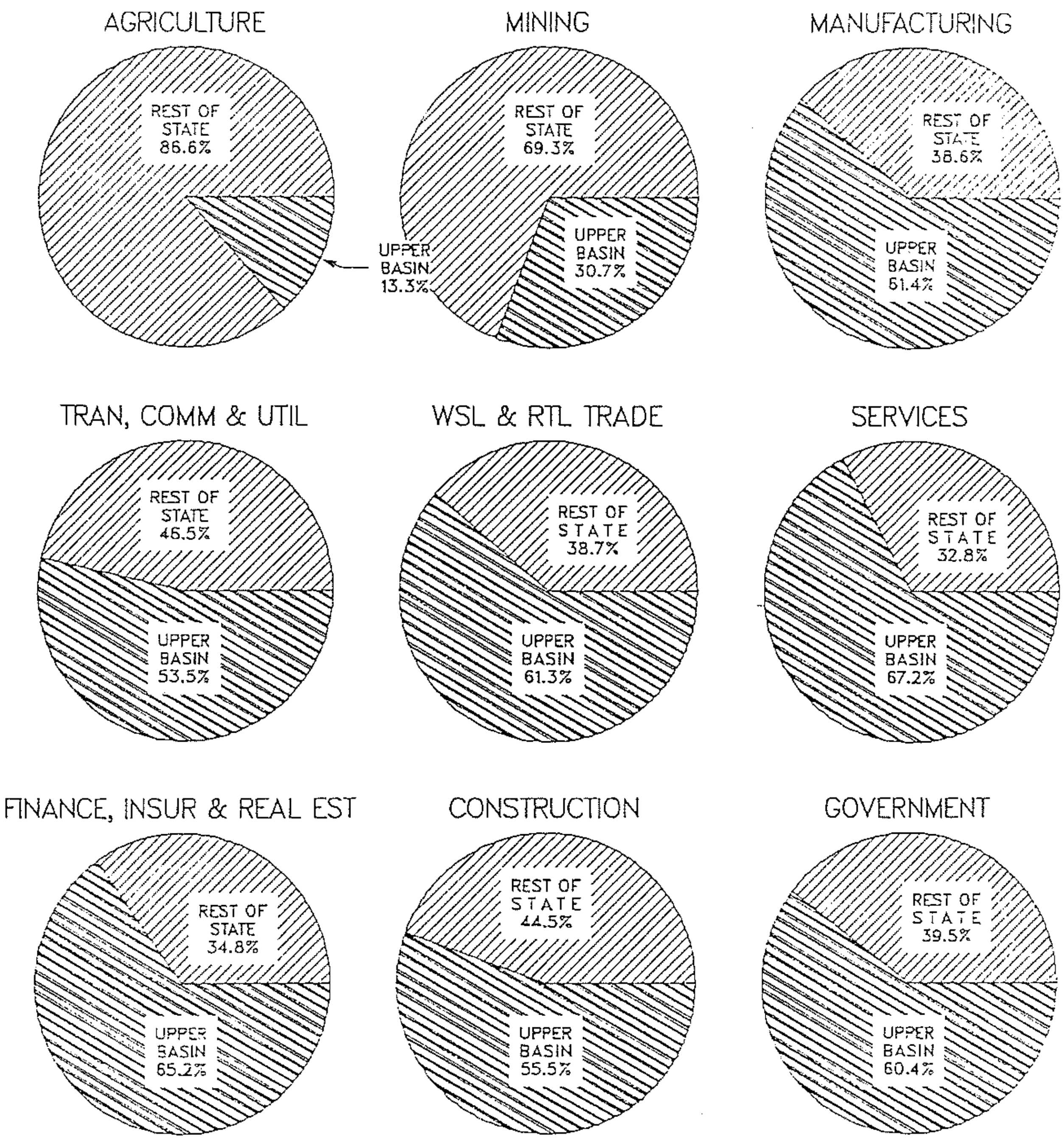
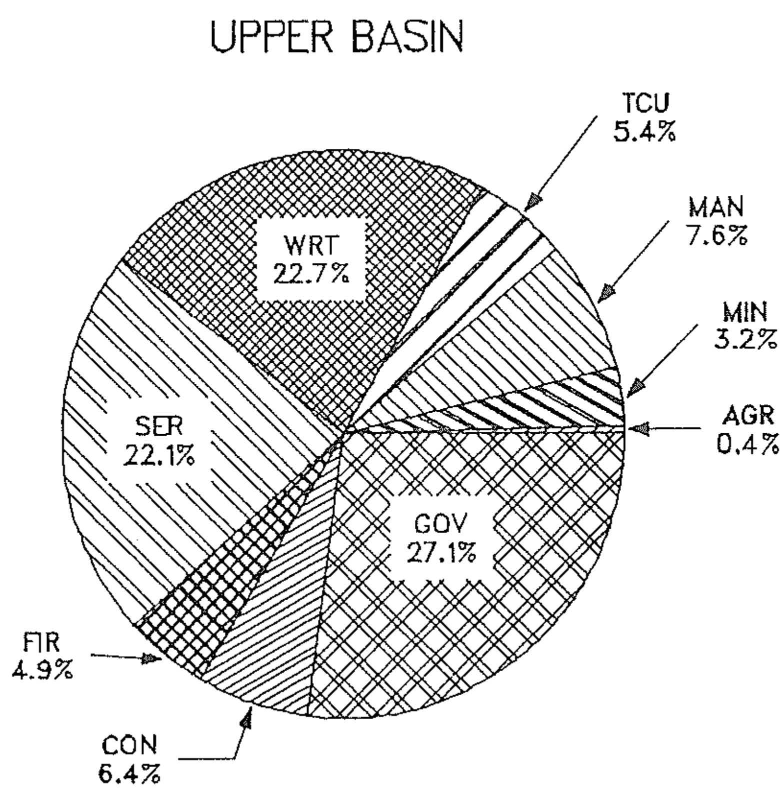
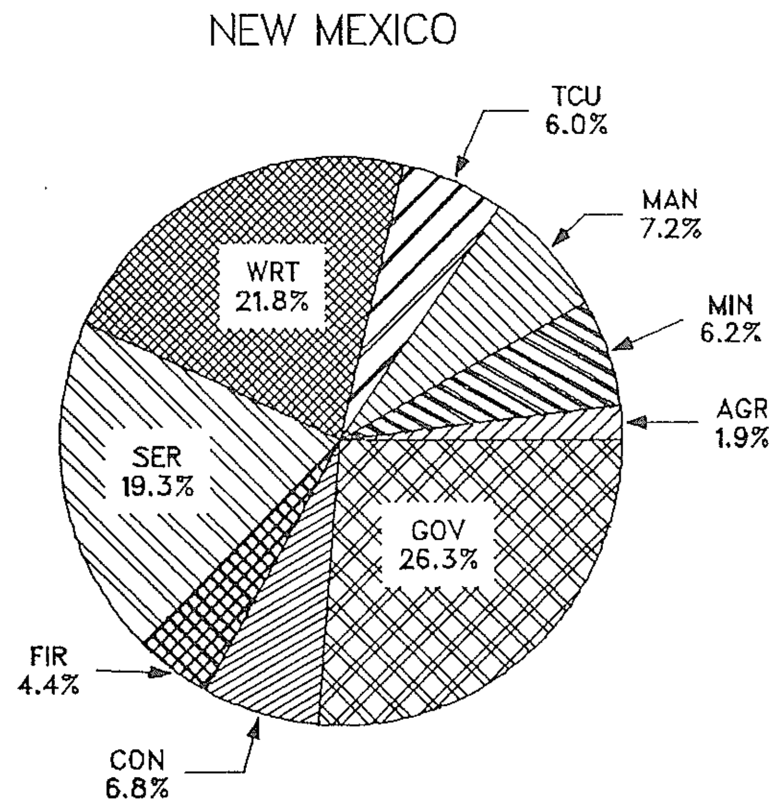


FIGURE 3.2
1980 EMPLOYMENT BY MAJOR SECTOR
UPPER RIO GRANDE BASIN AND STATE OF NEW MEXICO





3.1 and 3.2 provide pie chart comparisons of Upper Basin and statewide sectoral employment patterns. In comparing 1980 employment in the Upper Rio Grande Basin with the patterns of employment throughout the state several facts are clear. First, the largest sectors within both the Upper Basin region and the state as a whole are trade, services and government. Figure 3.1 shows that these three sectors in the Upper Basin, and indeed all other major sectors excluding agriculture and mining in the Upper Basin, provide for more than half of the statewide employment in each of the respective sectors.

On a statewide basis agricultural employment in the Upper Rio Grande Basin represents only 13.35 percent of total agricultural employment in the state, with the sector providing less than one-half of one percent of the total Upper Basin employment (Figure 3.2). It is clear that agriculture throughout the remainder of the state is much more significant to the economy than is its role in the Upper Rio Grande Basin -- as measured by these employment statistics. Mining in the Upper Basin is subject to much the same analysis. It should also be noted that employment in mining in the Upper Basin in 1980 included a substantial number of jobs in uranium mining which has since been subject to significant declines. Outside the Upper Basin region there is significant coal, copper, potash, oil and natural gas extraction activities which reflect the diverse natural resources of the state.

Compared to the state, manufacturing is more highly concentrated within the basin area due primarily to manufacturing activity within

Bernalillo County. In addition, trade, services, and finance, insurance and real estate sectors are more important to the Upper Basin region than throughout the remainder of the state. This data largely reflects Albuquerque's role as a regional center for trade, banking, health care and legal services; an economic pattern which certainly supports the contention that the Upper Basin's economy is in many ways insulated from economic shocks faced by the remainder of the state due to single sector dependency for economic health. The only real exception to this broad based Upper Basin economy relates to weakness in the transportation, communications and utilities sector. Yet, this pattern can be largely explained by employment by electric utilities in the northwestern portion of the state -- which supplies most of the Upper Basin's electrical power requirements -- and the natural gas utilities transport of gas produced outside the Basin to customers throughout the state and in interstate markets.

A total of 278,742 jobs were located in the Upper Rio Grande Basin in 1980, or 58.73 percent of all state employment. The disaggregation of employment, shown in Table 3.4, reveals the dominance of the Albuquerque metropolitan area in the manufacturing, trade, services, finance, insurance and real estate sectors. Also apparent from this table is the dominance of Valencia, Socorro, Santa Fe Counties and the Albuquerque metropolitan areas in agricultural employment. This principally reflects the role of the Middle Rio Grande Conservancy District in the agricultural sectors of the Upper Basin. Mining is concentrated in three counties: Taos (molybdenum), McKinley and Valencia (uranium). Taos and Santa Fe Counties have proportionally larger trade and service sectors reflecting the impact of tourism and winter sking. Los Alamos County is totally dependent upon the federal government's Los Alamos National Laboratories, while Socorro County's large government sector is due to the location of the New Mexico Institute of Mining and Technology in the City of Socorro.

The Upper Rio Grande Basin region of New Mexico is expected to be one of the fastest growing areas in the U.S. between 1980 and 2000. In a news release in March, 1980 Chase Econometrics' Regional Forecasting Group ranked Albuquerque sixth among the top ten U.S. growth areas in the 1980s.[81] Uranium mining, while presently extremely depressed primarily due to national concerns about nuclear energy and its by-products, is expected to undergo some minimal recovery in the future. However, significant new coal developments are anticipated in the region. Several electronics manufacturers (e.g., Intel, Signetics, Motorola) have recently constructed new plants within the Albuquerque area and have plans to expand manufacturing employment by more than 10,000 jobs by 1990. In addition, there are presently planned two new electrical power plants in the coal-rich western reaches of the basin which might see construction in

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81 Chase Econometrics, "Chase Names Top Ten U.S. Cities for Job Growth in the 1980s," News Release, March 28, 1980.

the period between 1990 and 2000 and have effect on Basin water resource demands. All these new developments will be forced to rely on the water resources of the region, and as will be more clearly shown later, these new economic activities and population increases may also result in localized or regional water scarcity conditions.

E. Definition of Economic Sectors Modeled

It is possible in a model such as the one employed here to describe in minuet detail the specific economic activity which occurs within the state. However, this is neither the intention nor the purpose of this analysis. The aggregation of many of the 24 sectors (described below) groups both similar and dissimilar firms together, using the measure of "dollar output levels" as the amalgamator of dissimilar economic activity. In the brief descriptions of each of the sectors which follows there will be emphasis placed on the specific industries that dominate each of the state's 24 sectors, and there will be a limited attempt to describe the geographic distribution of these industries in the Rio Grande and throughout the remainder of the state.

Sector 1: Cattle, Sheep, Hogs, Wool, Poultry, Milk, Eggs.

Region One consists principally of cattle, with significant level of both sheep and milk production; Region Two is dominated by cattle production, with significant level of all other products, particularly milk and eggs; Region Three dominated by cattle with significant milk production; Region Four largely cattle production, with significant milk and egg production.

Sector 2: Corn, Wheat, Oats, Barley, Sorghum, All Hays.

Region One dominated by hay production, some significant wheat production; Region Two dominated by hay production with moderate levels of output in all other crops; Region Three almost entirely hay production; Region Four is principally hay with significant wheat production.

Sector 3: Cotton, Cottonseed.

Only in Regions Four and Five is there any cotton or cottonseed production, and it is a very significant product.

Sector 4: Beans, Potatoes, Lettuce, Onions, Tomatoes, Peaches, Apples, Pecans, Peanuts, Sugar Beets.

Region One principally potatoes and lettuce; Region Two principally lettuce and onions; Region Three no production; Region Four dominated by pecans and lettuce.

Sector 5: Agricultural Services (SIC 700).

Sector 5 is present in all regions except Region Three and is most significant in Region Two.

Sector 6: Metal Mining (SIC 10), Mining and Quarrying of Nonmetallic Minerals except Fuels (SIC 11), Coal Mining (SIC 11 & 12).

Region One dominated by metal mining (specifically molybdenum mining); Region Two nearly exclusively metal mining (specifically uranium mining); Regions Three and Four are almost insignificant; sector is dominated by output in Region Five.

Sector 7: Crude Petroleum, Natural Gas, Oil and Gas Field Services (SIC 13).

Regions One and Two modest levels of output, but sector is dominated by Region Five.

Sector 8: Meat Products (SIC 201).

Regions One and Four small levels of output; Region Two fairly significant level of output; sector is dominated by output in Region Five.

Sector 9: Dairy Products (SIC 202).

All regions have some level of output; but sector is dominated by Region Two.

<u>Sector 10</u>: Grain Mill Products (SIC 204), Bakery Products (SIC 205).

Only Region Two output is significant, although some lesser output found in Region Five.

<u>Sector 11</u>: Canned and Preserved Fruits and Vegetables (SIC 203), Sugar and Confectionary Products (SIC 206), Fats and Oils (SIC 207), Beverages (SIC 208), Miscellaneous Food Preparations and Kindred Products (SIC 209).

The majority of sector output is attributable to the beverage and the miscellaneous food preparation industries, the majority of output is found in Regions Two and Five.

<u>Sector 12</u>: Lumber and Wood Products, except Furniture (SIC 24), Furniture and Fixtures (SIC 25), Paper and Allied Products (SIC 26), Stone, Clay, Glass, and Concrete Products (SIC 32).

Regions One and Two significant output in lumber and wood products, and stone, clay, glass, and concrete products, Region Two dominates all regions.

<u>Sector 13</u>: Chemicals and Allied Products (SIC 28), Petroleum Refining and Related Industries (SIC 29), Rubber and Miscellaneous Plastic Products (SIC 30).

Dominated by the petroleum refining industries, and significant output in chemicals; output found in Region Two, and, to a much greater degree, Region Five.

<u>Sector 14</u>: Primary Metal Industries (SIC 33), Fabricated Metal Products, except Machinery and Transportation Equipment (SIC 34), Machinery, except electrical (SIC 35) Electronic Machinery, Equipment, and Supplies (SIC 36), Transportation Equipment (SIC 37), Measuring Analyzing, and Controlling Instruments; Photographic, Medical, and Optical Goods; Watches and Clocks (SIC 38).

Output levels relatively uniform over the six SIC codes included, with some dominance by the electronics sector. Region Two dominates (particularly fabricated metal products, machinery, electronics and transportation equipment); Region Five significant also.

Sector 15: Textile Mill Products (SIC 22), Apparel and other Finished Products made from fabrics and similar materials (SIC 23), Printing, Publishing, and Allied Industries (SIC 27), Leather and Leather Products (SIC 31), Miscellaneous Manufacturing Industries (SIC 39).

Output dominated by apparel, finished products, printing, publishing, and miscellaneous manufacturing industries. Region Two dominates; Region One relatively small output; and Region Five a slightly larger output.

Sector 16: Railroad Transportation (SIC 40), Local and Suburban Transit and Interurban Highway Passenger Transportation (SIC 41), Motor Freight Transportation and Warehousing (SIC 42), Water Transportation (SIC 44), Transportation by Air (SIC 45), Transportation Services (SIC 47).

Output dominated by motor freight, with significant output by railroad transportation, and local, suburban and interurban transportation. Region Two dominates output, with significant output in Regions Four and Five, and to a lesser degree Region One.

Sector 17: Pipelines, except natural gas (SIC 46), Natural Gas Transmission (SIC 4922).

Output is largely from pipelines not transmitting natural gas, although natural gas transmission sector is significant. Region Five dominates although small level of output from Region Two.

Sector 18: Communication (SIC 48), Electric, Gas, and Sanitary Services (SIC 49), except Natural gas transmission (SIC 4922).

Output from the two major SIC sectors nearly equal, with the majority of output in Regions Two and Five, and to a lesser extent Regions One and Four.

Sector 19: Wholesale Trade--Durable Goods (SIC 50), Wholesale Trade--Nondurable Goods (SIC 51), Building Materials, Hardware, Garden Supply, and Mobile Home Dealers (SIC 52), General Merchandise Stores (SIC 53), Food Stores (SIC 54), Apparel and Accessory Stores (SIC 56), Furniture, Home Furnishings, and Equipment Stores (SIC 57), Miscellaneous Retail (SIC 59).

The majority of output is wholesale trade (both durables and nondurable), with significant levels of output in both food stores and general merchandise stores. Region Two dominates, with Region Five a close second, and lesser levels of output in Regions One and Four.

Sector 20: Automotive Dealers and Gasoline Service Stations (SIC 55), Eating and Drinking Places (SIC 58).

Output principally auto dealers and gas stations. Regions Two and Five dominate, with significant levels of output also found in Regions One, Three and Four.

Sector 21: Banking (SIC 60), Credit Agencies other than banks (SIC 61), Security and Commodity Brokers, Dealers, Exchanges, and Services (SIC 62), Insurance (SIC 63), Insurance Agents, Brokers, and Services (SIC 64), Real Estate (SIC 65), Holding and Other Investment Offices (SIC 67), Owner Occupied Housing.

The principal subsector is real estate, with a calculated value for owner occupied housing significant to this sector. Output dominated by Region Two, with decreasingly significant output in Regions Five, One and Four.

Sector 22: Hotels, Rooming Houses, Camps, and Other Lodging Places (SIC 70), Personal Services (SIC 72), Business Services (SIC 73), Automotive Repair, Services, and Garages (SIC 75), Miscellaneous Repair Services (SIC 76), Motion Pictures (SIC 78), Amusement and Recreation Services, except motion pictures (SIC 79).

Output dominated by business services found principally in Region Two, with much less significant output in Regions One, Three, and Five.

Sector 23: Health Services (SIC 80), Legal Services (SIC 81), Educational Services (SIC 82), Social Services (SIC 83), Museums, Art Galleries, Botanical and Zoological Gardens (SIC 84), Membership Organizations (SIC 86), Miscellaneous Services (SIC 89).

Output principally health services and the broad category of miscellaneous services. Region Two dominates although all regions have some level of activity in this sector.

Sector 24: Building Construction--General Contractors and Operative Builders (SIC 15), Construction Other Than Building Construction--General Contractors (SIC 16), Construction--Special Trade Contractors (SIC 17).

Output is relatively uniform over the three subsectors in this sector. In descending order, significant output is found in Regions Two, Five, One, and Four.

A convenient summary of the specific level of activity in each of the sectors is provided by Table 3.5 which shows the average level of employment in 1975 for each of the model sectors. Discussion of the specific output levels for each of the sectors is postponed until the Base Year solution to the model is presented in the next chapter. The discussion of the Pueblo Model's implementation must now turn to specific definition of "imports" in the contest of this IOLP model.

TABLE 3.5

1975 COVERED AND NONCOVERED EMPLOYMENT[1] BY MODEL SECTOR

Sector	Region One	Region Two	Region Three	Upper Basin
1-4[2]	679	2,070	213	2,962
5	98	449	0	547
6	858	4,094	6	4,958
7	202	185	0	387
8	2	374	0	376
9	19	456	2	477
10	1	494	0	495
11	63	647	2	712
12	471	2,884	2	3,357
13	0	249	0	249
14	270	5,926	13	6,209
15	787	5,756	51	6,594
16	286	3,805	5	4,096
17	2	33	0	35
18	949	5,263	70	6,282
19	4,172	28,254	269	32,695
20	3,019	13,698	244	16,961
21	1,452	9,060	82	10,594
22	4,399	26,045	109	30,553
23	3,598	20,044	135	23,777
24	2,392	11,393	107	13,892

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1 Employment reported here is estimated based on covered (by unemployment compensation insurance) employment reported at the 4-digit SIC level, and covered and noncovered employment at the 9 major sector level (Table B) provided by Employment Services Division, Employment Security Commission of New Mexico.

2 Agricultural employment data provided by ESD cannot be divided according to model's agriculture sectors. Employment estimates from Mr. Larry Blackwell, ESD, Albuquerque.

F. Water Supply Conditions in the Upper Rio Grande Basin

The surface flows of the Upper Rio Grande have long been fully appropriated, in fact over appropriated. The region has long been characterized as water scarce. This scarcity condition continues today, reflecting the confluence of a water supply which is limited both physically and institutionally, and the pressures of expanding demands for water. In response to the water scarce conditions there has developed a series of institutional constraints and conditions on the use of the basin's water resources. The 1906 Treaty with Mexico,[82] the 1939 Rio Grande Compact,[83] and the New Mexico State Engineer's 1956 Declaration of the Rio Grande Underground Water Basin[84] all serve as limitations on the amount of water available for use in the Upper Rio Grande.

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82 Convention between the U.S. and Mexico, May 21, 1906, 34 Stat. 785, T.S. No. 455,

83 Rio Grande Compact (1938), N.M. Stat. Ann. § 75-34-3 (1953), Act of May 31, 1939, ch. 155, 53 Stat. 785.

84 The first declaration of the Rio Grande Underground Water Basin by the State Engineer, pursuant to N.M. Stat. Ann. § 75-11-27 (1953), was on November 29, 1956. There have been numerous extensions of the original basin such that now nearly all the surface drainage area of the Rio Grande above Elephant Butte is included within the declared basin.

It is the circumstance of water scarcity which led to the 1906 Treaty with Mexico. Mexico had filed claim for damages of $35 million against the United States, alleging that water shortages near Juarez were the result of increased diversions from the Rio Grande by users in Colorado and New Mexico. The 1906 Treaty settled this claim wherein the United States guaranteed the annual delivery of 60,000 acre-feet in the Rio Grande at the head of the Mexican Canal near El Paso. Elephant Butte Reservior was constructed at this time for storage and regulation of the Rio Grande so that the terms of the treaty could be met.

Interstate disputes by the three basin states -- Colorado, New Mexico and Texas -- over the division and use of the waters of the Rio Grande led to the formation of the Rio Grande Compact Commission in 1923 and a ratified Compact in 1939. The Compact provided for an equitable apportionment of the Rio Grande among the three states and for the required deliveries to Mexico under the 1906 Treaty. The annual riverflow is apportioned by a specific delivery schedule imposed upon Colorado and New Mexico. New Mexico's obligation[85] is a percentage of the water flow at the Otowi gage in north central New Mexico with delivery to Texas measured at a gage below Elephant Butte Dam plus the net change in storage in Elephant Butte Reservior. The

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85 For a summary of New Mexico's obligations see S.E. Reynolds and Philip B. Mutz, "Water Deliveries under the Rio Grande Compact," Natural Resources Journal, Vol. 14(2):201, April, 1974.

required percentage delivery is a progressively increasing one, increasing as the actual waterflow increases. For example, if the measured flow at Otowi is 100,000 acre-feet, then 57 percent or 57,000 acre-feet must be delivered at Elephant Butte Dam. If the measured flow is 1,000,000 acre-feet, then 62.1 percent or 621,000 acre-feet must be delivered. This percentage rises to 86.5 percent for water flows measured at Otowi of 3,000,000 acre-feet. Thus, the physical amount of surface water available to New Mexico within the Upper Rio Grande Basin is limited by both the Rio Grande Compact and the 1906 Treaty with Mexico.

A system of debits and credits is included in the delivery schedule for both Colorado and New Mexico. Colorado and New Mexico have both been in a debit status during most of the time since the Compact became effective. However, in recent years, Colorado has taken steps to reduce her accumulated deficit to 674,600 acre-feet as of the end of 1980, and New Mexico's accumulated deficit at that time stood at 148,000 acre-feet.[86] Reynolds and Mutz[87] outline reasons why upstream states will not likely accumulate deficits in the future, e.g., active litigation by Texas to enforce the Compact, stream

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86 Report of the New Mexico Interstate Stream Commission in S.E. Reynolds, Annual Report of the State Engineer of New Mexico, for the 69th Fiscal Year, July 1, 1980, to June 30, 1981, Santa Fe: New Mexico State Engineer Office, 1982.

87 Supra note 85.

improvements in the middle Rio Grande Valley, and control of groundwater use in the New Mexico Rio Grande Basin. This highlights the severe water supply limitations imposed on the Upper Rio Grande Basin by the Rio Grande Compact.

In most of the Upper Basin there exists a direct hydrological connection between the surface water and groundwater. Excessive groundwater pumping will, thus, ultimately reduce supplies of surface water available to valid appropriators and perhaps impair New Mexico's ability to meet its Rio Grande Compact commitments. For these reasons the New Mexico State Engineer declared the Rio Grande Underground Water Basin in November of 1956. The definition of this underground basin has been extended from Colorado to Texas through the years, and is inclusive of all lands on which it might be practicable to develop wells with yields sufficiently large to materially affect the river's flow.[88]

Within the underground basin the State Engineer permits the drilling of new wells and new withdrawals of groundwater only if the effects of such groundwater development on the surface flow of the Rio Grande (or its tributaries) are offset by the retirement of existing surface water rights. Since there is a time lag of varying duration (depending principally on depth and distance from the river) between

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88 J.D. Hudson and R.L. Borton, Ground Water Levels in New Mexico, 1970 Technical Report 39, Santa Fe: New Mexico State Engineer Office, 1974, p. 73.

the withdrawal of groundwater and its impact on surface flows, some portion of the new groundwater withdrawal reduces the amount of water in underground storage with no immediate effect on existing surface rights. The State Engineer has ruled that a new groundwater user does not have to offset this loss until such time as it impairs surface rights. Thus, some new water can be developed under this groundwater policy, but subject to strict regulation. The net effect of the State Engineer's declaration is to maximize the development of groundwater resources, while at the same time protecting the existing surface water rights and surface flow delivery commitments under the Compact. However, this policy has rigidly controlled the use of groundwater and has necessarily constrained new water development in the Upper Rio Grande Basin since 1956. The 1956 Declaration of the New Mexico State Engineer imposes yet another institutional constraint on water availability within this region.

Table 3.6 presents 1975 water use patterns by county within the New Mexico Upper Rio Grande Basin. The data represent total depletions in acre-feet from both surface and groundwater sources and, thus, the approximate quantity of water that is consumptively used within the region. Of the 373,814 acre-feet depleted in 1975, 76.8 percent is used by the agricultural sector (i.e., irrigated agriculture and livestock/stockpond evaporation). Water use described as urban and rural includes the "habitat" requirements of the state's population, as well as manufacturing and industrial uses, and is the

Table 3.6

COUNTY WATER USE PATTERNS IN THE NEW MEXICO UPPER RIO GRANDE BASIN
1975

	Total Depletions[1] (acre-feet)									N.M. Upper Rio Grande Total	Water Use Category as % Total
	Rio Arriba	Taos	Los Alamos	Santa Fe	Sandoval	McKinley[2]	Valencia	Bernalillo	Socorro		
Irrigated Agriculture	48,450.0	49,160.0	0.0	9,200.0	19,650.0	430.0	82,440.0	24,140.0	45,630.0	279,100	74.7%
Domestic Water Use Urban & Rural	838.0	684.5	2,178.0	3,832.5	1,765.3	76.5	2,548.7	43,936.9	859.6	56,720	15.2
Manufacturing	43.0	43.0	0.0	106.0	57.0	0.0	60.0	1,241.0	59.0	1,609	0.4
Mining/Minerals	35.6	1,256.4	0.0	40.0	15.0	1,940.0	2,601.5	196.5	8.0	6,094	1.6
Power	0.0	0.0	0.0	8.0	700.0	0.0	0.0	3,654.0	0.0	4,362	1.2
Livestock & Stock-pond Evaporation	1,532.0	402.0	5.0	826.0	912.0	811.0	1,476.0	687.0	1,285.0	7,936	2.1
Fish & Wildlife	646.0	64.0	2.0	30.0	270.0	0.0	579.0	375.0	6,561.0	8,527	2.3
Recreation (Land Based)	100.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	200	0.1
Reservoir Evaporation	2,387.0	415.0	0.0	408.0	47.0	300.0	1,429.0	0.0	10.0	4,996	1.3
Military	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4,270.0	0.0	4,270	1.1
COUNTY TOTAL	54,032.6	52,124.9	2,185.0	14,450.5	23,416.3	3,557.5	91,134.2	78,500.4	54,412.6	373,814	100.0%

1 Depletion is equal to water that is consumptively used by all factors, i.e., evapotranspiration, carriage loss, etc.; ground and surface water.
2 Includes only that portion within Upper Rio Grande Basin.
Source: Water Use by Categories in New Mexico Counties and River Basins, and Irrigated and Dry Dropland Acreage in 1975, New Mexico State Engineer.

next largest user of water within the region at 15.2 percent of total depletions. Self-supplied manufacturing, mining and power uses of water are relatively small although these uses, along with urban uses, are expected to expand in the future.

Water use in irrigated agriculture is greatest in Valencia, Bernalillo and Socorro Counties. These areas are largely within the Middle Rio Grande Conservancy District. Urban and manufacturing uses are greatest within Bernalillo County where the City of Albuquerque is located. Water use in mining is principally concentrated in Taos County where there is a large molybdenum mine, and in McKinley and Valencia Counties where there was significant uranium production in 1975. Most of the electrical power for the Upper Basin is generated in the Four Corners region of northwestern New Mexico. Within Bernalillo County both Public Service Company of New Mexico and Plains Electric Generation and Transmission Cooperative have small natural gas-fired electric power plants. The large fish and wildlife water use in Socorro County represents the Bosque del Apache Wildlife Refuge. Reservoir evaporation principally reflects El Vado, Heron and Abiquiu Dams in Rio Arriba County, and Bluewater Dam in Valencia County. The major individually identifiable water users within the Upper Rio Grande Basin are presented in Table 3.7.

TABLE 3.7

MAJOR IDENTIFICABLE WATER USERS
IN THE NEW MEXICO UPPER RIO GRANDE

User	1975 Water Depletion (acre-feet)
Middle Rio Grande Conservancy District	145,410
% of Total Depletions	38.9%
City of Albuquerque	35,328
% of Total Depletions	9.5%
City of Santa Fe	3,418
% of Total Depletions	1.0%
Kirtland AFB/Sandia Base	4,270
% of Total Depletions	1.1%
Public Service Company of New Mexico (power use only)	3,654
% of Total Depletions	1.0%

Source: Sorensen, Water Use by Categories in New Mexico Counties and River Basins, and Irrigated and Dry Cropland Acreage in 1975, New Mexico State Engineer.

The year 1975 was a near-normal year in terms of natural availability of water with in the Upper Basin. According to the U.S. Geological Survey in water year 1975 surface water flows at Rio Grande gauging stations near Lobatos, Colorado and Otowi Bridge, New Mexico were 94 percent and 98 percent of average discharge, respectively. These are significant gauges due to their importance to the administration of the Rio Grande Compact. Throughout the Upper Basin the other U.S.G.S. gauges reported similar conditions of water availability for 1975.[89]

With consideration of the institutional constraints on water availability discussed previously and the near-normal water supply conditions in 1975, the total depletions in the Upper Rio Grande Basin described by Table 3.6 are assumed to represent <u>the</u> naturally available water supply for the region. The significance of this assertion will be further described in subsequent chapters. There must be further consideration of additions to the natural water supply as the result of the San Juan-Chama transbasin diversion project, which are assumed <u>excluded</u> from the "economic uses "described by the 1975 data in Table 3.6.

The San Juan-Chama Project was approved by Congress on June 13, 1962, as a means to deliver to New Mexico its share of the surface

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89 See Technical Appendix TA-A3 for specific defense of the 1975 "Normal Water Supply" assertion.

waters of the Upper Colorado River. Water is diverted from the San Juan River, a tributary of the Colorado River in southern Colorado, passes through a series of tunnels across the continental divide, and augments the flows of the Chama River, a tributary of the Rio Grande in northern New Mexico. The annual diversion maximum for the project is 110,000 acre-feet, of which 101,800 is deliverable, with the diversion/delivery difference resulting from evaporation and carriage loss. Since the San Juan-Chama Project water represents new water to the Rio Grande Basin, all of the 101,800 acre-feet may be consumptively used within the basin. This deliverable quantity is a significant addition to the Upper Rio Grande Basin water supply, representing a 27 percent increase in the effective (depletable) water supply of the region.

San Juan-Chama Project water first flowed in early 1971,[90] although at levels far below capacity. Much of this initial San Juan-Chama water has been used to build up the reservoir storage for the project in Heron Reservoir, to create permanent recreation pools at Cochiti and Elephant Butte Reservoirs, and to add to available

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90 Much of the information on the San Juan-Chama project presented here was obtained from Mr. Joseph L. Miller (Projects Superintendent) and his staff in the Upper Rio Grande Basin Projects Office, Bureau of Reclamation, U.S. Department of Interior, Albuquerque. Their cooperation is acknowledged and appreciated. The specific delivery schedules of project water to project users for 1974-1982 are presented in technical Appendix TA-A1.

storage in El Vado and Abiquiu Reservoirs. Storage rights to about 80,000 acre-feet of San Juan-Chama water are held by the City of Albuquerque, which presently does not need the water and has accumulated its project deliveries in several reserviors. The specific use of the San Juan-Chama Project water in 1975 and prior years for reservoir storage and recreational pools provides defense for the previous assertion that 1975 reported depletions represents the natural water supply of the Upper Basin, although it should be noted that reservoir evaporation data may reflect (in part) the evaporation of the stored project water in 1975.[91] In 1980 the San Juan-Chama Project flowed at capacity and is now available for expanded water demands within the region.

What is significant in the preceding discussion is the <u>present surplus</u> water supply conditions within the New Mexico Upper Rio Grande Basin. This surplus condition is asserted to exist <u>only</u> as the result of the San Juan-Chama transbasin diversion project which has increased the effective supply of water in the Upper Basin from 373,814 acre-

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91 In 1975 38,614 acre-feet of San Juan-Chama water was made available to water users under contract commitments. Approximately half of this amount went to the City of Albuquerque which stored it; the rest went to users such as the City of Santa Fe and the Middle Rio Grande Conservancy District. Some of this latter amount may have been depleted by the users and, hence, reflected in the 1975 water use data. However, no precise information to document this is available. Since it represents such a small portion of the total San Juan-Chama project water, our assumption that this project water was not included in the 1975 water use data seems reasonable.

feet in 1975, to 475,614 acre-feet at the present time.[92] It is this favorable water supply condition which will allow continued economic expansion within the Upper Rio Grande Basin for several years without disruption due to basin-wide water supply scarcity constraints. It should be noted in concluding this discussion of Upper Basin water supplies that the City of Albuquerque has contracted with the Bureau of Reclamation for more than 47 percent of the additional supplies provided by the San Juan-Chama Project, and that many of the increases in water demands which are anticipated (and further described elsewhere) will be served by the Albuquerque municipal water system.

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92 That is, assuming 1975 water use in the Upper Basin (as reported by the State Engineer's Office) <u>defines</u> normal water supply availability in the region.

CHAPTER IV

SPECIFIC PUEBLO MODEL IMPLEMENTATION AND SOLUTIONS

A. Introduction

The Pueblo model, in short, can be described as a 120 sector five region, water constrained, input-output linear programming (IOLP) model of the New Mexico economy. The model functions to allocate available water resources to successively less socially beneficial economic activities until the available water resources are exhausted, or until all demands for goods and services in the state are satisfied (i.e., without exhausting available water supplies). The model is accurate to the extent that it correctly describes the interactions of the economic sectors based on the generalization of similar production activities among the specific industries which comprise each of the model sectors. The model is reliable for prediction to the extent that the generalized pattern of production activity remains relatively constant throughout the prediction period.

To provide an empirical base upon which these asserted relationships can be demonstrated, and upon which the "reality" of these assertions can be defended, the model was updated to a 1975 Base Year. The Base Year 1975 was chosen due to a) the improved reporting of sectoral water use by the State Engineer's Office (SEO) provided by Earl Sorensen in <u>Water Use by Categories in New Mexico Counties and</u>

River Basins, and Irrigated and Dry Cropland Acreage in 1975,[93] b) because it was felt that several significant changes in regional output patterns had occurred since the development of the Lansford, et al., model in the late 1960s, but most importantly, c) so that there could be more defensible assertion of full utilization of available water supply. This last condition is important in that it establishes an empirical bound describing the maximum quantity of actual, perfected state water right entitlements[94] which are available in a "normal" year[95] under natural flow conditions in the Upper Rio Grande Basin.[96] More will be said regarding this Base Year selection in a subsequent section of this chapter.

The specific implementation of the Pueblo model proceeded by first defining the Base Year solution to the model, then proceeding to a

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93 Sorensen, supra note 24; also there was reliance on the SEO data files which supported the preparation of this technical report, and were required for determination of some basin specific water use.

94 Water right deriving authority under N.M. Stats. Ann. §§ 75-1-1 through 75-40-3 and under N.M. Const., Art. XVI, generally.

95 Technical Appendix TA-A3 details the statistical normalcy of 1975's water availability.

96 Natural flow condition are synonomous with supply made available by normal precipitation levels in the surface drainage basin. Although there is some augmentation of available supply in 1975 associated with the San Juan-Chama transbasin diversion project, it is here assumed that this water did not augment the supply for economic activities in the Upper Basin in 1975. Further discussion of this assertion will follow.

Baseline projection of the growth and other related changes in the modeled economic system over a 25-year period. This can be thought of as a status quo projection which describes no significant structural change in the economy of the state from the pattern of economic activity observed in 1975.

After derivation of this Baseline solution the hypothesized scenarios for possible resolution of Pueblo Indian water right entitlements were allowed expression in the 25-year projection of economic growth and change. The model is asserted to be a qualitative description of the economic impacts associated with possible resolution of Pueblo Indian water rights. That is, will the change in total economic output of the Upper Basin be positive or negative, how will each Upper Basin region and sector be effected by the specific resolutions, and how will the scarcity of water be effected by the resolutions modeled.

The explanation of the Pueblo model's implementation presented in this chapter will track the pattern which the model's actual solution followed. In the previous chapter the regions and sectors modeled were defined in conjunction with a profile of the Upper Basin economy and water use patterns. These Base Year (1975) conditions must be modeled so as to reflect constraints on these activities imposed by the physical availability of resources, legal and institutional restrictions, and necessary analytical parameters which allow the statement of the Pueblo Indian water rights problem in a IOLP framework. This chapter will deal with the specific constraints and restrictions which allow implementation of the Pueblo model. Of course, the most important of the constraints relates to definition of the available water supplies in the Base Year, Baseline, and resolution scenario solutions modeled. This chapter concludes with a generalization of the economic questions assessed in this analysis of the impacts of alternative resolutions of Pueblo Indian water rights.

B. Definition of Constraints

It is a common tenet of both economic theory and actual economic activity that the scarcity of certain inputs constrains the specific level of output produced. In setting up a IOLP problem specific resources are asserted to be in scarce supply -- limited in finite quantity and/or available at a specific "cost" -- and therefore may constrain the solution of the modeling analysis. In New Mexico, for most of the specific activities modeled, the availability of land does not constrain economic activity as it might in other regions of the United States. However, it is reasonable to constrain the model's solution to employ labor only up to the point which it is actually available in each of the regions modeled.

The updating of the model to 1975 employment was significantly simplified by the data tape made available by the New Mexico

Employment Security Division (ESD).[97] These data allowed rather precise definition of employment in each of the 120 model sectors. The updating procedure for these labor coefficients, and the water coefficients as well, are presented in Technical Appendix TA-C, and therefore, will not be extensively discussed here. The region-specific employment and labor force data for 1975 are presented in Table 4.1.

TABLE 4.1

1975 LABOR FORCE AND EMPLOYMENT BY REGION

	Region One	Region Two	Region Three	Region Four	Region Five	State Total
Employment	41,528	173,147	3,119	26,692	153,231	397,717
Labor Force	48,279	192,095	3,452	29,831	170,638	444,295

Source: Table A, Employment Service Division, Employment Security Commission of New Mexico, 1975 (with 1977 revision).

More important to the questions addressed by the Pueblo Model are the physical constraints of water availability. Postulating growth in specific sectors of New Mexico's economy requires recognition of a corresponding increase in water use by that sector. Even with the augmentation of water supplies in the Rio Grande Basin by the San

97 Provided by ESD was 4-digit SIC covered employment data at the county level for 1975 and 1977. This data is subject to confidentiality restrictions which are protected by its aggregation to the 120 model sectors and incorporation with noncovered employment data.

Juan-Chama Project, the water resources of the Rio Grande will grow increasingly scarce with significant future economic growth. It is commonly thought that as this scarcity grows increasingly acute there will be economic reason(s) for implementation of water conservation techniques, improving the efficiency of water use by each sector of the economy and thereby postponing acute water shortages.[98] However, it may be plainly asserted that economic growth in the Upper Rio Grande will eventually result in a shift in use of available water resources by one sector so as to allow that water's "higher-valued use" by another sector. This must occur when total water supply is insufficient to meet all demands on the water resources and when efficiency improvements are more costly than the expense of water right purchase and transfer.

The water laws of the state clearly accommodate such transfers of water; and, in many regions of the state, the water resources are already so scarce as to necessitate implementation of water conservation practices. DuMars, et al., have described many possible scenarios which can be hypothesized regarding the resolution of Pueblo

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98 More technically, this mechanism is known as price elasticity of consumption demand, whereby the rising cost of water use (i.e., both actual and opportunity costs) provide economic incentive to alter use patterns in accord with the maximization behavior of consumers (see supra note 44). Empirical studies of water price elasticity are provided, for example, by Gilbert Bonem, et al., "Water Demand and Supply in the Albuquerque Greater Urban Area (AGUA), 1975-2030," Bureau of Business and Economic Research: University of New Mexico, December, 1977.

Indian water right claims,[99] with each of these possible scenarios implying distinctly different water availability conditions in the Upper Rio Grande Basin.

Therefore, without prejudice to its effects on the modeling outcomes, the following two assumptions regarding water availability were utilized to constrain the solutions to the model: 1) 1975 represented a "normal water year",[100] with water users in all regions utilizing the full available supply of water; and, 2) the only additional water supply which will be available in the Rio Grande Basin between 1975 and 2000 will be the result of the San Juan-Chama Project. The additional availability of this San Juan-Chama water was distributed to the three regions of the Upper Basin based on current contractual obligation between the Bureau of Reclamation and the contract users of that project's water.[101] Thus, the specific level of future economic activity in all regions and sectors modeled cannot exceed a level which would result in full utilization of the 1975 available water supply (i.e., water use in 1975 as reported by the SEO), plus the additional water which is made available by the San Juan-Chama Project to the Upper Rio Grande regions of the model.

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99 DuMars, et al., supra note 22.

100 That is, the available supplies of water can be statistically shown to be near average throughout the Upper Rio Grande Basin (see Technical Appendix TA-A1).

101 A listing of specific contract user and history of deliveries of San Juan-Chama project waters is provided in Technical Appendix TA-A.

A final constraint on the model solution is not a "constraint" in the formal sense provided by linear programming modeling. This constraint is rather a "technical constraint," in that the model's solution is required to satisfy the water needs of the urban and rural populations modeled prior to fulfilling any specific economic sector's demands for water. From a practical standpoint this constraint is quite reasonable. Any growth or expansion of a region's economy can be anticipated to result in an increase in population in that region. It is therefore reasonable to assume that the water requirements of this increased population will be met prior to the expansion of water use by a specific sector.

The Base Year solution to the model required each sector to utilize no more water than was described by the 1975 SEO data.[102] This constraint distinguished between surface water and groundwater depletions, and incorporated in updating the full sectoral definition information provided by the SEO reporting. Tables 4.2 through 4.4 summarize this water use information according to the correspondence of definitional categories between the Pueblo model sectors and the SEO sector data.[103]

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102 That is, the model is specified such that regional water use be less than or equal to the 1975 SEO reported use for the region, with the models sectors of the region subject to the same inequality condition as regards corresponding SEO sectoral defined water use.

103 Sorensen, supra note 24.

Table 4.2

1975 SURFACE AND GROUND WATER DEPLETIONS
REGION ONE
(Acre-Feet Dp)

SEO Water Use Category	SEO Surface Dp	SEO Ground Dp	Pueblo Model Surface Dp	Pueblo Model Ground Dp	Pueblo Model Sector
			54,666	484	101
Livestock	483	484	45,484	3,729	102
Stockpond Evaporation	1,798	0	0	0	103
Irrigated Agriculture	101,180	5,630	2,883	1,759	104
			0	20	105
	103,461	6,114	103,033	5,992	
			500	802	106
			0	29	107
Minerals	502	831	500	831	
			0	0	108
			0	1	109
			0	0	110
			2	11	111
Self-Supplied Manufacturing	0	192	9	47	112
			0	0	113
			1	3	114
			3	16	115
Power	0	8	1	6	116
			0	0	117
			33	166	118
Recreation	0	200	61	305	119
			24	122	120
			50	251	121
Urban	2,147	4,060	41	204	122
			32	158	123
			62	309	124
			1,281	2,663	Urban
	2,147	4,460	1,600	4,262	
Rural	0	1,326	0	1,291	Rural
Total	106,110	12,731	105,133	12,376	Total

SEO State Engineer Office data

Note: Model sector number should be read as region and model sector number (e.g., 107 is Region One, model sector 7)

Table 4.3

1975 SURFACE AND GROUND WATER DEPLETIONS
REGION TWO
(Acre-Feet Dp)

SEO Water Use Category	SEO Surface Dp	SEO Ground Dp	Pueblo Model Surface Dp	Pueblo Model Ground Dp	Pueblo Model Sector
			46,350	571	201
Livestock	571	571	78,205	117	202
Stockpond Evaporation	2,744	0	0	0	203
Irrigated Agriculture	122,550	4,110	1,273	3,968	204
			0	20	205
	125,865	4,681	125,828	4,676	
			0	4,642	206
			0	110	207
Minerals	0	4,753	0	4,752	
			0	155	208
			0	100	209
			0	24	210
			0	263	211
Self-Supplied Manufacturing	0	1,358	0	887	212
			0	603	213
			0	298	214
			0	215	215
Power	0	4,354	0	265	216
			0	19	217
			0	4,850	218
Military	0	4,270	0	6,827	219
			0	1,878	220
			0	5,168	221
Urban	0	44,891	0	3,523	222
			0	2,913	223
			0	4,854	224
			0	21,938	Urban
	0	54,873	0	54,780	
Rural	0	3,437	0	3,438	Rural
Total	125,865	67,744	125,828	67,643	Total

SEO State Engineer Office data

Note: Model sector number should be read as region and model sector number (e.g., 207 is Region Two, model sector 7)

Table 4.4

1975 SURFACE AND GROUND WATER DEPLETIONS
REGION THREE
(Acre-Feet Dp)

SEO Water Use Category	SEO Surface Dp	SEO Ground Dp	Pueblo Model Surface Dp	Pueblo Model Ground Dp	Pueblo Model Sector
			8,170	293	301
Livestock	294	293	19,670	18,695	302
Stockpond Evaporation	698	0	0	0	303
Irrigated Agriculture	26,900	18,730	0	0	304
			0	0	305
	27,892	19,023	27,840	18,988	
			0	8	306
			0	0	307
Minerals	0	8	0	8	
			0	0	308
			0	1	309
			0	0	310
			0	3	311
			0	2	312
			0	0	313
Self-Supplied Manufacturing	0	59	0	1	314
			0	2	315
			0	1	316
			0	0	317
			0	76	318
			0	114	319
Urban	0	761	0	64	320
			0	82	321
			0	28	322
			0	35	323
			0	81	324
			0	326	Urban
	0	820	0	816	
Rural	0	98	0	98	Rural
Total	27,892	19,949	27,840	19,910	Total

SEO State Engineer Office data

Note: Model sector number should be read as region and model sector number (e.g., 307 is Region Three, model sector 7)

It is appropriate to highlight some definitional differences between the model and the SEO data. The most important of these definitional differences is in the category of Urban water use. In the SEO report the category describes the amount of water depleted by municipalities of more than 2,500 people, including any manufacturing or industrial uses which are supplied by these municipal water systems. In the Pueblo model the category of Urban use describes only the depletion of water by the population which resides in communities of more than 2,500 persons, and includes no manufacturing or industrial use of water. The category of use describing rural communities in the state (less than 2,500 persons) in the SEO reporting may include some manufacturing and industrial uses, but for the purposes of the Pueblo model it is assumed that these "economic" uses of water in rural communities are negligible. Therefore the Rural water depletions described by the model refer only to human consumption and habitat requirements (e.g., lawns, pools, parks, etc.).

The SEO reporting of water depletions includes several categories which must be assigned to specific sectors, or groups of sectors, in the Pueblo model. The SEO reports Self-Supplied Manufacturing,[104]

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104 Self-supplied manufacturing describes firms with their own source of supply (ground or surface water), which are therefore entirely (or partially) independent or a municipal water system.

Power, and Recreation[105] as separate categories of use. In the Pueblo model water use by these specific categories cannot be so clearly defined. Therefore, these SEO categories are incorporated in the available supplies provided by municipal water systems to those sectors which include these specific economic uses in the model.[106] Water use by mineral industries is reported by the SEO as a distinct class, and there is no difficulty in conforming their definition of water use with the Pueblo model's description of water use in its mining sectors (Sectors 6 and 7).

Finally, the SEO data reports water use in three agricultural use categories: Irrigated Agriculture, Livestock, and Stockpond Evaporation. Although not clearly defined by the data presented in Tables 4.2 through 4.4, the SEO irrigated agriculture class of use describes water use in all five agricultural sectors of the Pueblo model. The SEO categories of livestock and stockpond evaporation must be assigned directly to depletions of water by Sector 1 (i.e., livestock, wool, milk, and eggs) in the model.

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105 SEO recreation category is limited to land-based recreation (e.g., skiing), and staff members with the SEO have indicated an "incompleteness" in their definition and reporting of this category of water use in 1975.

106 The SEO category of power use can (and was) assigned entirely to Sector 18 in the model. This model sector also includes communication, gas, and sanitary services and thus model calibration was done so that water use in Sector 18 exceeded the SEO reporting of power water use in a region.

The uses of water reported by the SEO which do not have direct applicability to the economic activities described by Pueblo model sectors include Military, Fish and Wildlife, and Reservoir Evaporation. As has been previously described, economic activity which is generally described as "government" effects the model by increasing the final demand for any particular sector. Since the majority of this effect can be asserted to occur in the nonagricultural and non-mining sectors of the economy, the SEO reporting of water use by Military must be thought to augment the reported water use in model Sectors 8 through 24. In the case of Fish and Wildlife, and Reservoir Evaporation (reported by the SEO) there are no corresponding sectors of the Pueblo model which this water use can be properly assigned. Thus, the model was updated with exclusion of these water use categories; and, it can be said that this is done without loss of information regarding water depletions by economic activities in New Mexico. It should be noted that the model updating for each of the three Upper Basin regions resulted in water use patterns which accounted for more than 90 percent of water use reported by the SEO in 1975, and in many sectors this updating resulted in identical water use patterns by the model as compared to the SEO reporting.

The level of SEO reported water use (in 1975) was thus used to define the full available supply of both surface and groundwater in the model regions. Although the comparative patterns of water use (between the SEO and Pueblo model) could also be presented for Regions Four and Five, the focus of this report is the Upper Rio Grande Basin and thus these results are not presented here. It may be recalled that the assertion of 1975 reported water use as the long term naturally available supply is dependent upon several assumptions and assertions.

First, it is asserted that 1975 was a "normal" water supply year in the Upper Rio Grande Basin. This normal water supply assertion is statistically defended in Technical Appendix TA-A3. Second, it is asserted that a condition of full appropriation of available water supplies existed in all Upper Basin regions in 1975. Corresponding to this second assertion are the assumptions that future additional appropriations of surface water must be associated with San Juan-Chama project water availability, and that additional groundwater depletions must be offset by retirement of surface water rights. On a local scale either of the assertions could certainly be challenged, but over the large regions modeled -- and the quantity of water use described -- a constraint prohibiting any significant increase in water use (over the 1975 level) is a defensible and reasonable limitation on economic activity in the Upper Basin.

C. Definition of Imports

The role of imports in this IOLP model is not the same as the meaning commonly assigned the term in conversation, or in other forms of economic analysis. A IOLP structure can explicitly describe an independent sector of an economy called imports/exports which can accommodate the more common meaning of the term "import," and account for <u>all</u> purchases or sales of goods from/to parties outside the economic system modeled. This is <u>not</u> the meaning of the import sector in the model used in the present analysis.

The I/O structure which was utilized requires that a feasible solution satisfy the final demands of each of the sectors modeled, as well as all "intermediate demands" for goods and services which are sold between economic sectors. Stated more plainly, a feasible solution to the model requires that <u>all</u> demands for goods and services produced by a sector be satisfied. The Base Year Solution (i.e., 1975) requires that no excess demand exist.

More specifically, the Base Year Solution describes an equilibrium condition where the various intermediate and final demands of all agents in the New Mexico economy are satisfied. This Base Year Solution describes a pattern of necessary inputs and resultant outputs which provide for an equilibrium relationship among all sectors -- <u>and implicitly assumes</u> a specific pattern of imports occurs (from outside the modeled economic system) so as to support any economic activity requiring input(s) which are not produced within the state. The specific pattern of these implicit imports is <u>not</u> explicitly described in this Base Year Solution (i.e., is "implicit" to Base Year Solution); indeed, the Base Year Solution must be specified in this particular model so that <u>no explicit</u> imports exist in the solution.

For the purposes of clarity the following definitions of explicit and implicit importation activity as found in the model solutions are provided.

Explicit Imports

> The importation of a good to satisfy a demand for that good in one of the five model regions. The good is a normal output from the New Mexico economy; but is imported due to some resource constraint which limits production of that output by the sector in which explicit importation occurs. Explicit imports substitute for output from one of the modeled sectors.

Implicit Imports

> The importation of a good which serves as a normal input to a modeled sector's production process. The implicitly imported good may or may not be a normal output of the New Mexico economy. The implicit import is assumed to be available as an input to production in quantitities necessary to allow the output levels described (unless otherwise specified). Implicit imports are structural to the model, cannot be substituted for, and are not explicitly detailed in a sector's production function as specified in the model.

In the IOLP structure employed "explicit imports" are allowed for Sectors 1 through 5 and 8 through 15, chosen, by assumption, as those sectors which produce commodities which could be transported into the state in response to rapid changes in demand conditions. Although the Base Year Solution implicitly includes imports in any of the 24 sectors, the activity in each of the thirteen explicit import sectors of the model is equal to zero in the Base Year Solution.

As the economy of the state grows the output of a specific sector may increase faster than output in another sector. If the faster growing sector requires inputs produced by the slower growing sector, the later may be unable to fulfill the demands of the former, as well as all other demands for its output(s). If such a case does occur in this model, a feasible solution may be obtained by satisfying the excess demand with "explicit imports." Therefore, as used in this model, the inclusion of explicit imports in the model solution describes a need to satisfy a commodity demand which cannot be satisfied by internal production within the New Mexico economic system.

D. Pueblo Model Assumptions and Alternative Scenarios Considered

The range of possible resolutions of Pueblo Indian water rights claims is incredibly broad. Irrespective of the legal theory on which it is based, there are essentially only three important questions: 1) How much water will the Pueblo Indians be entitled to? 2) What will be their priority date? 3) To what specific uses may the water rights be assigned?

Before developing specific economic scenarios to describe the answers to these questions, it may be helpful to more fully describe the dispute resolution process and why the author exercises such flexibility in selecting the particular scenarios modeled. The continuing history of the Aamondt litigation and the unending saga of the Arizona v. California litigation graphically illustrate that modern day courts are ill equipped to handle this type of complicated social and economic question. As a result, it is expected that the full range of federal machinery will be brought to bear on this question. If this is true, then through congressional, administrative and judicial action any of the suggested outcomes are feasible. Therefore, scenarios should be selected along the continuum of possible economic impacts that reflect the largest representative range. This would enable the readers to draw their own conclusions regarding impacts falling with the range of scenarios modeled.

To make the task manageable, a number of assumptions have been made about the future outcomes. Several of these assumptions have already been stated; however, the specific model results are highly dependant upon the assumptions employed, and thus those previously stated are reiterated here.

1) The average annual naturally available water supply of the Upper Rio Grande Basin was fully appropriated in 1975, actual 1975 water availability in the Upper Rio Grande is equal to the average availability, and, therefore, 1975 water use in the Upper Rio Grande Basin defines full available water supply in this region and describes the full utilization of all valid and existing water right entitlements in this region. This description of the available water supply describes only natural stream runoff in the region and is not supplemented by any transbasin diversion water supplies in 1975.

2) Water rights taken from non-Indians would only be water rights appurtenant to irrigated lands. This would exclude from potential transfer all water rights associated with urban, rural, manufacturing, mineral, power, recreation, or federal water uses (including the use of federal "project water").

3) All existing interstate and international water delivery compacts would remain in force and be unaffected by quantification and utilization of Pueblo Indian water right entitlements.

4) Additional water supplies (e.g., San Juan-Chama water) not naturally available in the upper Rio Grande stream system will not be priced as a "commodity" until there is a transfer of these water supplies from their original contract user, and in such a case they will be priced at a "market price" (which is unrelated to the SJ-C contract obligation "price").

5) The Pueblo Indians are currently irrigating up to 24 percent of the present irrigable cropland in the Upper Rio Grande Basin.

6) Implicit in (2) above is the important assumption that not only will non-Indian nonagricultural groundwater rights not be transferred to the Pueblos, but existing off-reservation non-Indian nonagricultural groundwater pumping will be allowed to continue unabated.

7) Due to insufficient hydrological data, the assumption must also be made that neither the Pueblos nor the non-Indians will be able to engage in any groundwater mining to augment their surface supplies.

8) The economic feasibility of projects implemented under alternative resolutions of Pueblo Indian water rights is assumed, which would include repayment obligations for the construction of alternative projects.

9) Finally, the assumption is made that the potential for multi-jurisdictional disputes on the Pueblo Indian lands is insufficient to deter normal economic growth on those lands.

Needless to say, expansion of the Pueblo culture into various areas of agri-business would have extensive sociological impacts, as would elimination of the Hispanic farming communities. I cannot and do not explore these possibilities. Rather, this study examines only the economic consequences of the different legal outcomes.

1. Baseline Scenario

The first scenario modeled describes the economic consequences of a resolution that the Pueblos have no additional water rights in excess of what they are now using. This would be the so-called "baseline" against which the other outcomes would be measured. The Baseline Scenario models economic growth and water availability conditions in the year 2000 without resolution of Pueblo Indian water right claims in the Upper Rio Grande Basin.

This Baseline Scenario, with no change in the fundamental Pueblo Indian water rights entitlements, would also describe Pueblo water right resolutions which limit these water right claims to actual historical use (as measured by 1975 uses). This scenario would in no way inhibit the individual Pueblos from acquiring additional water rights, with the exception that they will be required to pay the market price for transfer of existing water rights and comply with state water laws.

2. Pueblo Indian Agricultural Use Scenario

The second scenario postulates a broad range of possible resolutions based on the Pueblos' application of water to the irrigable acres on their reservations. The model describes future Indian and non-Indian agriculture as equally productive, and depicts specific levels of Pueblo agriculture under differing quantitative resolution scenarios. As the level of Pueblo Indian agriculture rises, the effects on non-Indian agriculture increases due to the water supply constraints.

The specification of minimum levels of agriculture associated with resolution of Pueblo Indian water rights has the potential for forcing the scarce water resources' use in agriculture when that resource could, alternatively, be used in a more economically productive use. This scenario also addresses the potential that compensation may be paid to the non-Indians whose water entitlements are reallocated to the Pueblo agriculture enterprises. As will be seen, the specific parties compensated and the level of compensation have little impact on the regional economic effects of the alternative Pueblo Indian agriculture resolutions.

3. Pueblo Indian Leasing Scenario

Under this final modeling scenario there is considered the potential that a particular resolution of Pueblo Indian water right claims will describe a specific quantity of water right entitlements which the Pueblos will be allowed to lease to alternative on or off-reservation users of the water. Modeled in this scenario are specific prices at which this water is leased, differing quantitative resolutions of the Pueblo's water right claims, and differing regional patterns of water availability associated with these specific quantitative resolutions.

In this lease scenario, as in the Pueblo Indian agriculture scenario, the model solution attempts to satisfy all the demands for economic goods and services which are described by the Baseline solution. These demands can alternatively be satisfied by importing the desired commodities, although this activity occurs with an incumbent cost which can be foregone if the commodity can be produced within the modeled economic system.

Thus, the modeling scenarios are able to describe the relative benefits or costs associated with alternative resolutions of Pueblo Indian water rights on a regional, and even statewide basis. The expression of these benefits and costs by the model are in terms of sectoral output activities increased or decreased as a result of specific resolution of Pueblo water right entitlements. Table 4.5 provides a composite summary of the alternative solutions and scenarios considered by this IOLP modeling of Pueblo Indian water rights resolutions.

E. The Economic Questions

It is asserted by some that there are no economic questions which should be considered in resolution of Pueblo Indian water rights. It may be that specific quantification of these water rights should be based solely on the "social obligation" to these people. Yet it would seem that if both Indian and non-Indian society can be demonstrated to derive larger economic benefits from one alternative resolution of Pueblo Indian water rights (i.e., relative to the other alternatives) then the economic questions cannot be ignored. Stated in alternative form, if economic analysis can demonstrate the more efficient use of the scarce water resource under one of the alternative resolution scenarios, should resolution of these water rights claims be done without consideration of these factors?

Indeed, this analysis can be depicted as "snapshots" of economic conditions associated with alternative resolution of Pueblo Indian water rights. This portrayal freezes two points in time. First, the model is defined empirically by economic circumstances at a starting point (1975) where full appropriation of available water supplies can be observed and defensibly asserted, and where there is no resolution

TABLE 4.5

SUMMARY OF ALTERNATIVE PUEBLO INDIAN WATER RIGHT RESOLUTIONS
PUEBLO MODEL SCENARIOS ANALYZED AND SUMMARY OF RESOLUTION PROCESSES CONSIDERED

Pueblo Model Scenarios	Summary of Scenario	Quantity of Water Rights Reassigned to Pueblo Indians	Likely Resolution Process
Baseline Scenario	Projection of 25 year economic and demographic growth in Upper Rio Grande Basin and no judicial imposition of additional Pueblo Indian water rights	No additional rights	Judicial determination of Pueblo Indian water rights equivalent to current use levels, or no specific judicial resolution of Pueblo Indian water rights
Pueblo Indian Agricultural Use Scenarios	Projection of 25 year economic and demographic growth in Upper Rio Grande Basin with the imposition of additional Pueblo Indian water rights based on the actual use of water in irrigated agriculture on the Indian lands of the Basin	Additional Pueblo Indian water rights increasing to a maximum reassignment of 191,167 acre-feet from existing non-Indian surface water irrigators*	Judicial determination of Pueblo Indian water rights based on a legal theory requiring use of water on the "practicably irrigable acres" of the Pueblo lands in the Upper Basin
Pueblo Indian Water Right Leasing Scenarios	Projection of 25 year economic and demographic growth in Upper Rio Grande Basin with the imposition of additional Pueblo Indian water rights in a specific quantity which may be leased to users and uses anywhere within the Upper Basin at a specific price	Additional Pueblo Indian water rights increasing to a maximum leasable water right entitlement of 191,167 acre-feet reassigned from existing non-Indian surface water irrigators*	Judicial determination of Pueblo Indian water rights based on a legal theory allowing the off-reservation use of Pueblo Indian water rights by non-Indian users, with the possibility of intervention by the legislative or executive branch in resolution process

* Specific description of maximum Pueblo Indian water right quantification under specific scenarios are presented in Chapter V. Note that each alternative scenario was modeled parametrically such that Pueblo Indian water rights would increase by ten percent increments to the maximum quantification resolution under the Pueblo Agriculture Scenario, while under the Peublo Leasing Scenario there were considered several levels of water right quantification with parametric increasing in lease prices over a relevant range of prices.

of Pueblo water rights. Then the empirically defined Pueblo Model is used to provide a 25-year projection of economic growth both with and without specific resolution of Pueblo Indian water rights. The analysis provides comparisons of likely future impacts which are neutral with respect to specific Indian versus non-Indian economic activity. It is quite possible that quantification of Pueblo rights, at the time of quantification (i.e., assumed to occur between 1975 and 2000 in our analysis), will effect only the agricultural sector. Yet, with continued economic growth it is quite possible that these impacts (both direct and indirect impacts) will spread to nonagricultural activities as well. The economic model employed here will identify the direction and general magnitude of both direct and indirect impacts associated with the quantification scenarios identified.

The question as to what can be gained by such an analysis is indeed appropriate. Some economists will assert this to be a form of normative analysis which should be avoided; if for no other reason due to its lack of precision. This contention is rejected based on the assertion that consideration of economic efficiency requires this regional analysis. If piecemeal adjudication of Pueblo Indian water rights based on sound project feasibility benefit-cost analysis leads to conflicts between the individual Pueblos -- which must be resolved by further adjudication -- can the "efficiency" of these piecemeal adjudications be defended? It is clear that the water resources of the Upper Basin are finite and serve as a defined limit to the quantification of Pueblo Indian water rights. If judicial efficiency is an important consideration -- efficiency interpreted as both the time required to resolve these claims and the social values affected by the specific resolutions -- then can the courts ignore some form of regional economic analysis? The court's and participating litigants' answer to this regional analysis question has been a resounding "no"! Yet it is hoped that this investigation provides persuasive justification for at least partial consideration of these regional economic questions. It may serve as a foundation upon which there can be introduction of broader economic perspectives in the adjudication of Pueblo Indian water right entitlements which will affect Indian and non-Indian society alike.

CHAPTER V

MODEL IMPLEMENTATION AND INTERPRETATION OF RESULTS

A. Introduction

The initial solution of the Pueblo Model required numerous data collection, data sorting, coefficient updating and computer modeling steps. Although many details of these toils are extraneous to understanding the results provided by the alternative model runs, a stepwise discussion of the specific model implementation provides a convenient structure for describing the particular conditions and model characteristics which affect the solution. Thus, the following presentation of the Pueblo model's implementation and solution first details the specific updating of the model to the 1975 Base Year. This is then followed by alternative projections of 25 year growth and economic development under the differing possible resolutions of Pueblo Indian water right claims in the upper Rio Grande Basin.

The Base Year data describing actual employment, output, and water use in the specific regions of the model were critical to development of this Pueblo Indian water rights analysis. Not only did this data define a convenient "starting point," the improvement in the quality of the data itself (particularly the water data) allowed better specification of a water constrained economic projection model than previously possible. The specification and implementation of the model focused on the Upper Rio Grande Basin where all but one of the

19 Indian Pueblos are located. Thus, there is present in the discussion of the model solutions which follows results for only the three Upper Basin regions.

This geographic limitation on the results discussed is a reflection of actual legal, economic, and physical circumstance. The hydrologic insulation of the Upper Rio Grande Basin from the remainder of the state's water supply is clear.[108] The concentration and extent of urban development found in the Upper Basin is found no where else in the state, and corresponding to this urban development is a concentration of economic activity also not found elsewhere in the state. Indeed, it is the Rio Grande itself which has provided for much of this extensive concentrated development historically, and it is the water supplies of the Upper Basin which will be the basis for any quantification of Pueblo Indian water rights in the future.

The results obtained from this qualitative model must be discussed and understood in a manner which properly reflects the accuracy of the analysis. To accomplish a proper level of analytical precision all

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108 This is due principally to the geohydrologic structure of the basin. The only area where this assertion is subject to qualification is near the continental divide in McKinley and (then) Valencia County, where there was determined to be a significant hydrologic interconnection between the Upper Colorado River Basin and the Rio Grande Basin as applies to aquifer dewatering for underground uranium mining. See, for example, Findings and Order in the Matter of Application No. SJ-109 of Phillips Uranium Corp. to appropriate the waters of the San Juan Underground Basin, before the State Engineer of the State of New Mexico (October 11, 1979).

results obtained will be summarized according to nine major economic sectors, defined as follows:

TABLE 5.1

DEFINITION OF AGGREGATE PUEBLO MODEL SECTORS

Aggregate Sector (Abrv.)	Pueblo Model Sector Number(s)
Agriculture (AGR)	Sectors 1 through 5
Mining (MIN)	Sector 6
Petroleum (PET)	Sector 7
Manufacturing (MAN)	Sectors 8 through 15
Transportation, Communications, and Utilities (TCU)	Sectors 16 though 18
Wholesale and Retail Trade (WRT)	Sectors 19 and 20
Finance, Insurance and Real Estate (FIR)	Sector 21
Services (SER)	Sectors 22 and 23
Construction (CON)	Sector 24

Although the model defines and functions within the framework of 24 sectors in each region, the results obtained have greater interpretative significance when summarized according to these nine major sector definitions.[109] That is, for example, a Pueblo Indian water rights resolution which impacts one specific model sector included in the Manufacturing group may, in fact, more generally affect the

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109 This model is intended to provide a qualitative description of the impacts which can be anticipated from alternative Pueblo water right resolutions. Many of the 24 sectors possess similar use characteristics, and the specific economic activities can be anticipated to be similarly effect by the modeled scenarios. Thus the level of analytical precision desired suggests a less detailed description of the modeled impacts is appropriate.

Manufacturing group. This interpretation is in large part due to the linear programming algorithm used to obtain the specific results.[110]

Finally, prior to the presentation of the specific results, the question must also be asked as to the results which should be interpreted to have qualitative significance. More simply, how does one assess "significant results" obtained from model solutions? Does one rely on output changes greater than $1 million as a "significance" measure, or is it more appropriate to describe changes as a percentage of Baseline output for each sector? It would seem that the latter of these output measures is more meaningful; but in a water constrained economic model it is possible that a "significant" change in sector water use over the Baseline level of use would be (at least) equally meaningful. Without defining precisely <u>the</u> significant values for each of these measures of change, the reader is admonished to recognize observed changes in appropriate perspective. When required, this perspective will be described in the summary description of the

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110 That is, the linear programming algorithm would allocate all remaining available water to the most economically efficient user of that water -- even if the efficiency of use difference between the last sector receiving water and the next most efficient sector (which does not receive water) is less than 1 percent. Since the majority of manufacturing use is supplied by municipal water systems (which do not follow this strict allocation rule) it can be assumed that the actual effect of such a Pueblo Indian water rights resolution would be felt more generally among the sectors model. The discussion here which applies to the manufacturing sector (as an example) also applies to the other nine summary sectors.

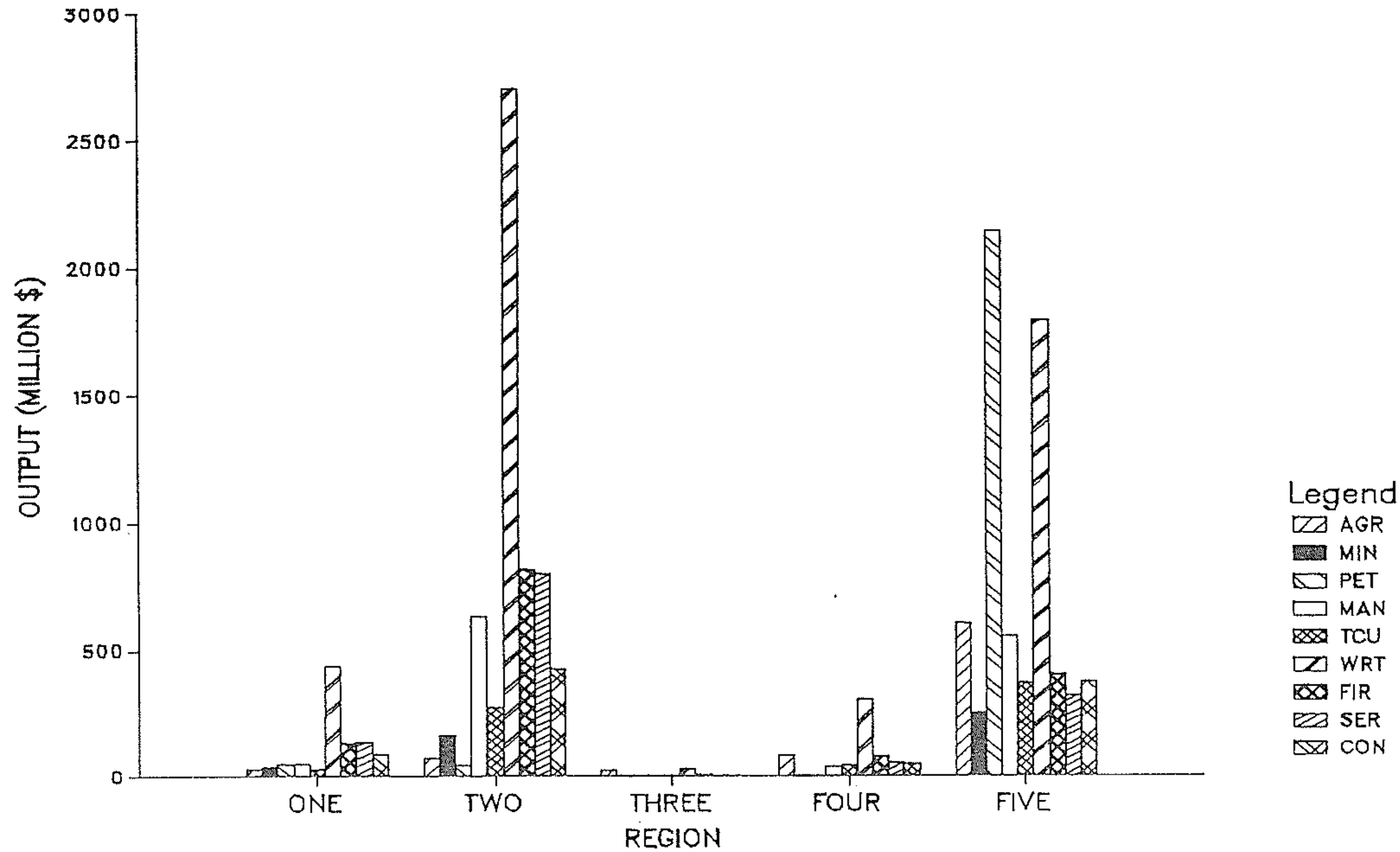
results provided herein. It is now appropriate to turn to a specific discussion of the Base Year solution.

B. Base Year Solution (1975)

The updating of the model to 1975 employment and water use patterns resulted in a model solution which did not require the use of any of the "purchase" or import mechanisms available in the model. That is, in the Base Year solution there are no imports of commodities, "purchases" (or imports) of labor from outside the model, or transfers of water in the modeled system. Thus, the specific pricing of these mechanisms is immaterial to the Base Year solution. It is, therefore, appropriate to turn directly to discussion of output and water use as found in the Base Year solution.

To place this analysis into a better perspective regarding the relative size of sectors within particular regions, and the regions relative to each other, Figure 5.1 describes the 1975 level of output in each of the nine summary sectors for each of the five regions (note: this is the only summary of Regions Four and Five to appear herein). It is clear from this presentation that Regions Two and Five are dominant in nearly all sectors, with wholesale and retail trade in Region Two surpassing 1975 output levels for all other sectors in the state's economy. It is equally clear that Region Three generally, and specific sectors within Regions One, Two and Four, are relatively insignificant when placed in this particular perspective.

FIGURE 5.1
REGIONAL OUTPUT BY MAJOR SECTOR
FIVE MODEL REGIONS -- 1975



In order to place this economic analysis itself in proper perspective, it is appropriate to note that this conclusion regarding the relative "insignificance" of particular sector(s) should not be construed or interpreted as a conclusion regarding the social insignificance of a particular sector. Throughout the descriptions of the model results which follow similar economic conclusions will be provided. These conclusions are both inescapable and illusory. For example, Figure 5.1 clearly shows the level of agricultural output in Region Two to be comparatively insignificant in relationship to the other economic activities within that region -- but at the same time, the culture and heritage of the majority of this region is dominated by activities related to this agricultural sector. The reader is thus provided a warning that the results described herein are limited to economic conclusions unless otherwise described. There is required specific recognition that the economic conclusions discussed may not describe the actual decisions society would make with consideration of these exogenous social and cultural values. The solutions provided herein should be considered to be rational economic decisions regarding resource use.

Figures 5.2 through 5.4 identifies for each of the Upper Basin regions the level of 1975 output and water use by major sector group. Figure 5.5 shows the 1975 levels of Urban and Rural populations in each of the Upper Basin regions and the level of water use associated with those populations. These water use levels are the combination of

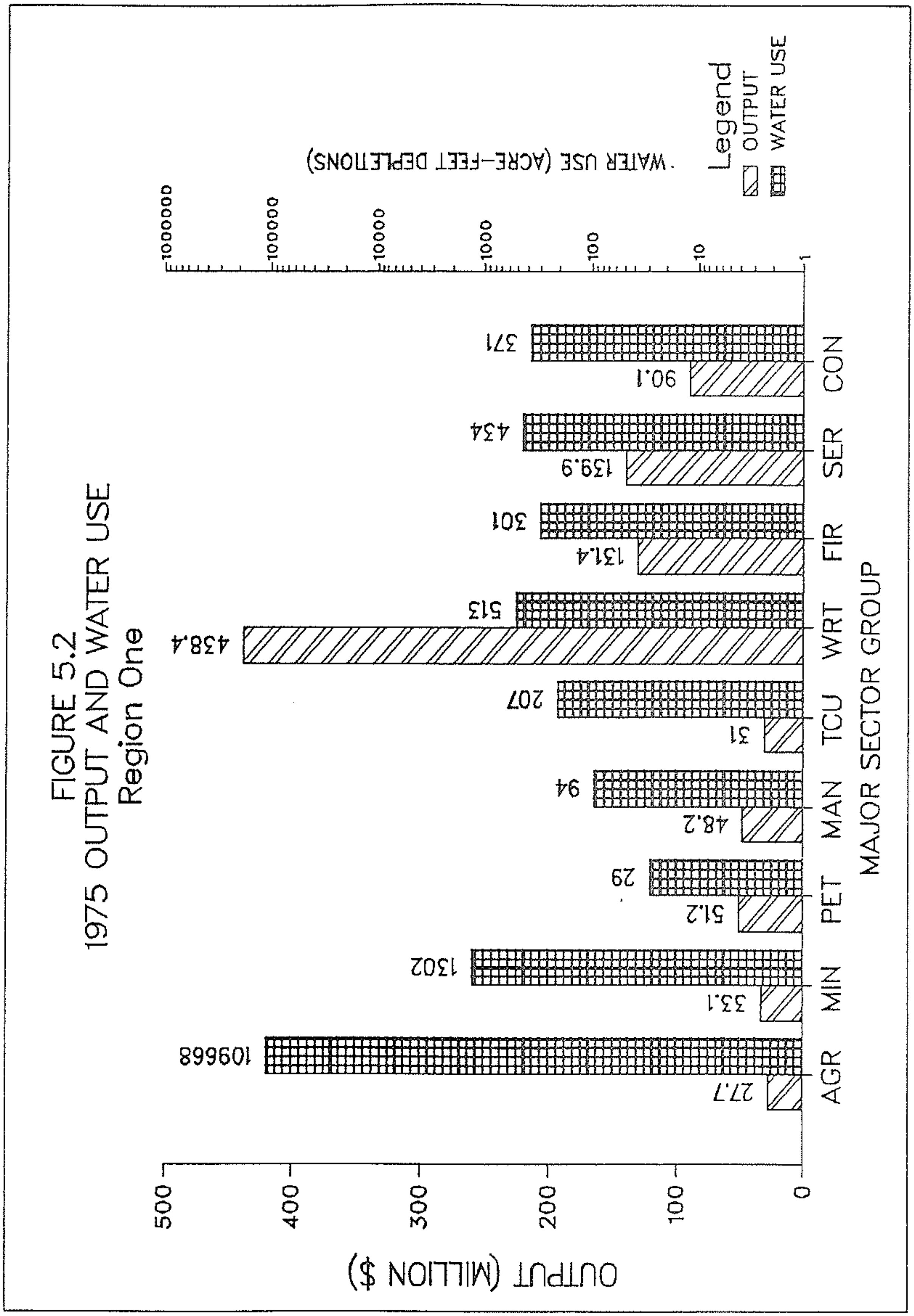


FIGURE 5.2
1975 OUTPUT AND WATER USE
Region One
OUTPUT (MILLION $)
0
100
200
300
400
500
WATER USE (ACRE-FEET DEPLETIONS)
1
10
100
1000
10000
100000
1000000
Legend
OUTPUT
WATER USE
AGR
MIN
PET
MAN
TCU
WRT
FIR
SER
CON
27.7
109668
33.1
1302
51.2
29
48.2
94
31
207
438.4
513
131.4
301
139.9
434
90.1
371
MAJOR SECTOR GROUP

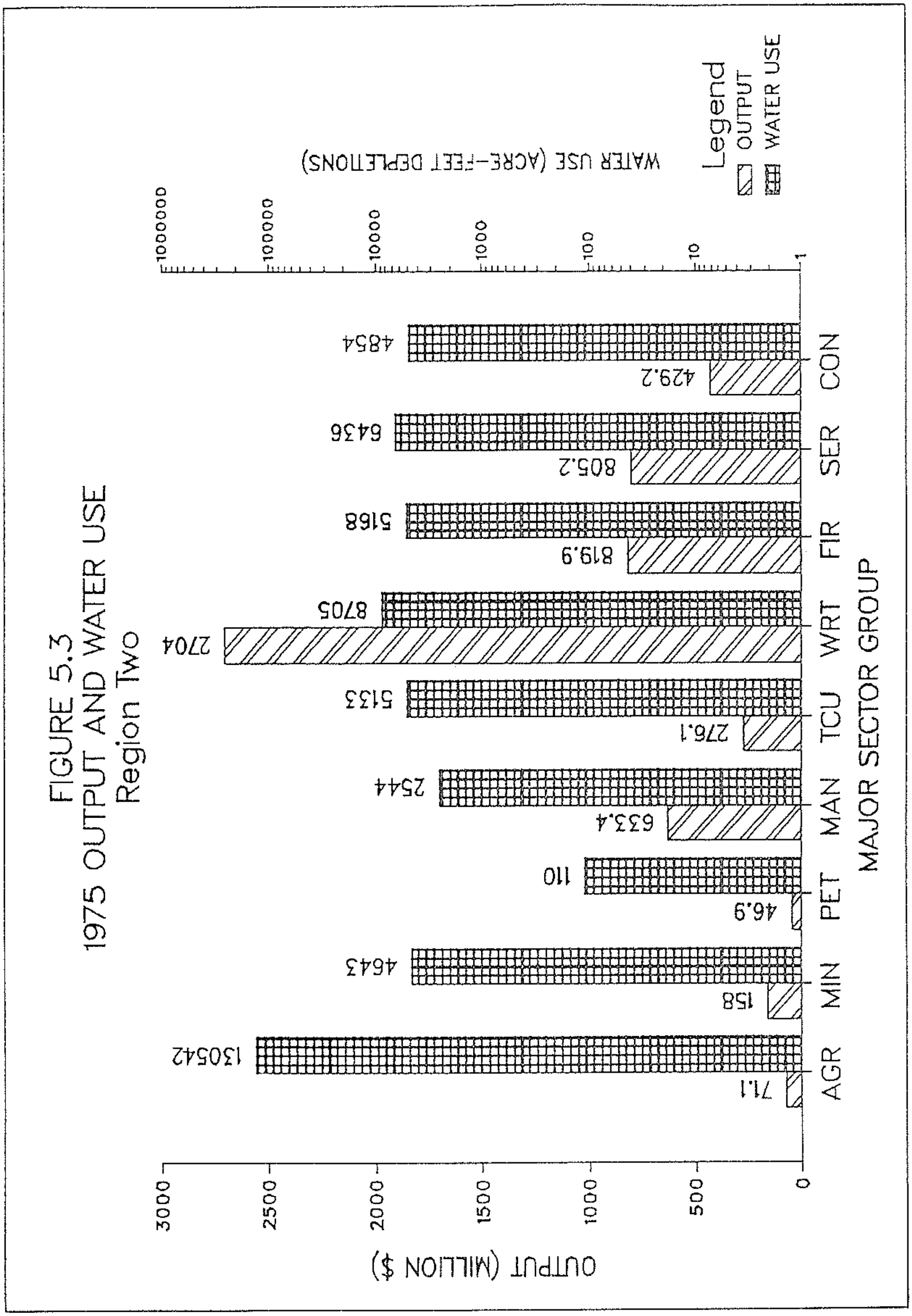
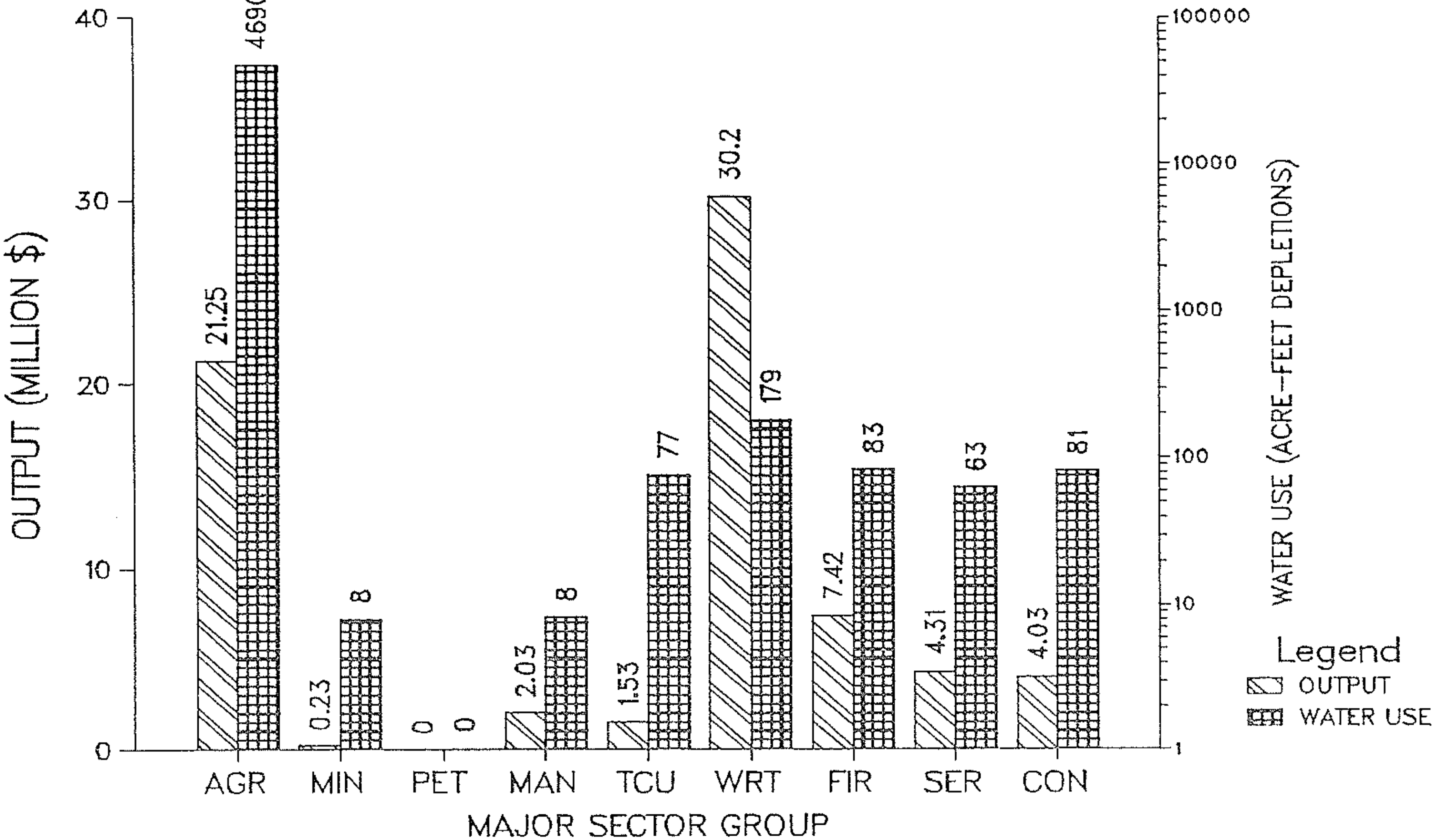


FIGURE 5.3
1975 OUTPUT AND WATER USE
Region Two

FIGURE 5.4
1975 OUTPUT AND WATER USE
Region Three



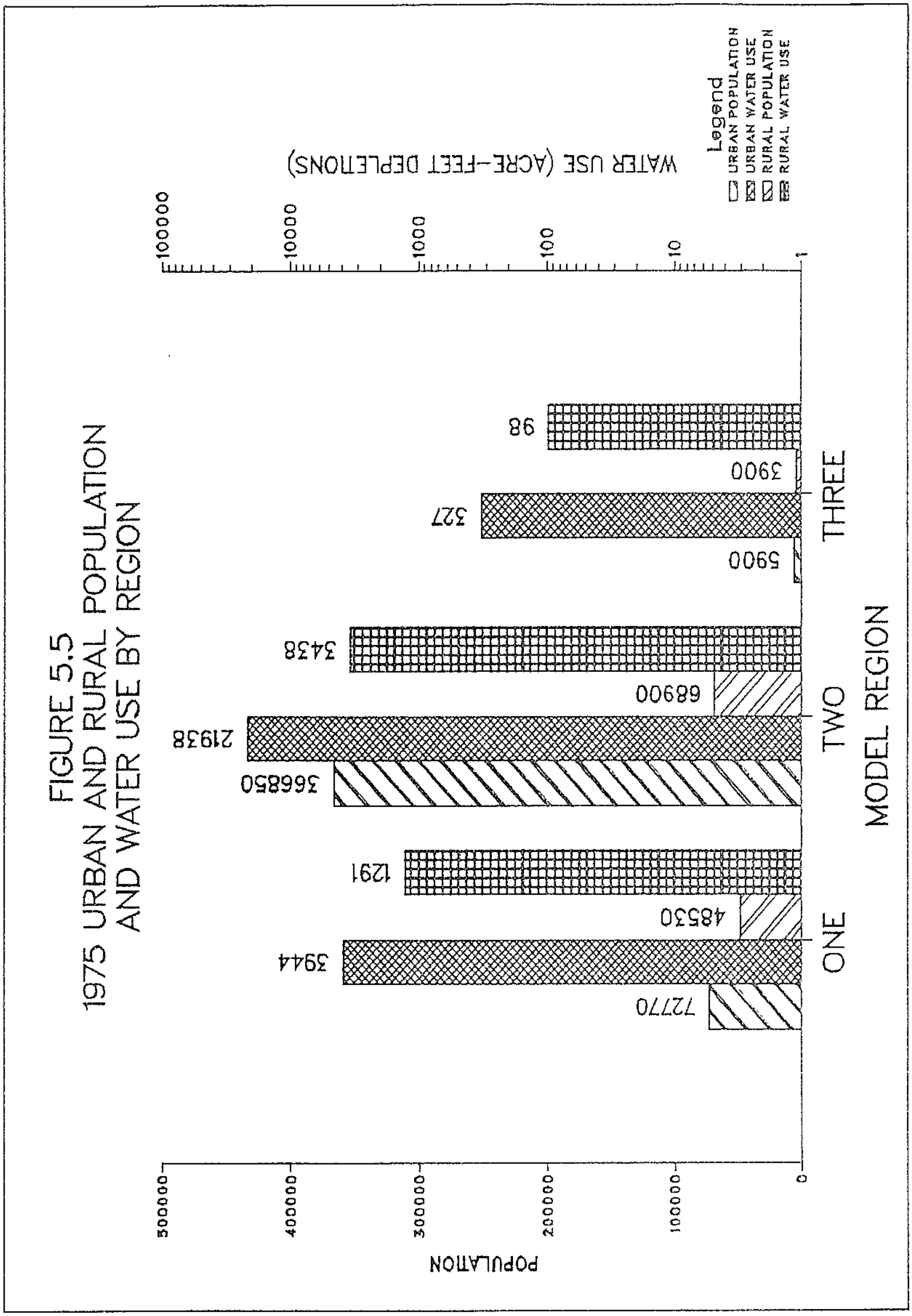
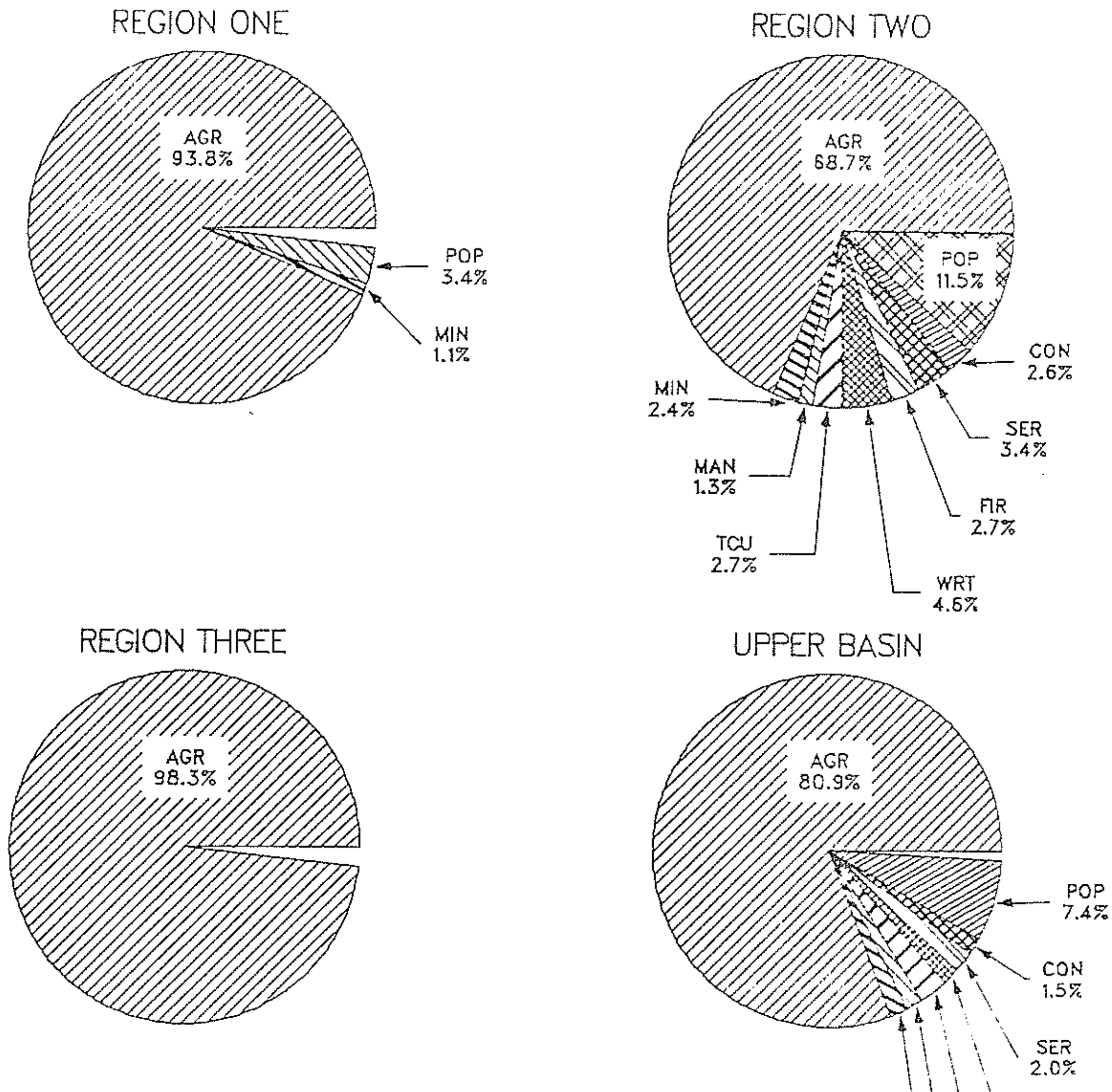


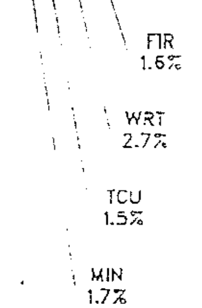
FIGURE 5.5
1975 URBAN AND RURAL POPULATION AND WATER USE BY REGION

surface and groundwater sources of supply, and describe the water depletions by the inhabitants of each region associated with their personal consumption and habitat needs. Finally, water use in the Upper Basin regions and the region as a whole is graphically illustrated in Figure 5.6 as pie charts of the water use by sectors in the three separate regions and the Upper Basin as a whole. Clearly the agricultural use of the available water resources dominates (92.7 percent of Region One's use, 67.5 percent of Region Two, 98.1 percent of Region Three, and 79.8 percent of total Upper Basin use). It is somewhat surprising the degree to which the pattern of water use in Region Two also describes the pattern of water use in the Upper Basin.

For the reader interested in the specific values of water use per million dollar of output, (i.e., the water depletion coefficients) utilized to generate the patterns of water use described here there is provided a Technical Appendix Chapter (TA-C1) which describes the derivation of these water coefficients and the specification of these coefficients in the Base Year, Baseline, and the modeled scenarios. These specific coefficients are not provided here for two reasons. First, the description of the analysis performed is not materially improved by presentation of all the specific input data which generated the modeling output results described. Secondly, the specific values of the water depletion coefficients reflect (for many sectors) the combination of dissimilar production processes with differing water use characteristics which, when aggregated as a

FIGURE 5.6
1975 WATER DEPLETIONS BY SECTOR
UPPER RIO GRANDE BASIN MODEL REGIONS





PERCENTAGE DEPLETIONS NOT SHOWN:

REGION ONE
PET 0.02%
MAN 0.08%
TCU 0.18%
WRT 0.44%
FIR 0.26%
SER 0.37%
CON 0.32%

REGION TWO
PET 0.06%

REGION THREE
MIN 0.02%
MAN 0.02%
TCU 0.16%
WRT 0.38%
FIR 0.17%
SER 0.13%
CON 0.17%

UPPER BASIN
PET 0.04%
MAN 0.75%

depletion coefficient per unit of output, have little interpretive significance.

There are many other details of this Base Year solution which could be presented. Much of the specific information which could be presented regarding this 1975 Base Year solution can be better presented as it applies to the Baseline (year 2000) solution. It is therefore appropriate to leave any further description of the Base Year solution until it can be compared to the results obtained under the Baseline solution. Thus, the discussion of model solutions now turns to description of the specific projection of Baseline conditions.

C. Baseline Solution (Year 2000)

For the model to describe the effects of alternative Pueblo water right resolutions there is required first a description of economic conditions without the imposition of these "new" rights on the system, as well as the subsequent discussion of the specific effects of the scenarios modeled. Growth and change of an economic system over a 25-year period is a complex interaction between economic principals and social circumstances. Many of these changes can be anticipated with significant accuracy, while other changes may defy prediction of even the direction of change (i.e., positive or negative). The specific values chosen for the projection of Baseline conditions for this qualitative analysis should be considered as relative indicators of likely changes, with these values based on empirical observations of population growth rates, per capita income changes, or other evidence which lends credence to their assertion.

The projection of change in the water supply is largely dependent on increases in supply associated with completion of the San Juan-Chama project. Also incorporated are changes in the efficiency of water use for some sectors. The projection of economic growth rates in specific sectors is a much more subjective estimation which should be interpreted primarily on a comparative regional basis rather than as actual growth rates. The dollar values described here are expressed in real dollars (1975 dollars), and it should be noted that under this Baseline projection there continues to exist Pueblo Indian economic enterprises which expand/contract from their 1975 level at a rate equal to the rate applied non-Indian activities of the same type and region.

It is appropriate to recall the nature of the analytical model employed prior to the description of the Baseline solution. The most important characteristic of the solutions derived from a IOLP model (as employed here) is that they describe the economically optimal allocation of the available resources to their alternative and competing uses. Thus, as water (or any other constraining resource) becomes scarce relative to total water demands, the model allocates water sequential--first to the highest valued use (i.e., lowest water use per dollar unit of output), and then to successively less valuable uses until the available water supply is exhausted.

In order to obtain a Baseline solution such elements as general economic growth rates for the state, specific rates of growth in output for particular sectors, improvement in labor productivity, changes in water depletion coefficients, and changes in available water supplies must be carefully specified in the economic projections which are made. Several of these dynamic modeling parameters can be based on empirical data, while others must be modeled on theory-based assertions or plausible assumption. It is, therefore, important to present a detailed description of these modeling elements as they are specified for the Baseline solution.

1. Economic Growth Rates

In a IOLP structured model used for projection of changes in output levels (and water use) there are required specifications of changes in final demand for outputs of the sectors modeled. The simplest explanation of this requirement is provided by equation 2.5.

$$X = (I-A)^{-1}Y \qquad (2.5)$$

This expresses (in matrix notation form) the direct relationship between output (X) and final demand (Y). Since the projection done here holds the intersectoral trade (technical) coefficients constant (i.e., $(I-A)^{-1}$ unchanged), the specification of final demand (Y) in the projection determines the level of sectoral output (X). All intermediate demands are internalized in the technical coefficients matrix, so a change in final demand determines both the direct and indirect impacts on output levels in the model. That is, if final demand for a particular sector increases by ten percent, then output in that sector must increase by (at least) ten percent (i.e., the direct impact). However, output in other sectors must also increase to provide the intermediate goods used in the production processes of the sector whose final demand increased (i.e., the indirect impact). Ultimately, the level of output for all sectors is determined internally based on the level of final demand specified for each sector. However, it should be noted that output may be constrained by water availability, forcing explicit importation activity in the model if such a condition exists.

Final demand, as described in the Pueblo Model, consists of consumption by consumers, government purchases, and exports from the state. If this model perfectly described all economic activity in New Mexico, then all income earned by residents of the state either is spent on consumption, saved instate, or saved out-of-state. If the percentage of income saved out-of-state is small relative to the income remaining instate, then an increase in personal income will be manifested in an increase in final demand for consumption. This assertion does not ignore the portion of income saved instate since these savings serve as funds for the output services of the banking and investment sectors in the model.

In some sectors final demand is largely composed of instate consumption demand, with significant export demand, and almost no government demand (e.g., meat products, Sector 8). Alternatively, sectors such as the pipelines sector (Sector 17) are comprised almost entirely of exports. In general, it can be concluded that the final demand of the sectors describing the extraction of natural resources from the state are largely composed of export demands, and sectors describing consumer commodities are largely composed of final consumption demand within the state (and potentially significant government purchases). The model's final demands for the service sectors consist of all three sources of demand (i.e., instate consumption, export, and government purchases). Thus, the specification of final demand in the model generally includes all three demand groups, with the projection of specific growth in final demand for any particular sector effected by the composition of that sector's final demand itself.

If the portion of final demand associated with government purchases and exports is small relative to the consumption demand, and are thus temporarily ignored, then it can be asserted that changes in final demand are directly the result of changes in gross income levels in the state. This change in gross income can be said to be the direct result of two factors: a) changes in per capita income, and b) changes in population. Since no data is available which describes the historic pattern of changes in government "final demand" expenditures, nor does there exist data on the changes in state exports, it is asserted that a default rate of final demand growth in each of the five model regions will depend on the changes in per capita income and population within the region.

Stated more explicitly, the "base rate" used for projection of final demand growth in each region will be the multiplicative product of the annual rate of change in per capita income in the region (the historic trend over the five years from 1975 to 1980) and the annual rate of change in the region's population (the historic trend over the ten years from 1970 to 1980). Defined in this manner the default rate of final demand growth describes an annual compound growth rate. This base rate (or default rate) shall be modified for specific sectors in particular regions to reflect additional information or knowledge regarding anticipated growth in a sector over the period being considered.

The first general modification of this default rate asserts that the level of final demand for the agricultural sectors does not change significantly with increases in per capita income. In more formal terms, the income elasticity of agricultural final demand is very low, with growth in final demand tied only to the rate of population growth in a region. Table 5.2 presents all the compound annual growth rates utilized in the model for sectoral final demand growth projections, including population and per capita income growth rates, for the three Upper Basin regions of the model. On a region by region basis the final demand growth rate assumptions used in projection of a Baseline solution were made as follows.

TABLE 5.2

COMPOUND ANNUAL GROWTH RATES BY SECTOR
FOR THE UPPER BASIN REGIONS

Sector	Region One	Region Two	Region Three
1	2.043%	2.389%	2.260%
2	2.043	2.389	2.260
3	2.043	2.389	2.260
4	2.043	2.389	2.260
5	2.043	2.389	2.260
6	2.811	0.000	0.000
7	0.000	0.000	0.000
8	4.463	4.459	0.000
9	4.463	4.459	0.000
10	4.463	4.459	0.000
11	4.463	4.459	0.000
12	4.463	4.459	0.000
13	4.463	4.459	0.000
14	4.463	7.459	0.000
15	4.463	4.459	0.000
16	4.463	4.459	3.457
17	4.463	4.459	3.457
18	4.463	4.459	3.457
19	4.463	4.459	3.457
20	4.463	4.459	3.457
21	4.463	4.459	3.457
22	4.463	4.459	3.457
23	4.463	4.459	3.457
24	4.463	4.459	3.457
Population Growth	2.043	2.389	2.260
Per Capita Income Growth	2.371	2.022	1.170

Region One Sectors 1 through 5 in this region rely on the 1970 through 1980 population growth rate in the region for the final demand growth projections. The final demand growth rate for Sector 6 indicates a doubling of final demand during the 25-year modeling period. The principal mining company comprising this sector has plans for the doubling of production by the year 2000, with the vast majority of output from this sector exported from the state. All of the expected growth in Sector 7 output is thought to occur outside the region, although it is likely that final demand for the output of this sector in the region will remain constant (at its 1975 level).[111] For the remaining Sectors 8 through 24 the default base rate was used for the projected growth in final demand due to lack of alternative information to base these growth rate projections upon.

Region Two Final demand in Sectors 1 through 5 again grows equal to the rate of population growth in the region during the 1970s. Both Sectors 6 and 7 are thought to have no growth in final demand over the period projected. In the case of Sector 6, which includes a substantial level of uranium production in 1975, this no growth projection may be too optimistic given the substantial production cutbacks which have occurred in this industry during the period since 1975. It is quite plausible that by the year 2000 this sector will have returned to its 1975 output levels due to the many economic, political, and

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111 Oil and gas output in Region One for 1975 includes output from a portion of Rio Arriba County not in the Rio Grande Basin. No attempt was made to identify the output of wells located within the basin, primarily because of the low water use by this sector. Substantial increases in output from portions of Rio Arriba County in the Colorado River Basin can be anticipated, but these production increases are properly excluded from Region One final demand growth.

social factors which affect this industry.[112] The remaining Sectors 8 through 24 relied on the default base rate, with the exception of Sector 14 which grows at a rate three percent greater than the default rate. More than one-third of the 1975 level of output in Sector 14 was the result of output in the electronics industry. This industry in Region Two is thought to be the region's growth leader in the next several decades. The assumed higher final demand growth rate, which is slightly less than twice the rate of final demand growth for the other manufacturing sectors, seems a reasonable assumption for Sector 14 as a whole.

Region Three final demand in Sectors 1 through 5 grow at the rate of population increase experienced during the 1970s in the region. Since there are very small Mining and Manufacturing sectors in Region Three, and no significant change in these sector appears likely, the growth rates for Sectors 6 through 15 were assumed to be zero with final demand expected to remain at its 1975 level. In Sectors 16 through 24 (the Services and Construction sectors) there was assumed a final demand growth rate equal to the default rate; that is, the rate of population growth multiplied by the rate of per capita income growth in the region.

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112 For detail discussion of the New Mexico uranium industry and its future see Brian McDonald and Philip Farah, "New Mexico Uranium Industry; Current Assessment and Outlook," report prepared for New Mexico Mining Association, Bureau of Business and Economic Research, September, 1982. Only under their high scenario projection does uranium output return to a level greater than 1975 output by the year 2000.

Growth rates for final demand projections were also established for Regions Four and Five. The reader interested in these specific rates for the regions outside the Upper Basin is referred to the Technical Appendix TA-C3. The default base rates were generally used in these regions, with the exception of a two percent addition to the base rate for growth in Manufacturing final demand in Region Four. This is based on the rapid expansion of manufacturing output observed in this region between 1975 and 1980, and the anticipation of continuation of the present growth of this attractive sunbelt manufacturing region in the future. It should also be noted that the specific growth rates in Regions Four and Five are not of any primary significance to the analysis which was performed. As will be described more fully, the final demand for most of these outputs can be met alternatively by importation of the output commodity. Thus, for the purposes of the analysis undertaken here, the solution obtained is unaffected by the specification of final demand growth in Regions Four and Five.[113]

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113 This is true under only if the following additional conditions are satisfied:

a) There exists sufficient water available such that output in Sectors 16 through 24 can be produced so as to meet all intermediate and final demands faced by these sectors, and

b) There continue to exist legal and administrative restriction on the transfer of water out of the Upper Basin and transfers across the boundaries of Regions Four and Five remain impossible.

The model was also able to allow restriction of sectoral outputs levels by the "bounding" of specific sector columns. The assumption was made that the agriculture sectors throughout the Upper Basin would be unable to produce more than 110 percent of their 1975 output levels in the Baseline solution. This restriction assumes a limit to the improvement of crop productivity over the 25 year projection period, and is combined with the unlikelihood of significant increases in agricultural acreage within the region. As is discussed subsequently, the sectors are allowed increased efficiency of water use during this period. However, it is clear that some limit on agricultural acreage and productivity constrain output from these sectors in the Upper Rio Grande Basin. Thus the (somewhat arbitrary) assertion of a 110 percent (of 1975 level) constraint on output in the agricultural sectors. The final demand for agricultural is allowed to grow as described previously, but the constraint on output limits the demand which can be supplied by production within the Basin, and the constraint dictates that the unsatisfied demands for output be met by explicit importation of those agricultural commodities.

It may be recalled from the previous chapter that the model was specified so as to allow the importation of necessary outputs in Sectors 1 through 5 and 8 through 15 if resource constraints prevented their production internally in the model. That is, if there is insufficient water available to allow production of output in one of these 13 sectors, then the demand for output from this sector can be alternatively satisfied by importation of that output from outside the state. There are no bounds placed on the level of imports which can occur in a solution to the model, so conceivably the full level of output demand could be satisfied by imports (in the sectors where imports are allowed).

With the rates of growth utilized in this model for the 25-year projection of the Upper Basin economy the model was able to find feasible and optimal solutions without running out of available water. The Baseline solution to the model was also able to satisfy all output demands associated with the projected economic growth without the importation of commodities in any of the 120 economic sectors of the model, with the exception of the agricultural sectors.

Based on the evidence of stable or declining agricultural acreage in the Upper Rio Grande (see Chapter III) it was assumed that the real value of agricultural output would not grow to more than 110 percent of its 1975 value. Previously it was said that final demand for agricultural output would grow at the rate of population growth in each region, and this final demand growth rate is used in the Baseline solution. The 110 percent of 1975 output constraint placed on the agricultural sectors simply recognizes the limited potential for large output increases in the agricultural sector during 25-years model period. The increase in demand (both intermediate and final) which exceeds these 110 percent output constraints is able to be met by imports in the respective sectors. Thus, imports are found in the

Baseline solution where agricultural output demands exceed the 110 percent output constraint.

Annual population growth rates for each of the five model regions during the decade of the 1970s was relied on in the specification of model growth rates for Urban and Rural populations, as well as for the growth in the labor force available in each region.[114] The model was specified with the water requirements of the Urban and Rural populations as a priority use of water.[115] Therefore, these growth rates can significantly effect the specific solution obtained. In the Baseline solution the following growth rates (Table 5.3) were used in projection Urban population, Rural population, and available labor force in each of the three Upper Basin regions.

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114 This growth rate was derived as an annual compound population growth rate for each region as a whole. It was assumed there would be no change in either the ratio of urban to rural population from its 1975 pattern in each region, nor in the labor force participation rate. Population data provided for 1970 and 1980 by the U.S. Bureau of Census, and for intercensal years by Lynn Wombold, Demographer, Bureau of Business and Economic Research, University of New Mexico. Per capita income data provided by U.S. Department of Commerce, Bureau of Economic Analysis, Regional Information System, Per Capita Personal Income, Washington, D.C.: U.S. Department of Commerce, April, 1982.

115 More precisely, the model solution is required to meet the full depletion requirements for both urban and rural populations in each of the regions. This is easily justified by considering the contradictions of hypothesizing economic output without a population base available for its production and/or consumption.

TABLE 5.3

GROWTH RATES OF URBAN AND RURAL POPULATION,
AND AVAILABLE LABOR FORCE BASELINE PROJECTIONS

	Region One	Region Two	Region Three
Annual % Compound Growth	2.043%	2.389%	2.260%

2. Efficiency of Resource Use Changes

A second area of change which must be specified in the Baseline solution is the rate at which model sectors utilize the available resource inputs in their production processes. With respect to water resources there is clear evidence of some elasticity of demand to variations in water prices. This effect which is manifested in the rate at which sectors of the model utilizes the water resource in the production of output. Likewise, there is a substantial body of economic theory describing the effects of technological innovations on labor productivity.

There are several empirical measures of specific labor productivity changes at a national level.[116] These analyses reflect historic

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116 The measurement and definition of productivity has been the subject of continuing discussion in economics. See John W. Kendrick, Productivity Trends in the United States, Princeton, N.J.: Princeton University Press, 1961; Solomon Fabricant, "Meaning and Measurement of Productivity," in J. Dunlop and V. Diatchenko, eds., Labor Productivity, New York : McGraw-Hill Book Company, 1964; John W. Kendrick and Beatrice N. Vaccara, Conference on New Developments in Productivity Measurement and Analysis, Williamsburg, Va., 1975, Chicago : University of Chicago Press, 1980.

patterns of labor productivity change, and may or may not serve well as estimates of future labor productivity changes in the specific economic sectors analyzed here. An alternative measure of changes in labor productivity are changes in real per capita income. Although the previously mentioned national industry-specific productivity information might provide justification of productivity changes for a particular industry in an IOLP model, no consistent set of these industry-specific productivity estimates for the full range of economic activity described by the Pueblo model exists.

A real per capita income measure of productivity change can be based on historic measurement for each of the five model regions. This measure defines, on a region by region basis, the change in real earning power of labor within that particular region of the state. This is hardly a precise measure of labor productivity change in each of those regions, but can serve well as a surrogate (in absence of a better, consistent alternative) in a qualitative model such as is intended here. The model is thus specified such that the productivity of labor is improved in each sector at an annual rate equal to the annual rate of change in real per capita income. The specific rates of labor productivity change as used in the model for the Upper Basin regions are presented in Table 5.4.

TABLE 5.4

CHANGE IN LABOR PRODUCTIVITY FOR
THE UPPER BASIN REGIONS
(Annual Compound Rate)

Region One	Region Two	Region Three
2.371%	2.022%	1.170%

Source: Derived for regions from county level data for 1970 through 1980 provided by U.S. Department of Commerce, Bureau of Economic Analysis (Regional Information System), "Per Capita Personal Income in SMSA's Counties, and Independent Cities in Selected Years (Residence Adjusted)," Washington, D.C.: BEA.

As was the case with the output of certain model sectors, a shortage of labor in any solution of the model may be satisfied by the purchase, or "importation", of labor services. This alternative source of labor is available to all sectors of the model at a "welfare price" of $2,000 per unit purchased. This price has no significant meaning and was chosen such that the purchased labor price itself did not constrain the use of the labor purchase mechanism in a preliminary solution to the model.[117]

117 The technique for determining the price was to reduce available labor supply in a preliminary Baseline solution to the point where output utilizing the full available supply in a region, then increasing the price of purchased labor to a price where it becomes "too expensive" to justify its purchase. The $2,000 price is substantially less than the "threshold" price where labor became "too expensive" to justify its purchase.

The trend toward increasing efficiency of water use has been noted by several authors,[118] with these scholar finding evidence of price elasticity regarding urban water demands and price-related efficiency improvements common to nonurban uses as well. The trend toward increased water use efficiency seems to be dependent on two cost measures. First, the use of urban water resources appears sensitive to cost of water, particularly as it affects the residential use of water (i.e., human consumption and habitat requirements). Evidence of this effect is provided by observations of use patterns in Santa Fe and other southwestern cities[119]

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118 The topic of increasing water use efficiency is a recurring theme in much Western water research today. See, for example, Loyal M. Hartman and Don Seastone, Water Transfers: Economic Efficiency and Alternative Institutions, Resources for the Future, Inc., Baltimore : Johns Hopkins Press, 1970; Charles J. Meyers and Richard A Posner, Market Transfers of Water Rights : Toward an Improved Market in Water Resources, National Water Commission, Arlington, Va. : National Technical Information Service, 1971; Maurice M. Kelso, William E. Marin and Lawrence E. Mack, Water Supplies and Economic Growth in an Arid Environment, Raymond L. Anderson, "Transfer Mechanisms Used to Acquire Water for Growing Municipalities in Colorado," paper presented at Western Farm Economics Association meeting, July 24, 1978; H. Stuart Burness and James P. Quirk, "Appropriative Water Rights and the Efficient Allocation of Resources," American Economic Review, VXIX (March 1979) : 1-36; Lee Brown, Brian McDonald, John Tysseling and Charles DuMars, "Water Reallocation, Market Proficiency and Conflicting Social Values," in Gary D. Weatherford, Ed., Water and Agriculture in the Western U.S.: Conservation, Reallocation and Markets, John Muir Institute, National Science Foundation, Boulder, Co.: Westview Press, 1982.

119 See Charles W. Howe and F. P. Linaweaver, "The Impact of Price on Residential Water Demand," Water Resources Research 3(1)

[continued on next page]

The second cost considered is referred to by economists as the opportunity cost of maintaining existing water use patterns. The courts have been affected by this cost, with several cases in which farmers have succeeded in selling a portion of their water right entitlements, and at the same time continue to irrigate the same acreage with more efficient techniques.[120] Indeed, such practice has become so common that it has resulted in explicit SEO policies to deal with such transfers.[121] From this evidence it can be concluded

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(1967); S. H. Hanke and R.K. Davis, "Demand Management Through Responsive Pricing," Journal of the American Water Works Association 67(5) (1971); Robert A. Young, "Price Elasticity of Demand for Municipal Water: Case Study of Tucson, Arizona," Water Resources Research 9(4) (August, 1973): 1068-72; Henry Foster and Bruce Beattie, "Urban Residential Demand for Water in the United States," Land Economics 56(1) (February, 1980); Jennifer Zamora, Allen V. Kneese and Erick Erickson, "Pricing Urban Water: Theory and Practice in Three Southwestern Cities," The Southwestern Review 1(1) (Spring 1981): 89-113; Charles W. Howe, "The Impact of Price on Residential Water demand: Some New Insights," Water Resources Research 18(4) (August, 1982): 713-16.

120 The two leading cases in the west dealing with the transfer of water saved through improved use efficiency are Salt River Valley Water User's Association v. Kovacovich (3 Ariz. App. 28, 411 P.2d 201 (1966)) and East Bench Irrigation Co. v. Desert Irrigation Co. (2 Utah 2d 1970, 271 P.2d 449 (1954)).

121 The State Engineer in New Mexico has adopted a policy which has limited the need for litigation in the transfer of water rights in conjunction with increased use efficiency. The administration by the State Engineer of water right transfers in accord with N.M. Stat. Ann. §§ 75-5-21 to 75-5-23 allows an agricultural user to sell and transfer a portion of their water right, and then "spread" the remaining entitlement over the same acreage

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that <u>some</u> degree of water use efficiency improvement should be included on a broad scale across the modeled sectors.

The evidence of increasingly efficient water use is clear, but this evidence in no way provides for specific estimates of the rate of water use efficiency change. Thus, several assumptions were relied upon to frame these conditions in the model. First, as a group of economic sectors, agriculture is anticipated to have the greatest potential and likelihood for improved water use efficiency.[122] Second, firms producing higher valued outputs per unit of water have less incentive for making efficiency improvements due to their ability to "justify" the cost of the water input. Finally, residential water use demand is at least as sensitive to cost (i.e., price elastic) as is agriculture and will, therefore, improve water use efficiency at (at least) the same rate as agriculture.

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with <u>proof</u> that such actions will not impair other valid rights. Typically the State Engineer requires metering of actual appropriations in conjunction with his approval of the transfer application, and this is so stipulated in his order approving the Application for Change.

122 Two factors enter into this assumption: a) that agriculture is the least efficient user of water (per $ unit of output), and b) that water use efficiency improvements in agriculture can be accomplished with positive net benefits (i.e., the cost of transferring right and making efficiency improvements are less than the benefits thereby derived) over a relevant range of efficiency improvement values (i.e., up to 20 percent reduction in water use coefficients in model over 25-year period modeled).

Consistent with these assumptions regarding changes in water use efficiency, all agricultural sectors, urban, and rural water use coefficients in the model will be reduced by 10 percent in the year 2000; all other sectors in the model (Sectors 6 through 24) are assumed to improve their water use efficiency by 5 percent over the period modeled. Although these are rather arbitrary values, they are applied on a consistent basis throughout the model. Given the qualitative character of the model, the specific values selected will have little effect on the conclusions regarding the effects of Pueblo Indian water right resolution.[123]

3. Water Transfer Mechanisms

It was felt that the model required some formal mechanism to allow transfers of water from surface to groundwater sources of supply within a region, and from one region to an adjacent region. Both of these mechanisms are found in common application in New Mexico water law. However, there are significant restrictions placed on some of these specific transfers[124] which required their application with a

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123 This statement is only true over a relatively small range in specific value choices. For example, if the model were to postulate a 25 percent improvement in water use efficiency by agriculture, with a 5 percent change by the remaining sectors a significant different qualitative solution would be obtained than is described here. The 5 and 10 percent values which were chosen do have effect on the solution, but at the same time seem both analytically defensible and subjectively reasonable.

124 The largest and most important category of these restrictions can be best summarized as institutional restrictions. Included

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degree of caution. In addition, there was need to recognize a hydrologic/legal reality regarding the administration of groundwater law in the Rio Grande Basin by the State Engineer.

The explicit water transfer mechanisms which were specified in the Pueblo model provide for the commonly observed transfer of water right entitlements among individuals in New Mexico. It is relatively common to observe conversion of a surface water right transfer to a groundwater right, and somewhat less common to observe transfers of surface water rights between regions in the Upper Basin.[125] These transfers also have a social cost related to the necessary administrative hearings, filing, etc., which are part of this transfer/process.

The transfer mechanisms employed in the model were of rudimentary form, in that they allowed only the one-to-one transfer of rights from

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in this group in the Upper Basin are: a) the Rio Grande Compact, which restricts transfers from Region One to Region Two, and visa versa (at Otowi Bridge), b) the 1906 Treaty with Mexico restricting any substantial increase in Upper Basin depletions, c) the 1956 declaration of the Rio Grande underground basin which restricts a large group of potential transfers on impairment (and other) grounds, with many other less circumspective restriction at specific locals throughout the Upper Basin regions.

125 An interregional transfer between Regions One and Two (as defined by the model) in the Upper Basin is significantly restricted due to Rio Grande Compact modifications and amendments required by such a transfer. It is possible though, as is evidenced by the arrangements and modification to the compact required by the San Juna-Chama project.

surface to groundwater and from region to region. The one-to-one transfer of surface rights to groundwater is a fairly good assumption near the river, but as the distance from the river increase and/or the depth of the well increases the relationship becomes increasingly more untenable. The specific inaccuracy of the one-to-one transfer of water from region to region can be more precisely described. Water transferred from a downstream user to an upstream user in the model understates the water which would be made available by an actual transfer (in most cases), while a transfer from upstream to downstream in the model typically overstates the quantity of water which would actually be allowed transferred by the SEO.[126] The significance of the imprecision in the specific model solutions obtained depends entirely on the quantitative levels and specific types of transfers found in those solutions. The summary of model results which follows will note this imprecision when appropriate.

The model was specified to allow surface to groundwater transfers up to the point where 50 percent of a region's available supply of surface water could be so transferred in the model solution (an

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126 An upstream transfer (from a downstream use) generally has less transmission of carriage loss than at its former point of use, with limited impact on return flow patterns, thus allowing potential of increased diversions at the upstream transfer-to location. A downstream transfer works the opposite generally, with increased transmission losses and potential return flow problems which may reduce diversions allowed at the transfer-to location than formerly allowed at the transfer-from location.

arbitrary, but reasonable value). The model was then run for preliminary Baseline solutions to determine a maximum objective function "price" for the transfer mechanisms, where the solution was unconstrained by the specific price. That is, a price was chosen so that the cost of a surface to groundwater transfer in no way prohibited output by any sector of the model. By this mechanism it was determined that a "welfare price" of $60 per acre-foot of surface water transferred to groundwater would be used in the model.

A similar analysis of the pricing of interregional transfers, although the precision in specifying the price in the model was not as great as for surface to groundwater transfers. This analysis resulted in the welfare pricing of interregional transfers at $100 per acre-foot transferred, with the exception that transfers from Region Three to Region Two would be priced at $10 per acre-foot. The lower value for the Region Three to Two transfers simply reflects the relative simplicity of such a transfer within the geographic confines of the Middle Rio Grande Conservancy District which comprises nearly all surface right within Region Three.

4. Available Water Supply Changes

The Baseline solution to the model relies on the available surface and groundwater resources as constraints to economic activity in each of the Upper Basin regions. The changes to the 1975 available supply can be summarized as follows:

a) available supply increases associated with the completion of the San Juan-Chama transbasin diversion project,

b) entry of non-Indian water brokers with water available for sale (i.e., sale by the City of Albuquerque of surplus San Juan-Chama rights),

c) retirement of surface water rights due to groundwater pumpage (i.e., basin-wide SEO administration of City of Albuquerque v. Reynolds decision), and

d) projected increases in "allowed" groundwater depletions associated with administration of c).

It is appropriate to discuss individually each of these specific changes as they affect the available supply for both clarity and as a vehicle to understanding of the water resource dynamics in the Upper Basin over the 25 year model period.

The San Juan-Chama transbasin diversion project was originally authorized under P.L. 87-483 in 1962 by Congress. The project was completed in late 1969 and early 1970, with the first diversions of water from the Upper Colorado River Basin in 1971. Prior to 1977 there were only 38,600 acre-feet of the project's water under contract, with neither of these contract users (the City of Albuquerque and the Middle Rio Grande Conservancy District) requiring use of these additional water resources in 1975.[127] The majority of

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127 According to data used in the SEO's calculation of required use of Albuquerque's San Juan-Chama water rights the city will not require the San Juan-Chama rights until after 1990 to offset groundwater pumpage under City of Albuquerque v. Reynolds. See D.N. Stone, "City of Albuquerque 1982 Effect Study," (preliminary) Albuquerque, N.M. : District I, New Mexico State Engineer Office, May 1932. The nonuse of San Juan-Chama water by the MRGCD is somewhat less clear. According to the 1975 SEO water use data irrigated acreage and water use (Dp = Depeletions

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deliveries from the project in 1975 went to the development of the permanent pools at Elephant Butte and Cochiti reservoirs, and thus the deliveries from the project were considered not to affect the available supply of water in the Upper Basin in the 1975 Base Year solution to the Pueblo model.

With the full utilization of the San Juan-Chama project (as currently authorized) there is made available to the Upper Basin an additional 101,800 acre-feet of surface water for depletion. At this time the project has contracted for delivery of 89,750 acre-feet to users in the Upper Basin regions, with the specific allocation of these additional waters to the contract users as shown in Table 5.5. It is clear that only 78,750 acre-feet of this contracted use will effect the supply of surface water which is available for depletion by

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(acre-feet)) in the MRGCD were as follows:

Irrigated Acres	Total Dp	Surface Dp	Ground Dp
58,300	145,410AF	128,190AF	17,220AF

The MRGCD vested and perfected water rights (excluding all San Juan-Chama rights) can be associated with 131,615 acres of irrigated land providing an estimate 303,391 acre-foot depletion right. Clearly the 1975 use was significantly less than the estimated vested rights, and thus the conclusion regarding the nonuse of their San Juan-Chama rights. A further adjudication of these rights might conclude otherwise, but this observation will be left to the realm of speculation. See Sorenson, supra. Note 24; and McDonald, Tysseling, Browde, and Brown, supra, Note 16, p. 58.

economic activity described by the model in the Upper Basin. It should also be noted that the quantities of water made available by the project are both diversionary and depletion (consumptive use) rights because this is federal project water made available to these specific users, and do not convey corrollary return flow dependence to downstream users.[128]

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128 See Willis H. Ellis and Charles T. DuMars, "The Two-Tiered Market in Western Water," Nebraska Law Review 57(2): 333-367.

TABLE 5.5

SAN JUAN-CHAMA PROJECT CONTRACT USERS

Acre-Feet	Region One
15	Twining Water and Sanitation District
400	City of Taos
1,030	Pojoaque Valley Irrigation District
1,200	U.S. Department of Energy-Los Alamos
1,000	City of Espanola
5,605	City and County of Santa Fe
9,250	Total Region One
	Region Two
20,900	Middle Rio Grande Conservancy District
48,200	City of Albuquerque
69,100	Total Region Two
	Region Three
400	City of Los Lunas
78,750	Total Upper Basin
	Recreational Pool Contract Users
5,000	Cochiti Lake--U.S. Army Corps of Engineers
6,000	Elephant Butte Reservoir -- U.S. Bureau of Reclamation
89,750	Total Contracted San Juan Chama Project

Source: Fidel Fias, Projects Office, Bureau of Reclamation, U.S. Department of the Interior, Albuquerque, October 1982.

It can be asserted under current legal conditions that the City of Albuquerque (or any other user) would be allowed to sell its surplus San Juan-Chama water entitlements. There is no precise manner in which the quantity of these surplus rights can be arrived at, although projections have been done by both the City and the SEO. All these projections show that there will be a substantial quantity of surplus Albuquerque San Juan-Chama water available for sale in the year 2000, and it is possible other contract users of this water might have a similar surplus available. Since approximately 50 percent of the project's deliveries are to the City, and since it can be generally said that the other contract users did not purchase the water in recognition of similar long-term planning needs as faced by the City of Albuquerque, I chose to investigate only the City's surplus.

The estimation of surplus Albuquerque San Juan-Chama water was based on several assumptions. First, the residential population of the City would improve their per capita consumption by a total of 10 percent over the 25-year model period, while all other users dependent on the City's water system (e.g., manufacturing) would become 5 percent more efficient in their water depletion requirements over the same period. Second, that the "allowed" increase in groundwater depletion by the City under the SEO administration of the basin without acquisition of additional water rights will be 51,386 acre-feet resulting in a net surplus of Albuquerque San Juan-Chama water as shown in Table 5.6 (based on the Brutsaert model, explained subsequently).

TABLE 5.6
SURPLUS ALBUQUERQUE SAN JUAN-CHAMA ENTITLEMENT
BASELINE SOLUTION

Region Two

Baseline projected water depletion Sectors 8-17, 19-24, Urban[1]	115,452 AF
Percent Albuquerque of Region Two, 1975[2]	72.1%
Implied Albuquerque depletion, Baseline	83,241 AF
Projected "allowed" Albuquerque groundwater depletion in Baseline[3]	51,386 AF
Implied Albuquerque use of San Juan-Chama entitlement	31,855 AF
Albuquerque San Juan-Chama Entitlement	48,200 AF
Net Albuquerque surplus San Juan-Chama entitlement (i.e., surface water available for sale)	16,345

AF = Acre-feet
1 The majority of Sector 18 use in Region Two is self-supplied and thus excluded.
2 Assumed constant over model period.
3 See Technical Appendix (TA-C) for explanation.

It should be noted that the projection of surplus San Juan-Chama water done by the City arrives at a similar number as derived here, although the data used in estimating this surplus are significantly different.[129] The 16,345 acre-feet of surplus water was then

129 The specific differences between the City of Albuquerque is projection and the baseline model projections are as follows:

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subtracted from the San Juan-Chama's addition to the naturally available supply in Region Two. This water was treated as separate source of surface water which was available in the model for sale. The "price" for this water was established at six dollars per acre-foot, a price based on the maximum "revenue" generated in the Baseline solution of the model.[130]

Under the 1963 City of Albuquerque vs. Reynolds[131] decision

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129 [continued from previous page]

	Baseline Model Solution	City of Albuquerque Projection
Population	521,251[a]	540,600
Total Dp (acre-feet)	83,241	75,700
Assumed "Allowed" Groundwater Dp	51,386	75,700
Direct "Use" of ABQ SJ-C	31,855	12,696
Contracted "Use" of ABQ SJ-C	0	16,000[b]
Estimated Surplus ABQ SJ-C	16,345	19,504

a Based on maintenance of 1975 Albuquerque share of Region Two urban population in Baseline solution.

b Current contract obligation (in year 2000) to French Wine Growers Association.

Albuquerque projections from Mr. Jim Gill, Water Resources Department, City of Albuquerque, January, 1983.

130 The reader is reminded that the "pricing" is a social welfare cost measure, and thus the "revenue" so generated cannot be interpreted accord to its common meaning.

131 City of Albuquerque v. Reynolds, 71 N.M. 428, 379 P.2d 73 (1963). Under this decision the SEO administers the sur-

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there is required retirement of surface water rights in the future for present groundwater pumpage. The decision, and the groundwater law system now administered under the decision, acknowledges the interconnection of surface and groundwater sources of supply in the Rio Grande aquifer. Fortunately, the Pueblo model was able to rely upon work done by Brutsaert[132] and others in conjunction with the specification of the Lansford, et al., model upon which the Pueblo model is based. The specification of the Brutsaert model which was relied upon here describes the acre-feet of surface water rights which must be retired in each region, with the corollary assumption that by the year 2020 there will be a doubling of groundwater pumpage in each region. The values provided by this Brutsaert model were then calculated for each region to reflect conditions in the year 2000 Baseline solution.[133] The resulting values for required surface

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131 [continued from previous page]

face/groundwater interconnection with a set of quantitative relationships known as Theis' Formula which is based on common hydrologic variables (e.g., porosity, transmissivity, etc.).

132 For detailed description of the hydrologic basis upon which this interconnection relationship is expressed in the Lansford, et al., and Pueblo models see W. Brutsaert and C. Way, A Conjunctive Use Surface Water--Groundwater Simulator, Technical Report 33, Las Cruces, New Mexico: Water Resource Research Institute, New Mexico State University, 1973.

133 The specification provided by the Lansford model described both the required surface right retirement and pumpage increase for the year 2020. Since the Pueblo Model's Baseline projection was for the year 2000 there was required: a) the assumption that

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water retirement and "allowed" increase in available groundwater supply for the Upper Basin regions are presented in Table 5.7.

TABLE 5.7
SURFACE WATER RETIREMENT
(acre-feet)

	Region One	Region Two	Region Three
Surface Water Retirement Required	2,646	15,858	324

The general constraint of no increase in depletable water rights has been imposed on the model, with modification to the naturally available water supply (e.g., effective water rights) in the Baseline solution described in Table 5.7 and based on the work done by Brutsaert. In the year 2000 the 1975 surface water supply has been decreased by the required surface water (depletion) right associated with steady state management of the aquifer system, and the groundwater supply has been increased by the amount described by this same time lagged steady state management system.

The SEO in New Mexico has neither the resources or reason to specifically model the "allowable" depletion of groundwater based on

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133 [continued from previous page]

under the Brutsaert model 60 percent of the necessary surface retirement required in 2020 would be implemented by 2000, and b) the rate of pumpage increase would be a linear function of time which allowed a projected increase in pumpage in each region.

current pumpage rates on a statewide basis.[134] Although regional hydrologic studies in several basins and sub-basins are being done, there is no ability to draw upon these studies for the research conducted here. Thus, there was reliance on the only model for the state which would provide the water supply change data required in the Pueblo Model.

The second set of adjustments to the 1975 available water supply relates to the interconnection between the surface and groundwater supplies in the Rio Grande aquifer. Both topics have been partially explored in determining the surplus Albuquerque San Juan-Chama water, but have not been dealt with on the basin-wide scale required in the modeling. Relying on the Brutsaert model there was required retirement of surface water rights in each region as shown in Table 5.7. Clearly only in Region Two is there significant decline in the available supply in the year 2000 due to the required retirement of surface supplies to offset groundwater pumpage. There has been reference to "allowed" groundwater depletion in previous discussions. The use of the terminology is the result of there being no "official" projection of depletion increases associated with retirement mechanism on a basin-wide scale. Relying, again, on the Brutsaert model there

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134 The SEO prepared such a report for the City of Albuquerque in May of 1982 at the City's request. This study was based on data provided by the city, with the results very unofficial and subject to revision. Stone, supra, note 126.

was also an ability to project the Baseline depletion of groundwater associated with the surface water retirement requirement just described. The allowed increases in groundwater depletions according to the Brutsaert model presented in Table 5.8.

TABLE 5.8

BASELINE GROUNDWATER
AVAILABLE FOR DEPLETION
(acre-feet)

	Region One	Region Two	Region Three
1975 Groundwater Dp	12,731	67,743	19,949
"Allowed" Increase	3,007	28,665	421
Total "Allowed" Groundwater Dp in Baseline	15,738	96,408	20,370

Dp = Depletion

The tabulation of available water supply in the Baseline solution is presented in Table 5.9, and describes the amount of water available for depletion in, or available for transfer from, the regions of the Upper Basin. These values represents the constraints on the available supply, with the minor exception of Region Two where the surplus Albuquerque San Juan-Chama water is excluded from the "free" available supply, but augments that supply if purchased in a model solution.

TABLE 5.9

BASELINE AVAILABLE WATER SUPPLY

	Region One		Region Two		Region Three	
	Surface Water	Ground-Water	Surface Water	Ground-Water	Surface Water	Ground-Water
1975 Depletions	106,110	12,731	125,865	67,743	27,892	19,949
Required Surface Retirement	2,646		15,858		324	
Total San Juan-Chama Water	9,250		52,755		400	
Surplus Albuquerque San Juan-Chama Water Available For Lease			16,345			
"Allowed" Groundwater Depletion Increase		3,007		28,665		421
Total Baseline Water Supply	112,714	15,738	179,107	96,408	27,968	20,370

Note: All values are expressed in acre-feet depletion quantities

Finally it should be noted before describing the specific Baseline solution that all dollar values expressed in any solution are stated in terms of 1975 constant dollars. Since it was not possible to defend projections of relative price changes among the model sectors, and more importantly, it is not clear precisely how to model such a structural change in the IOLP framework, no sectoral price changes were included. The interpretation is a simple assumption of constant relative prices over the model period, with expressed values in all model solutions in 1975 dollars.

5. Baseline Model Solution

The economic growth of the Upper Basin as projected in the model, combined with the changes in the available resources associated with projection, provide for significant dynamics in the Upper Basin economy and water use over the 25-year modeling period. A comparison of the Base Year and Baseline solutions for the nine summary sectors, and their appurtenant water depletions, is presented for each Upper Basin region in Figures 5.7 through 5.9.

The most apparent of the results in this solution is that although agricultural output in the Upper Basin increases, the quantity of water used in the production of this output declines. This has a degree of intuitive sense to it, particularly with observation that significant research effort is currently being expended in search of more water efficient agricultural production practices in New Mexico and throughout the Southwest. The agricultural sectors also clearly dominate all others in water use, but there are significant increases in water use by many of the other sectors. It is noteworthy that Manufacturing (MAN), Transportation, Communications and Utilities (TCU), Wholesale and Retail Trade (WRT), Finance, Insurance and Real Estate (FIR), Services (SER), and Construction (CON) all more than double -- and in some cases more than triple -- their 1975 water use levels in Regions One and Two. In Region Two this growth has fairly

FIGURE 5.7
COMPARISION OF BASE YEAR AND BASELINE OUTPUT AND WATER USE
Region One

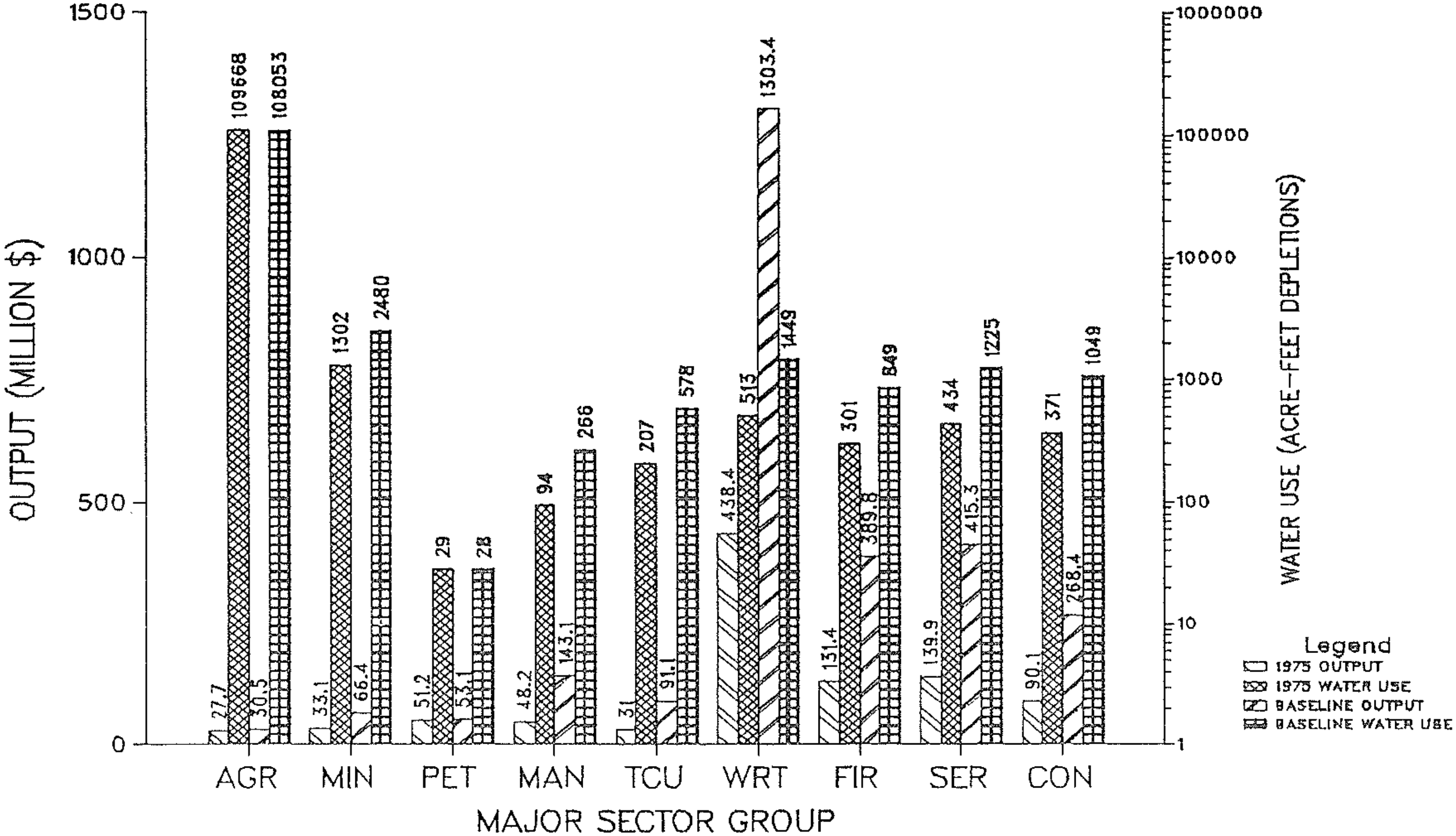
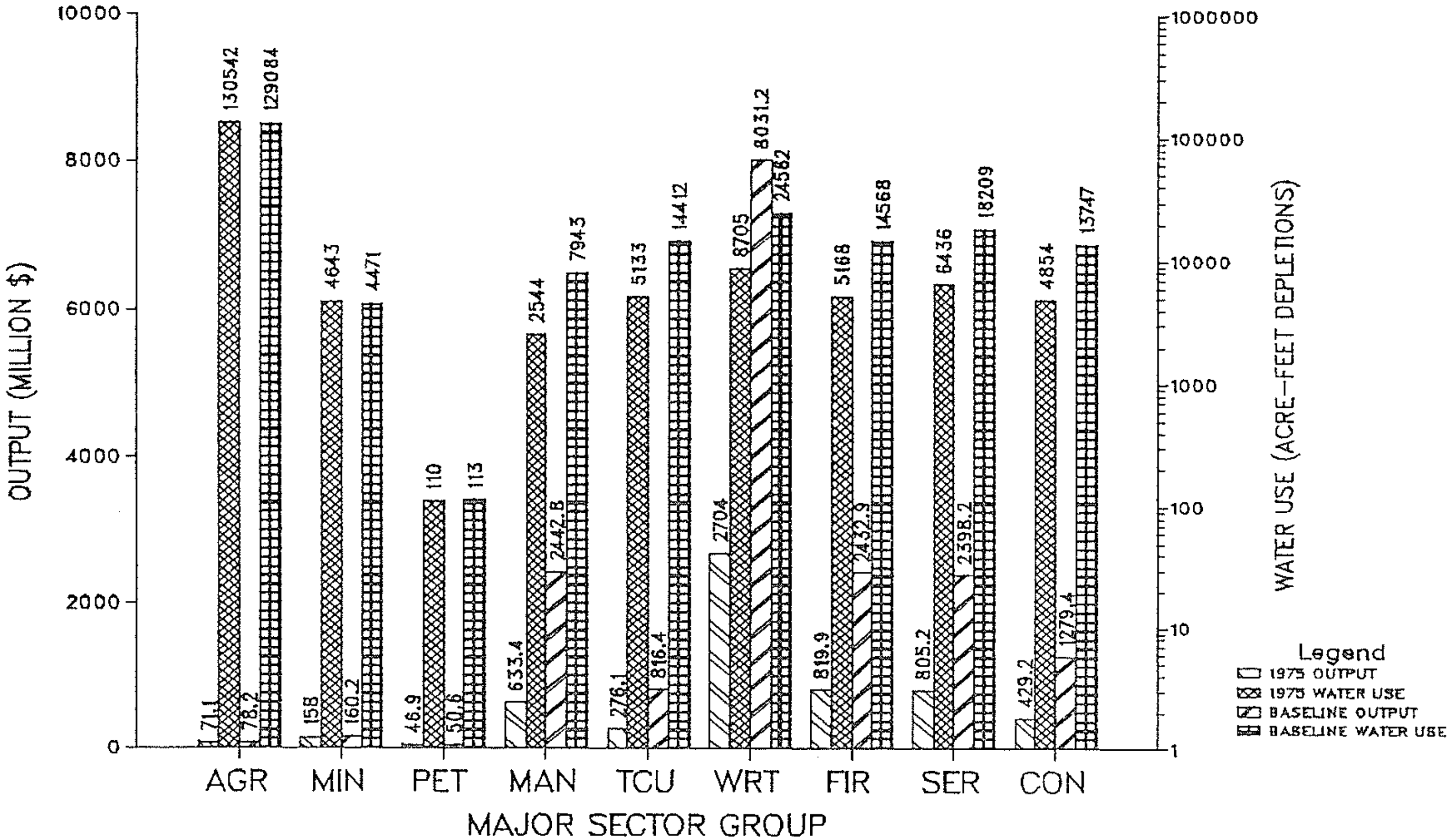


FIGURE 5.8
COMPARISION OF BASE YEAR AND BASELINE OUTPUT AND WATER USE
Region Two



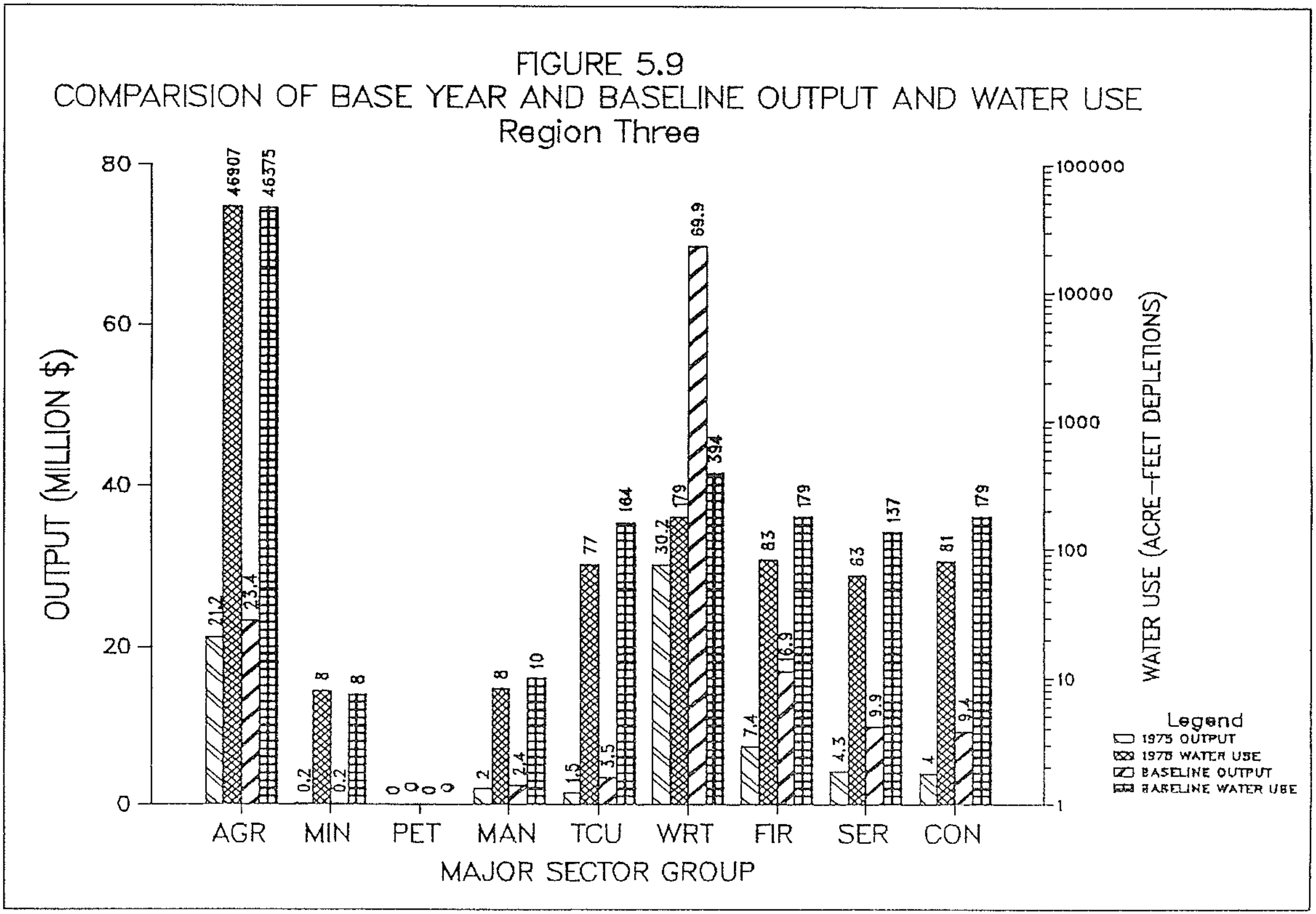


FIGURE 5.9
COMPARISION OF BASE YEAR AND BASELINE OUTPUT AND WATER USE
Region Three
OUTPUT (MILLION $)
80
60
40
20
0
WATER USE (ACRE-FEET DEPLETIONS)
100000
10000
1000
100
10
1
21.2
46907
23.4
46575
0.2
8
0.2
8
0
0
0
0
2
8
2.4
10
1.5
77
3.5
164
30.2
179
69.9
394
7.4
83
16.9
179
4.3
63
9.9
137
4
81
9.4
179
AGR
MIN
PET
MAN
TCU
WRT
FIR
SER
CON
MAJOR SECTOR GROUP
Legend
1975 OUTPUT
1975 WATER USE
BASELINE OUTPUT
BASELINE WATER USE

significant impact on the available water supplies. Many other details of this Baseline solution could be described, but these details will be left until their significance in relationship to the Pueblo water right resolution scenarios can also be presented. It is therefore appropriate to turn now to the specific implementation of the Pueblo water rights resolution scenarios in the IOLP framework.

D. Pueblo Indian Agricultural Use Scenario

For the reasons briefly described in Chapter I there are significant grounds for assertion of Pueblo water rights by actual application of water to beneficial use on the reservation. A party interested in acquiring the largest quantity of water right entitlement would generally consider the agricultural use of water for establishing the maximum right possible. Clearly any resolution of Pueblo water rights which require actual application of water to beneficial use would be manifest as an increase in the agricultural output from the lands of the Pueblos. Thus there was hypothesized a range of possible outcomes with a maximum scenario where all Upper Basin non-Indian agricultural water rights in 1975 are transferred to the Pueblo Indians (in Regions One and Two only).

The specific model mechanisms required provided greater complexity than the simple narrative description of the scenario would suggest. First there was required some assumption as to the level of Pueblo agriculture in 1975. The specific reasons and data upon which the assumed value are based were previously presented. It may be recalled that just less than 24 percent of the 1975 irrigated acres in the Upper Basin are assumed to be irrigated by the Pueblos. Thus, the water rights appurtenant to 114,838 acres in the Upper Basin, including all the irrigated acres in Region Three, could be assumed to potentially be transferred to Pueblo agricultural enterprises.

Several details of this scenario required close scrutiny. First there must be some allocation of the benefits of this scenario (i.e., new agricultural acres) among the 18 Upper Basin Pueblos. For lack of more precise or equitable formula it was assumed that the additional agricultural water would be allocated to Regions One and Two in proportion to the 1975 percentage of irrigable Pueblo lands (estimate) in each of the regions. Thus under this allocation, and in all runs of this scenario, Region One possess 47.1 percent of the irrigated Pueblo lands and Region Two possess 52.9 percent of these lands.[135]

Due to the transfer of additional water into Regions One and Two under this scenario there was required respecification of the agricultural output constraints for these two regions so that output could increase, while at the same time agricultural output in Region Three

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135 For those concerned with such details, there is deliberate "mixing" of the irrigable and irrigated terminology here. The allocation percentage is based on data defining irrigable lands within the Pueblo boundaries, while model solution by definition must describe irrigated lands. The imprecision is clear and acknowledged, but no better alternative was available. See Chapter II for discussion of the specific data problems encountered.

must decline under this scenario. The extreme case under this scenario is one where all non-Indian agriculture is replaced by Pueblo agriculture, an effect which would most clearly be observed in Region Three where there would be no agricultural output in the extreme. The transfer of available water from Region Three to Regions One and Two under this scenario would not have equal effects in Regions One and Two due to the differing agricultural productivity (per acre-foot of water) in each region. It was assumed that the transfer of water would not result in a shift in the relative patterns of output among the five agricultural sectors in each region, and thus additional water was allocated to each of the five agricultural sectors based on each sector's share of total agricultural water use in the Baseline solution. The sum of Baseline water use and additional water made available to each sector under the scenario was divided by the Baseline water coefficient for the sector to arrive at the new maximum level of output for that agricultural sector under this scenario.

The final demand conditions associated with this scenario could not be ignored either. In Region Three final demand for agricultural sectors must be less than its Baseline level in the extreme quantification resolution scenario, since output in these sectors goes to zero in the extreme.[136] Correspondingly, as additional

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136 Final demand, it may be recalled, consists of private consumption demand, exports and government purchase. Clearly the reduction of output to zero would eliminate export and

[continued on next page]

agricultural output occurs in Regions One and Two final demand for those agricultural sectors must also increase.

In the Baseline solution it was required that all agricultural final demands (as specified by the growth description provided herein) be fully satisfied in the Baseline solution. In the Pueblo Agricultural Use scenario it was required that the scenario solutions be greater than or equal to the Baseline final demand for Region One and Two (Sectors 1 through 4).[137] For Region Three the scenario specified that final demand in the agricultural sectors be less than or equal to the Baseline final demands for those sectors. Final demand and output conditions for all other sectors in the model remain the same as in the Baseline solution.

As described briefly in Chapter I there are several different levels at which quantification of Pueblo water rights could occur under this scenario. The extreme resolution considered is one in which all non-Indian agricultural water use in 1975 is transferred to the Pueblos. <u>Any</u> quantification of these rights up to this maximum

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136 [continued from previous page]

government purchases components of final demand, but some or all private consumption demand can be anticipated to remain. This demand can be satisfied by imports if the sector's output is zero.

137 Sector 5 had to be excluded due to low water use coefficient (per million dollars output) which resulted in absurd scenario solution.

level is also possible under this resolution scenario. In the extreme all agricultural output in Regions One and Two are outputs from Pueblo lands. In the intermediate cases some portion of (up to 100 percent) Region One and Two agricultural output is from Pueblo lands. Thus the Pueblo Agricultural Use scenario was specified as follows.

a. Required agricultural output is increased (Sectors 1 through 4) in Regions One and Two, while at the same time agricultural output in Region Three is correspondingly decreased.

b. The available supply of surface water in Regions One and Two is increased, while a corresponding decrease in Region Three available surface water is implemented.

The summary sector outputs and water use under the extreme scenario are compared to the outputs and water use for these sectors under the Baseline solution in Figures 5.10 through 5.12 for the Upper Basin regions.

The results presented in Figure 5.10 through 5.12 possess several additional modeling parameters. First, it is assumed under this version of the Pueblo agricultural use scenario that no compensation is paid to the non-Indian farmers whose water rights are taken away. Additionally, it is assumed that the funds for construction of Indian agricultural works will be provided exogenously (e.g., by Congress without repayment obligation), and that these new irrigation works are in place and operating at normal capacity. Finally, these solutions assume that the average yield, general farm management practices, and water use patterns (i.e., production functions) will remain the same

FIGURE 5.10
COMPARISION OF BASELINE AND EXTREME PUEBLO AGRICULTURE SCENARIO OUTPUT AND WATER USE -- Region One

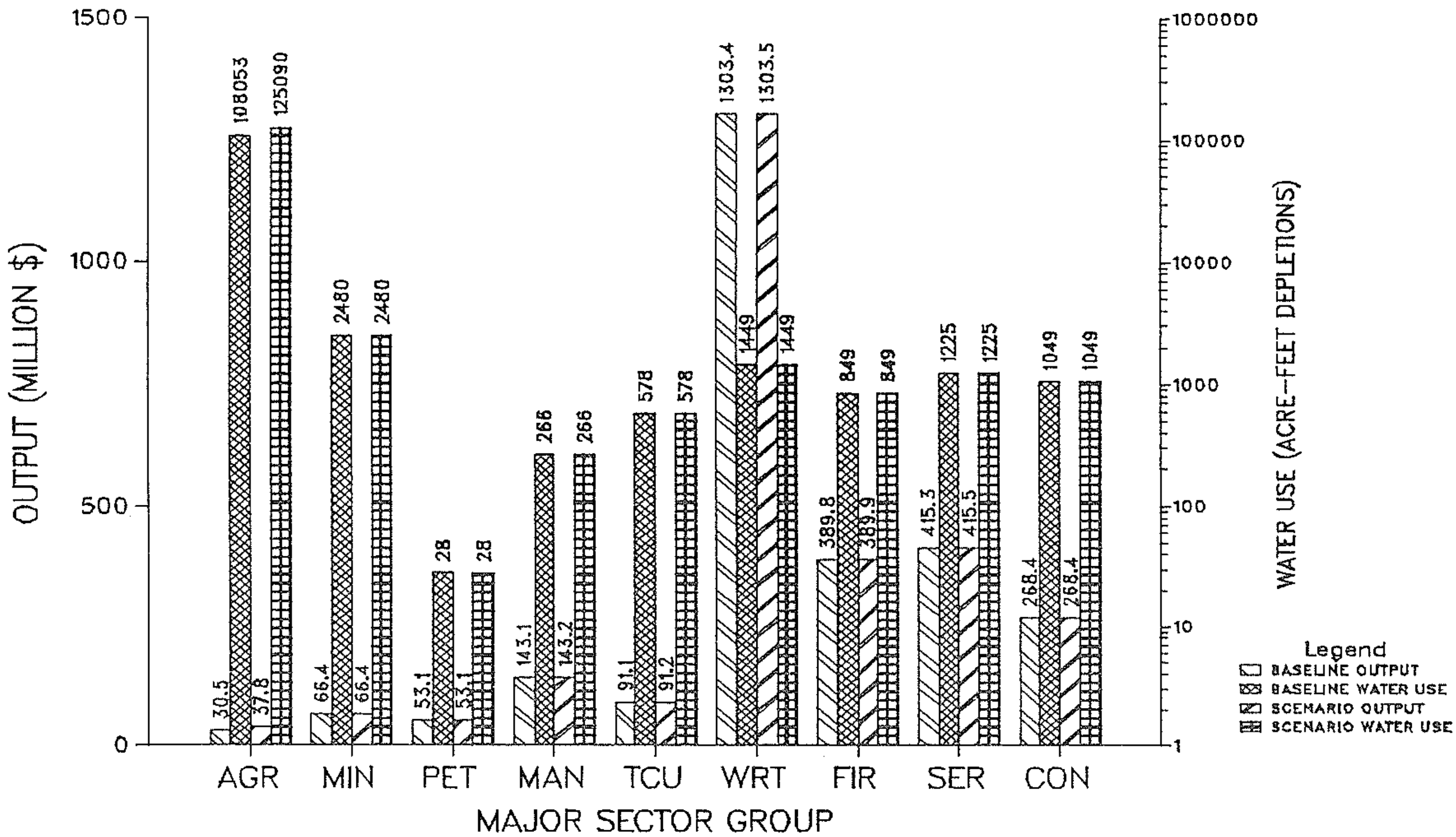


FIGURE 5.11
COMPARISION OF BASELINE AND EXTREME PUEBLO AGRICULTURE SCENARIO OUTPUT AND WATER USE —— Region Two

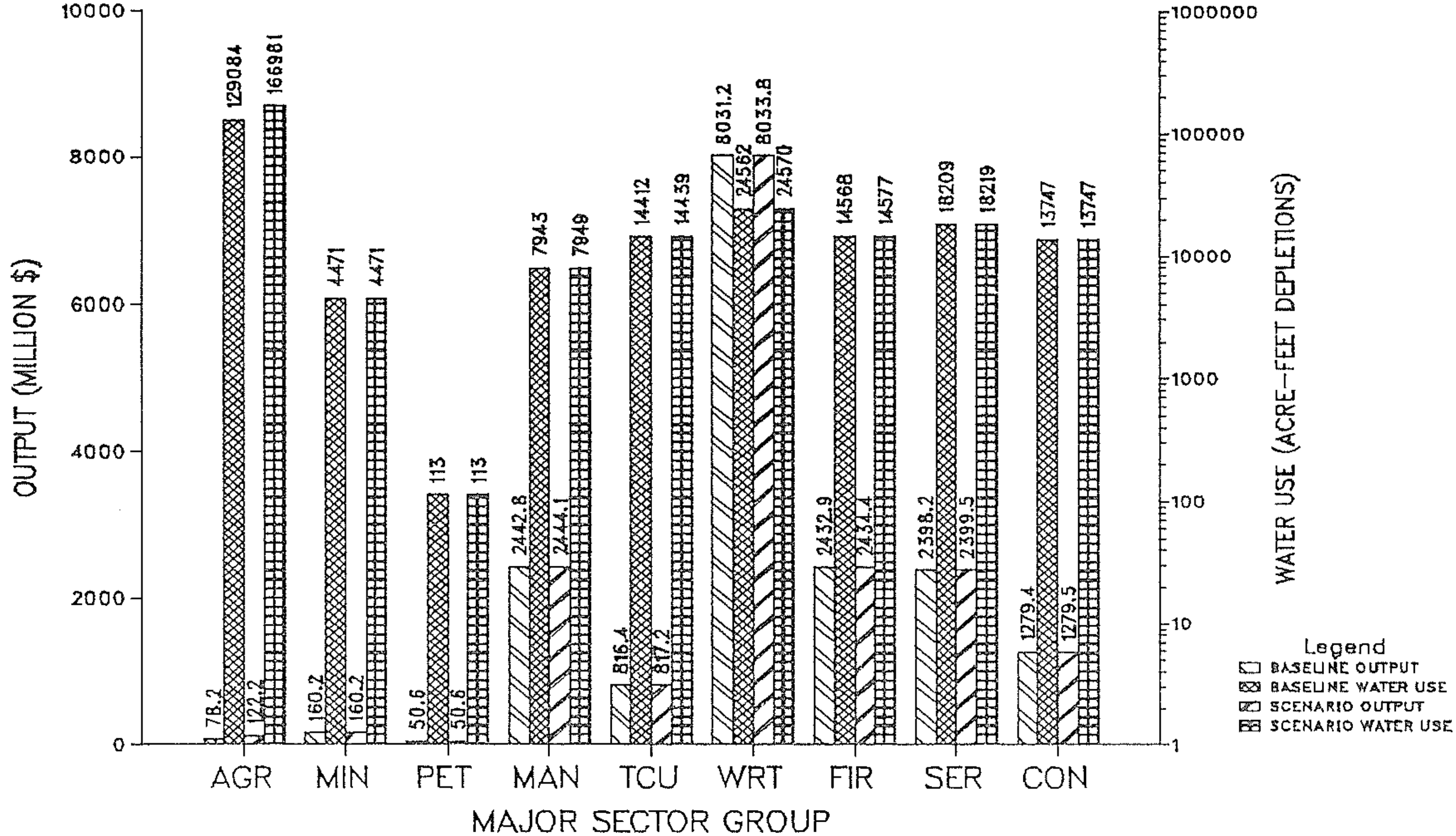
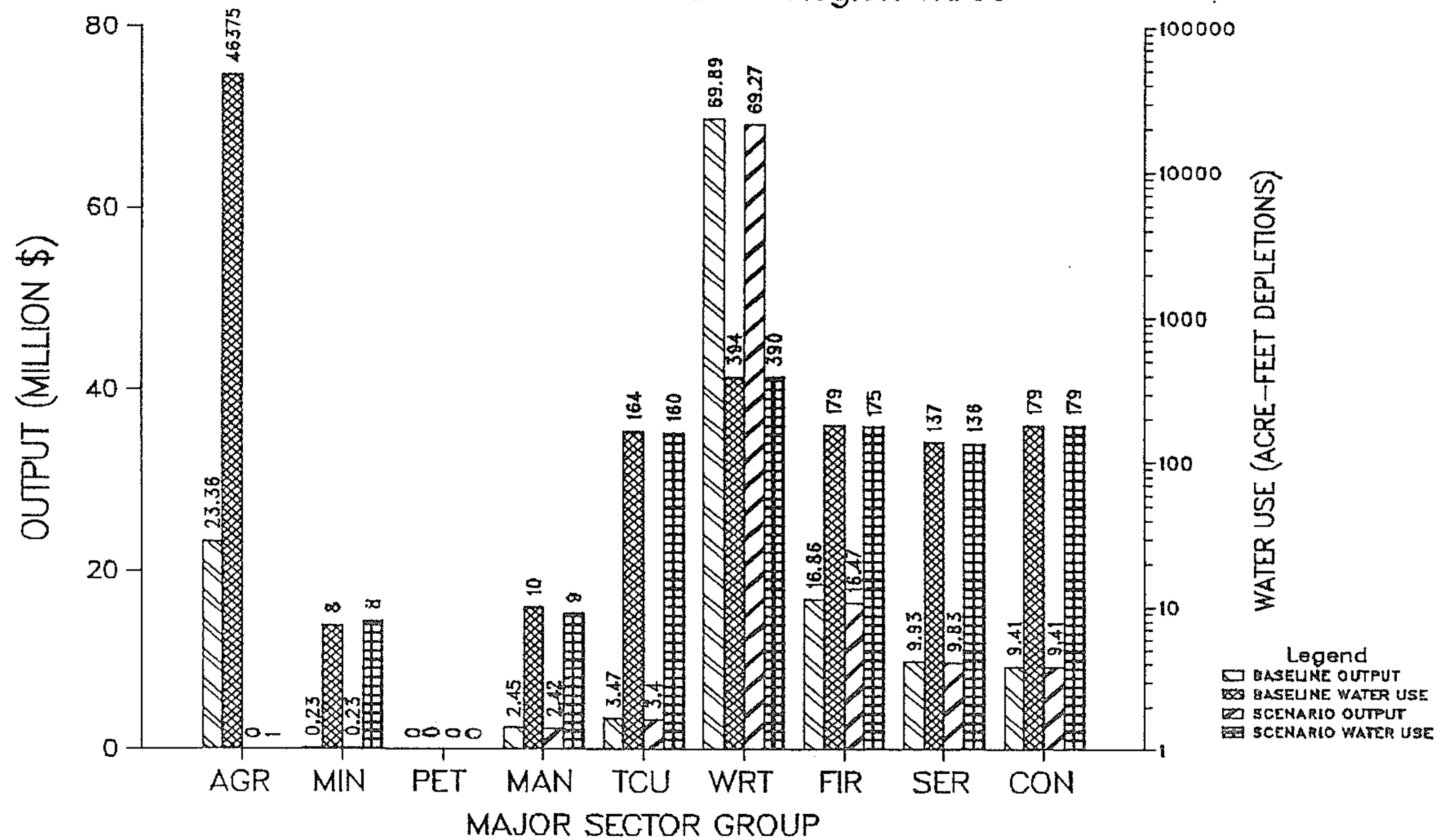


FIGURE 5.12
COMPARISION OF BASELINE AND EXTREME PUEBLO AGRICULTURE SCENARIO
OUTPUT AND WATER USE –– Region Three



on these new Indian agricultural lands as they were on the former agricultural lands located within the region where the specific Indian agricultural output occurs. It is admitted that these are to some extent imperfect assumptions; but at the same time, they are plausible and are asserted due to lack better information to base alternative assumptions upon.[138] Some of these specific conditions are altered in other runs of this Pueblo Agricultural Use scenario described subsequently.

Figures 5.10 through 5.12 reflect the specific changes which can be anticipated with maximum quantification of Pueblo agricultural water use in each region. The results under the extreme scenario are more easily interpreted as percent changes from the Baseline results,

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138 The issue of compensation to effected non-Indians is discussed in Chapter I herein. The issue of federal funding for Pueblo irrigation development is very uncertain at this time, making the assumption extremely tenuous if historic patterns of the federal role in these projects is undergoing significant change. There must be included discussion of a projects "economic feasibility," "practicably irrigable acreage," and "repayment obligation" for the actual federal funding of such projects (<u>see</u> Report of the Special Master, Elbert P. Tuttle (Supreme Court of the United States, October Term, 1981) in <u>Arizona v. California et al</u>., February 22, 1982; and H.S. Burness, et al., "The "New" Arizona v. California Practicably Irrigable Acreage and Economic Feasibility," <u>Natural Resources Journal</u> 22(3):517-523.
It should be noted that these assumptions are the most <u>optimistic</u> possible and reflect (most closely) the Pueblo's position in ongoing water rights litigation. The federal funding of such projects must be question, but lacking other evidence the federal funding of existing Indian irrigation projects (such as the Navajo Indian Irrigation Project) will be relied upon as the basis for our assumption.

as presented in Figures 5.13 through 5.15. It appears that the most affected nonagricultural sector in the Upper Basin under this extreme scenario is Transportation, Communications, and Utilities. However, no nonagricultural summary sector groups experience even a one-tenth of one percent increase in their output or water use levels over that described by the Baseline solution. Figure 5.15 reflects similar results for Region Two, where agricultural output increases by more than 56 percent and water use by more than 29 percent; but, again, none of the remaining sectors experience even a one-tenth of one percent change in either output or water use.

Figure 5.16 on the other hand describes significant changes in the economic and water use activities of Region Three from the original Baseline conditions as a result of the extreme Pueblo Agriculture water rights resolution scenario. Agricultural output drops from more than $23 million in the Baseline solution to zero, and the remaining sectors show declines in output and water use ranging from no change to a nearly six percent reduction in water use by Manufacturing in the Region. The remaining sectors show rather significant declines in both output and water use as compared to the level observed for these sectors in the Baseline solution, but there must also be recognition that the change in the Upper Basin as a whole is rather insignificant.

This relative change in the Upper Basin can be best seen in Figure 5.13 which shows the changes in output and water use for the Upper Basin as a percentage change from the Baseline levels of both

FIGURE 5.13
PERCENT CHANGE IN OUTPUT AND WATER USE FROM BASELINE
UNDER EXTREME PUEBLO AGRICULTURE SCENARIO
Upper Rio Grande Basin

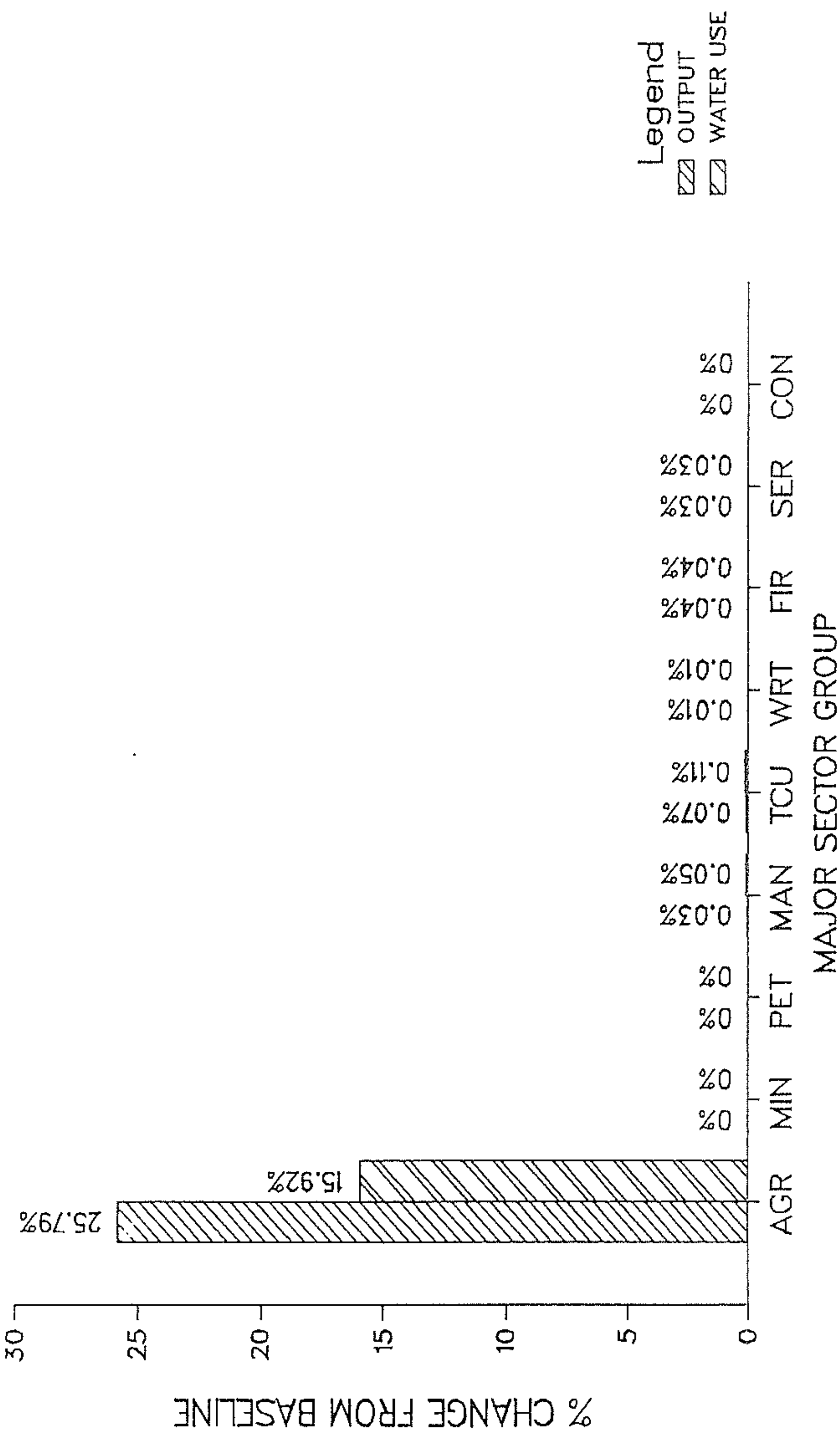


FIGURE 5.14
PERCENT CHANGE IN OUTPUT AND WATER USE FROM BASELINE
UNDER EXTREME PUEBLO AGRICULTURE SCENARIO
Region One

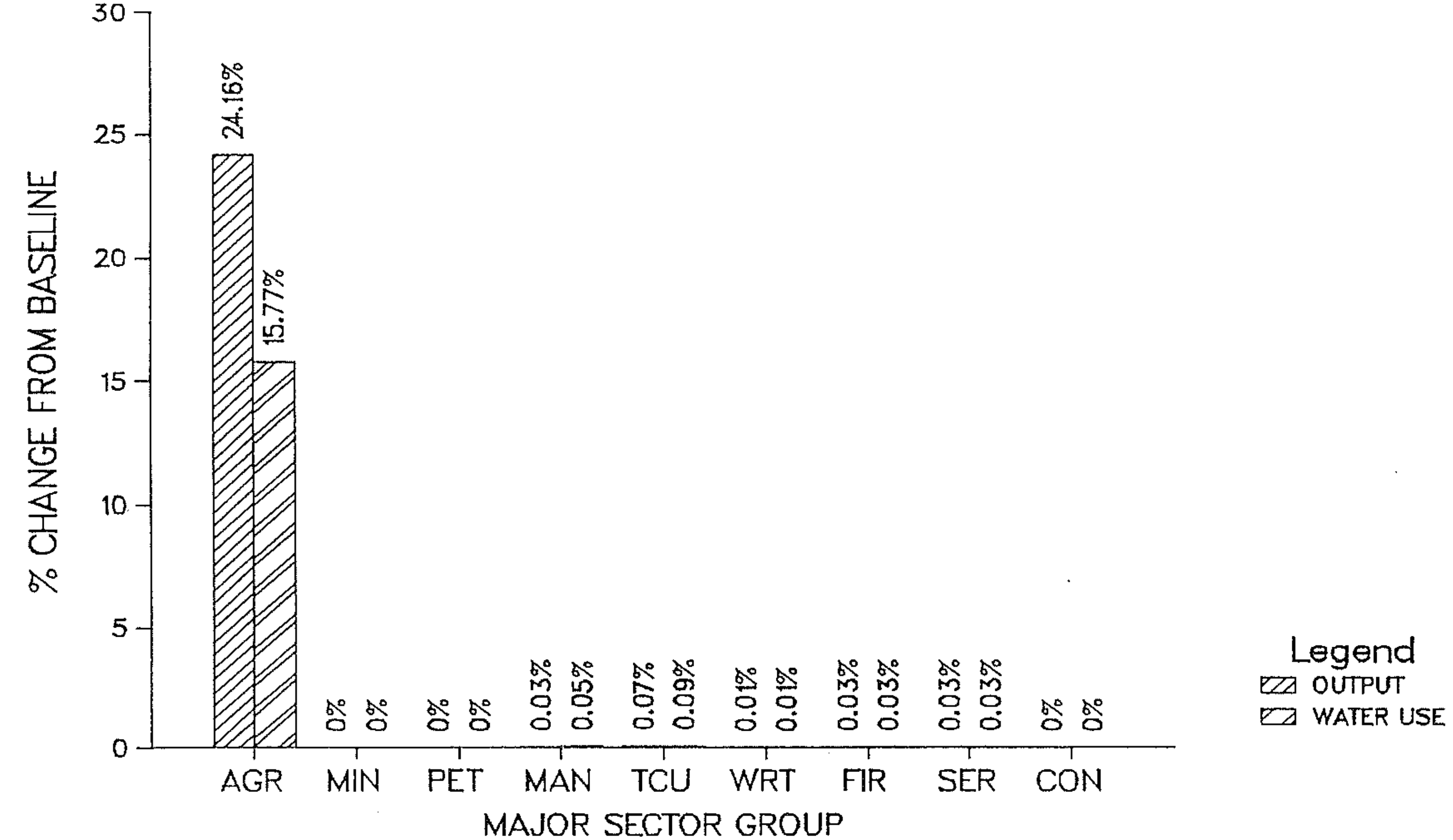


FIGURE 5.15
PERCENT CHANGE IN OUTPUT AND WATER USE FROM BASELINE
UNDER EXTREME PUEBLO AGRICULTURE SCENARIO
Region Two

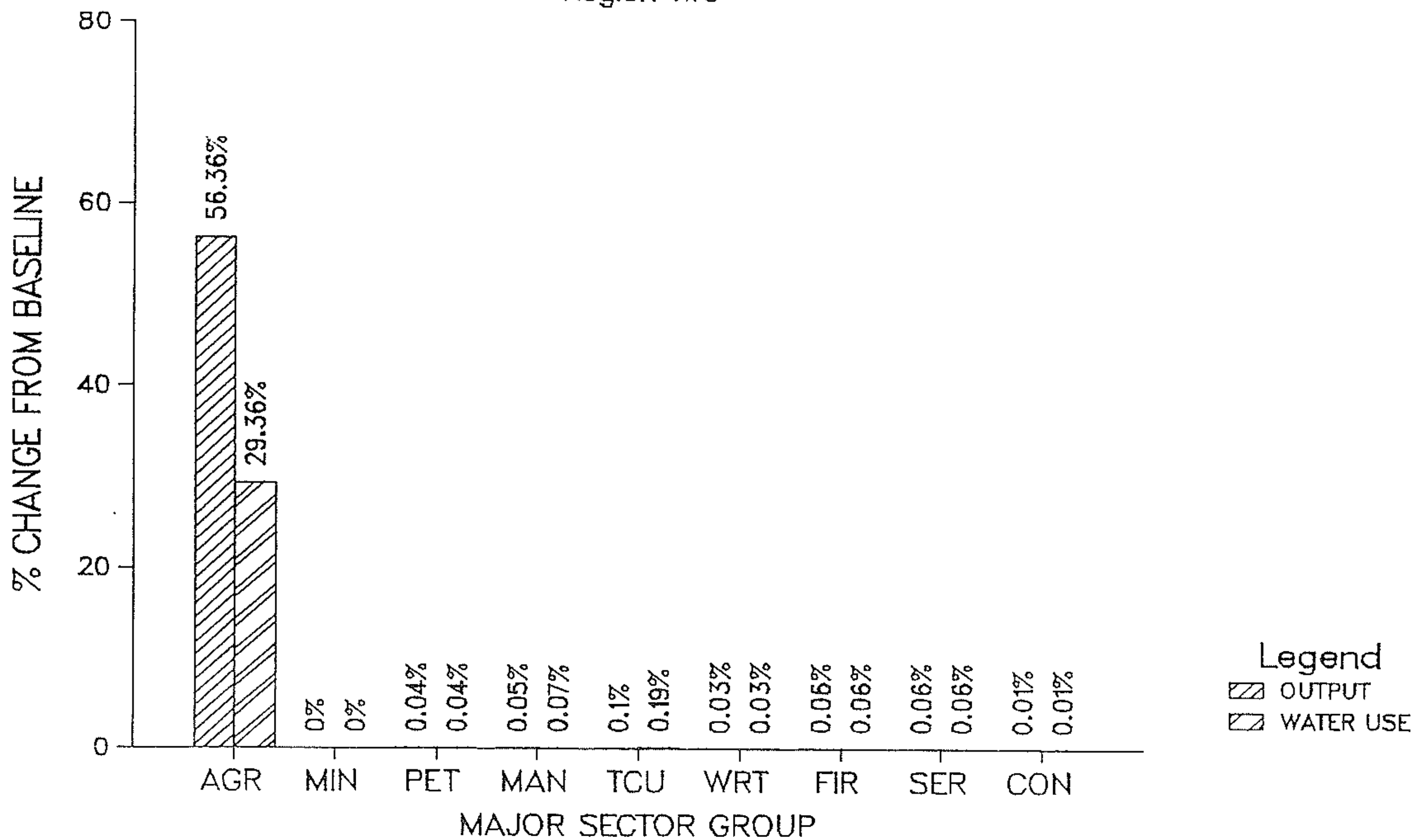
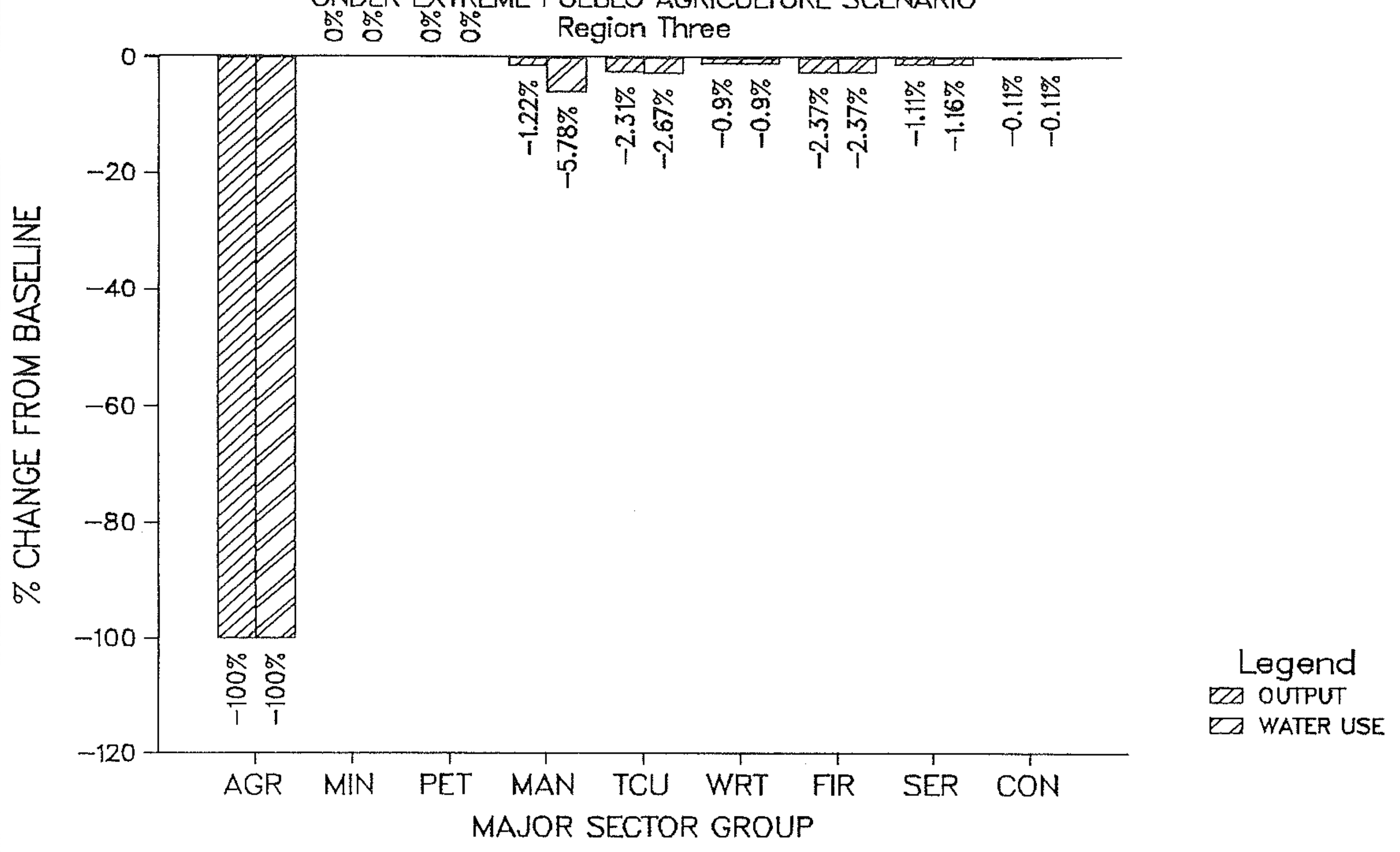


FIGURE 5.16
PERCENT CHANGE IN OUTPUT AND WATER USE FROM BASELINE
UNDER EXTREME PUEBLO AGRICULTURE SCENARIO
Region Three



variables. Clearly, the only change in economic activity levels associated with the extreme Pueblo agriculture use scenario significant to the Upper Basin as a whole is the more than 25 percent increase in agricultural output and the nearly 16 percent increase in agricultural water use. The only other sector in which either output or water use changes more than one-tenth of one percent (over its Baseline level) is Transportation, Communications and Utilities (where a rather insignificant 0.15 percent increase in water use can be observed).

Indeed, one is drawn to the conclusion that even under the most extreme Pueblo Agricultural Use resolution scenario, economic and water use conditions improve over their state in the Baseline solution. Several clarifications of this conclusion are appropriate. First, it must be recalled that under the Baseline solution the agricultural sectors were constrained to be less than or equal to 110 percent of their 1975 output levels.[139] Due to the allowed increase in Region One and Two agricultural output under the scenario, the model required specification which allowed final demand for agriculture to be greater than its Baseline level.[140] Thus the

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139 This constraint in recognition of historic trends, economic condition faced by agricultural enterprises, and general consensus regarding the present potential for development of private new agricultural enterprises in the Upper Rio Grande Basin.

140 It should be noted that under no circumstance described by the Pueblo agricultural use scenario did the agricultural final demand exceed its Baseline level, making specification of the model in this manner only a formality.

linear programming solution increased output in Region One and Two agriculture to the point where each region's water resources were exhausted and/or the sectors could no longer "afford" to transfer additional water into a region in support of the agricultural output water requirements.

This agricultural final demand specification can be interpreted in a more intuitive sense as well. Corresponding to the large scale change in water right ownership contemplated by this scenario, there can be anticipation that the least productive agriculture will be the first displaced by the Pueblo water right resolution. The net effect will be an increase in the average productivity of agricultural water use throughout the basin for those lands which are unaffected by the Pueblo water rights resolution (i.e., before achieving the maximum quantification resolution, or "extreme scenario"). The previously described assumption that the Pueblo's will produce the same cropping patterns as described in the Baseline solution remains, but is modified to the extent that "surplus" water within a region will be put to use in the most "economically productive" agricultural sector until the available water supply is exhausted.

The result is also intuitively sensible in that large scale displacement of existing agricultural enterprises (in favor of "new" agriculture) in the Upper Basin would demand full use of all existing water resources. The potential exists that, in total, the "new" uses and users will achieve a higher level of agricultural output than under the former patterns of agricultural water rights and use. Since the quantity of "surplus" water in the Upper Basin under the Baseline solution is small, there should be expected only a small increase in total agricultural water use even under the extreme Pueblo agriculture water right resolution scenario. Both of these intuitive results can be observed in the model's interpretation of the scenario.

A final observation regarding these specific results is the limited degree to which the other sectors of the Upper Basin economy are affected by the Pueblo agricultural use scenario. The results shown thus far do not reflect the "intermediate" solutions likely under this Pueblo agricultural use scenario, and describe only the case where no compensation is paid to the affected non Indian water right holders displaced by this resolution scenario.

Simple calculation of the magnitude of potential compensation suggests that the effect on the Upper Basin associated with either the specific dollar per acre compensation paid, or specific sectors effected by this compensation, is at best negligible. If it is assumed that of the 150,470 acres irrigated in 1975 in the Upper Basin 114,838 acres are non-Indian, and that the average compensation paid (in 1975 dollars) per acre is $500 for the appurtenant water rights (i.e., depletion rights), the total compensation paid will be less than $57.5 million. It is unreasonable to assume that any but the annual interest earnings (after tax) on this compensation will effect final demand in the Upper Basin in any single year.

Thus, if it is assumed that 10 percent of this one time compensation effects final demand in the Upper Basin in the year 2000 (a generous assumption), the total effect on Upper Basin final demand expressed in the model is less than $5.75 million. By contrast, under the Baseline solution total final demand for the Upper Basin is more than $17.5 billion, thereby, making the dollar compensation effect assumed under this scenario approximately three-hundreths of one percent (0.03%) of total Upper Basin final demand. Clearly, no significant change is anticipated as a result, but as a vehicle for looking at "intermediate" results under the Pueblo Agriculture scenario one run with compensation will be presented in contrast to a run without compensation over several "intermediate" levels of Pueblo water rights quantification.

In addition to consideration of the dollar level of compensation paid, there are several possible ways in which this compensation can be anticipated to effect final demand in the Upper Basin. The simplest of these would postulate that the final demands for all sectors in the region where compensation occurs will be augmented proportional to the sector's share of region's total final demand. It can be defensibly asserted that the agricultural, mining and petroleum sectors would not feel final demand change associated with the type of exogenous compensation discussed here,[141] and thus the effects of

141 That is, the majority of final demand in these sectors is composed of either export or government purchases demand.

compensation will effect only the final demand for Sectors 8 through 24. The second hypothesized compensation effect described allocation of the increased final demand to Sectors 8 through 24 in the region where the compensation occurs according to each sectors' share of the affected sectors' (8 through 24) summed final demand (for each region). Finally, it can be hypothesized that the "windfall" nature of the compensation and the elimination of existing (non-Indian) agricultural enterprise in the Upper Basin would result in allocation of these compensation effects to the final demands of Sectors 8 through 24 according to each sectors' share of the summed final demands (for Sectors 8 through 24) for all three Upper Basin regions. For example, if the final demand of Sector 15 in Region One is 5 percent of the total final demand for Sectors 8 through 24 in all three Upper Basin regions, then the final demand of that sector will be increased by 5 percent of the total compensation effect in the Upper Basin (i.e., 5 percent of $5.75 million implies an increase in final demand of $287,500 for the sector).

Since it is clear that the effects of this compensation (regardless of its specification) are rather nominal, I will only present the results of the modeling associated with the last of these alternative compensation schemes. Figures 5.17 through 5.20 compares several of the intermediate and the extreme solutions under the Pueblo agricultural use scenario for runs with the effects of compensation included.

FIGURE 5.17
AGRICULTURAL OUTPUT AND WATER USE
BASELINE AND SELECTED PUEBLO INDIAN AGRICULTURAL USE SCENARIOS
Region One

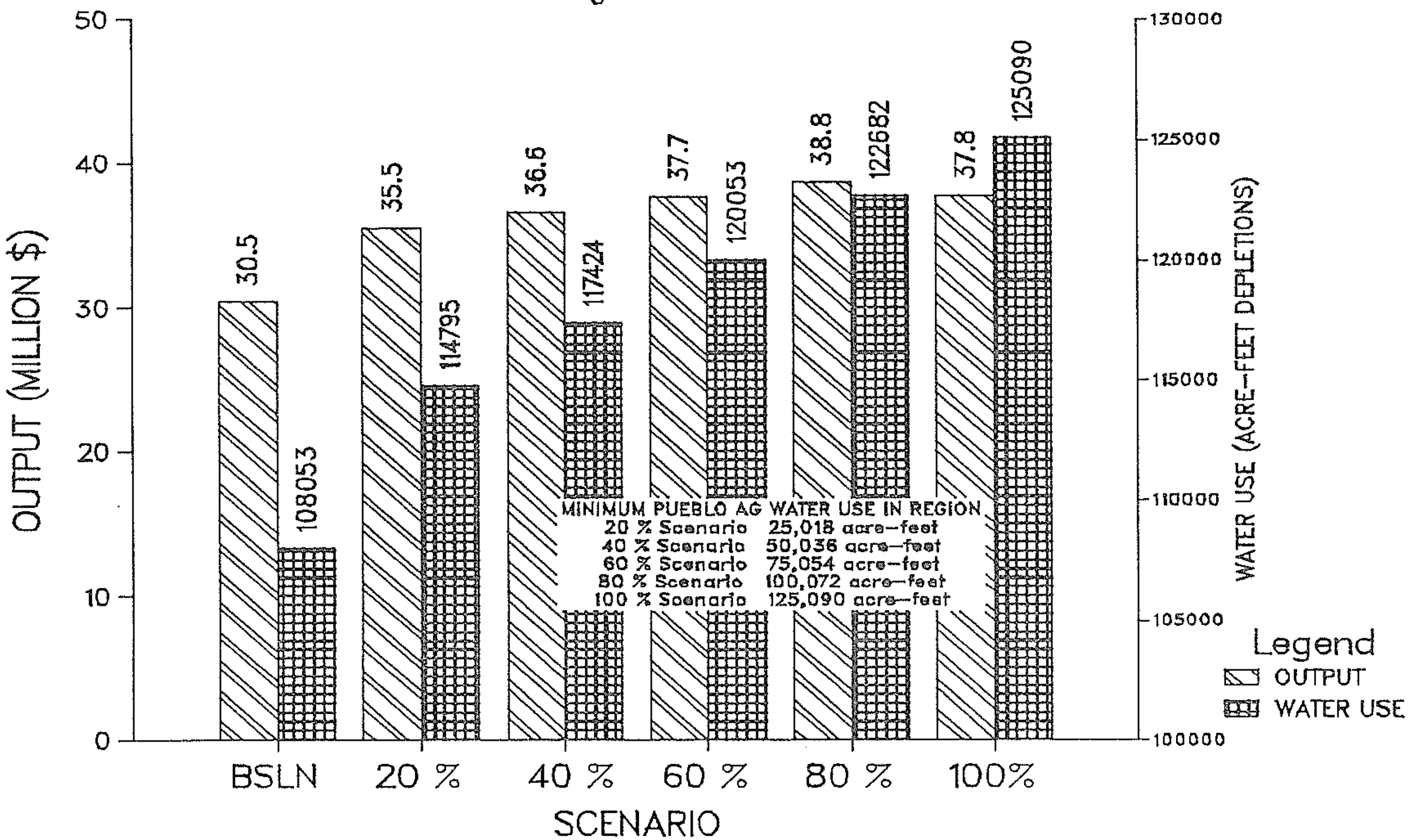


FIGURE 5.18
AGRICULTURAL OUTPUT AND WATER USE
BASELINE AND SELECTED PUEBLO INDIAN AGRICULTURAL USE SCENARIOS
Region Two

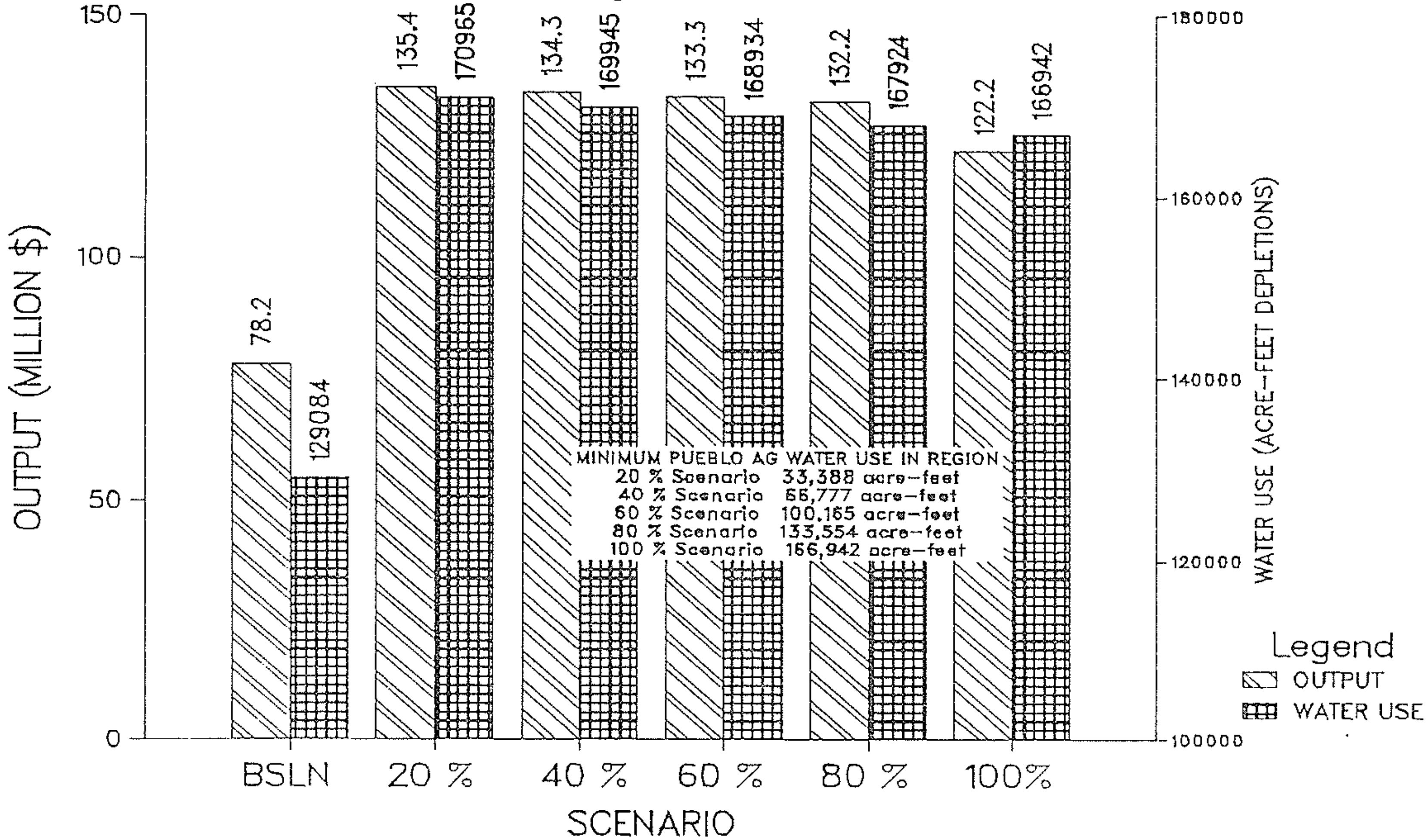


FIGURE 5.19
AGRICULTURAL OUTPUT AND WATER USE
BASELINE AND SELECTED PUEBLO INDIAN AGRICULTURAL USE SCENARIOS
Region Three

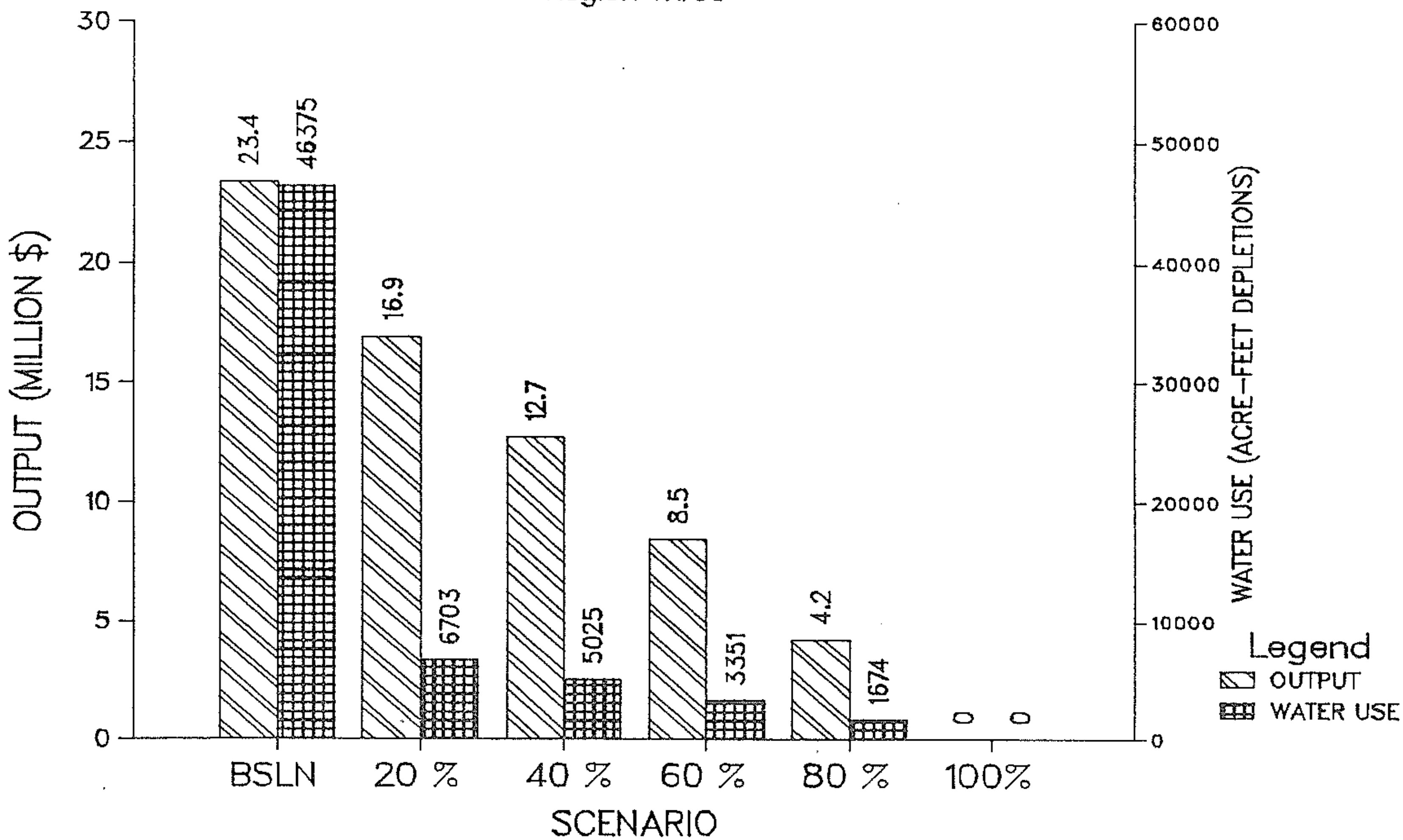
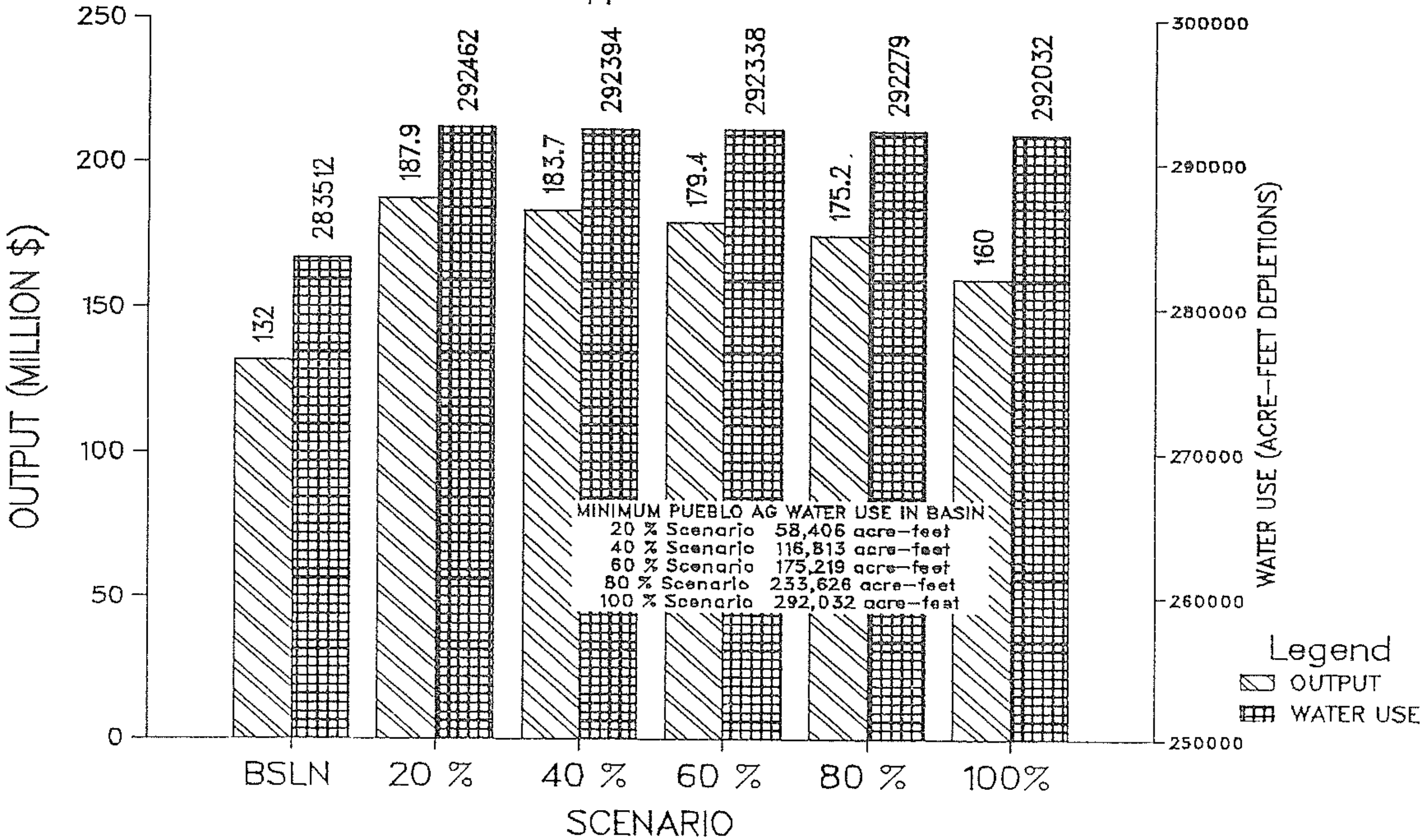


FIGURE 5.20
AGRICULTURAL OUTPUT AND WATER USE
BASELINE AND SELECTED PUEBLO INDIAN AGRICULTURAL USE SCENARIOS
Upper Basin



The significant results shown by the agricultural output and water use levels in Figure 5.17 through 5.20 does not involve the compensation/no compensation question. The interesting results deal with the effects of increasing required Pueblo agriculture in Regions One and Two over the "intermediate ranges" of the scenario described. It is most readily apparent that agricultural output and water use decline in Region Two even as the supply of water to that region increases.

This result occurs because the model requires that the Pueblos produce a crop mix which is the same as the 1975 mix of crops in both Regions One and Two. As the quantity of Pueblo agricultural rights increases to the extreme, the model has less "surplus" water to allocate to the most productive agricultural sectors. In the extreme case the crop mix is the same as in 1975, and all agricultural output is from Pueblo lands. A minimum quantity of Pueblo agricultural output can be defined in each of the intermediate cases, although it would be possible that Pueblo agricultural output could exceed these minimum levels. The point is simply that it is immaterial who produces a specific output; but rather, the significance of the results relates to the general economic effects on the Upper Basin observed in this resolution scenario.

One would be remiss to conclude that there is unambiguous improvements in social welfare in the Upper Basin as a result of this resolution scenario without also noting the cultural upheaval associated with the more extreme Pueblo Agricultural Use scenario results. It bares repeating that the extreme scenario contemplates the displacement of <u>all</u> non-Indian agricultural water right holders from their historic occupations. There is no reason to elaborate on the social stress associated with this displacement.

The conclusions regarding improved use of resources and changes in output under this scenario describe <u>economic</u> conditions only. However, with this final admonition, it can be clearly stated that there is no detriment, and possible improvement, in the Upper Basin economy as a result of even the extreme Pueblo Indian Agricultural Use water rights resolution scenario as described by this model. This extreme scenario contemplates the elimination of all non-Indian agricultural water rights which were in existence in 1975. This conclusion is unchanged by whether or not the displace non-Indian are compensated for the taking of their water rights.

It is now appropriate to turn to an alternative form which the resolution of Pueblo water rights in the Upper Rio Grande Basin might adopt under the legal theories described previously in Chapter I.

E. <u>Pueblo Leasing Scenario</u>

Under the legal assumptions described previously it is possible to assert that the Pueblos will be granted a specific water right quantity, and then be allowed to lease that water to users throughout the Upper Basin. As was the case with the previous scenario, the maximum quantity of water rights (depletion rights) which would be assigned under this leasing scenario will be assumed to be the 1975 surface water depletion by non-Indian irrigated agriculture in the Upper Rio Grande Basin.

The general outcome under this scenario is clear without any investigation of specific model runs. Depending on the price which is charged by the Pueblos there will be variable reduction in the agricultural use of water. However, the potential exists that at a sufficiently high price there will be eliminated all non-Indian agricultural output in the Upper Basin.

Clearly such an extreme result (i.e., elimination of all agriculture) does not benefit the Pueblos since their wish would more likely be to maximize the revenue generated by their leasing activity.[142] The leasing scenario solutions are based on the growth and efficiency change conditions previously described in the Baseline solution. The supply of Pueblo water available for lease is in direct competition with the surplus Albuquerque San Juan-Chama water, although the Pueblo water must be considered to be preferred to the Albuquerque surplus because it would be a perpetual water right.[143] The model solution

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142 There may be other economic (or social) criteria chosen by the Pueblos if such a pricing decision were actually made. The point is simply that they would most likely not choose to minimize total water purchased in such a decision.

143 The water rights granted to the Pueblos under this scenario are perpetual water rights, akin to private water rights under New Mexico water law. The City's rights are of a lesser quality simply because the users of these rights will be unable to

[continued on next page]

will attempt to produce output equal to the Baseline solution, but may in specific sectors be unable to "afford" to purchase water necessary for this level of production. It should be noted that under this scenario the total quantity of water available in each region is the same as under the extreme Pueblo Agricultural Use scenario, but a substantial portion of this water must be purchased under the Pueblo Leasing scenario when it had previously been available without explicit cost. It is appropriate to investigate each of these leasing scenario solution conditions more thoroughly.

Regardless of the specific price assigned the Pueblo water rights in this lease scenario the model must make the following production decisions: to meet the output demand faced by a model sector, is it less expensive to purchase the required inputs (e.g., water) to produce the output, or import the output demanded? It may be recalled that the "price" of imports in a sector is the opportunity cost of the forgone production, and it must be clearly understood that the price of water in this model does not describe a market price. Prior to this time it has been possible to disregard the specific value of priced inputs in the model, but with this scenario these prices must

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143 [continued from previous page]

depend on the water's future availability due to the City's required use of these rights at such future time. Thus it can generally be concluded that there would be preference by the lease users for the Pueblo rights upon which long term supply dependency can be based.

be presented explicitly with the results, and thus there must be extreme care in interpreting the results obtained. Again, the pricing of water reflects the social cost of such a transaction, not the observed market price of such a commodity. Note should also be taken that the price of surface to groundwater transfers and interregional transfers remains the same as in the previous solutions.[144]

Table 5.10 describes the specific data used for the calculation of the maximum leasing scenario. The 1975 data defines the acreage (with appurtenant water rights) which is subject to reallocation under the Pueblo Leasing scenario. The calculations provided in this table of effected (non-Indian) irrigated lands -- and the associated water rights which are "reallocated" under the Pueblo Indian water rights scenario -- are estimated based on the best data available regarding irrigable Pueblo acreage.[145]

Although all economic sectors are likely to be in some way affected by the Pueblo leasing scenario, it is again assumed that only the acres irrigated in 1975 will be directly effected by the specific water rights quantification resolution. The non-Indian water

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144 That is, surface to groundwater transfers occur at $60 per acre-foot. Surface water transfers from Region One to Region Two occur at $1,000 per acre-foot, transfers from Region Two to Region One and from Region Two to Region Three occur at $100 per acre-foot, and transfers from Region Three to Region Two occur at $10 per acre-foot transferred.

145 Pueblo irrigable lands data derived from State Engineer's office and U.S. Geological Survey Joint Study, <u>supra</u>, note 20.

TABLE 5.10

QUANTIFICATION OF ASSUMED MAXIMUM LEASABLE WATER
UNDER PUEBLO INDIAN WATER RIGHT LEASING SCENARIO

	Region One	Region Two	Region Three	
1975				
Acres Irrigated with Surface Water	79,380	53,700	17,390	acres
Assumed Irrigable Pueblo Acres	16,782	18,850	0	acres
Percent Irrigable Pueblo Acres of Region's 1975 Irrigated Acres	21.14 %	35.10 %	0 %	
Region's Irrigable Pueblo Lands as a Percent of Total Irrigable Pueblo Land	47.10 %	52.90 %	na	
2000				
Baseline Solution Surface Water Use in Agriculture	103,461	125,865	27,892	acre-feet
Assumed Percent Non-Indian Agricultural Land Within Region*	78.86 %	64.90 %	100 %	
Assumed Maximum Possible Non-Indian Water Rights Assigned to the Pueblo Indians	81,589	81,686	27,892	acre-feet
Maximum Leasable Pueblo Indian Water Rights in each Model Region**	90,040	101,127	na	acre-feet

* That is, 100 percent minus the percentage of irrigable Pueblo Indian acres of the region's 1975 surface water irrigated acres.

** That is, assumed maximum possible non-Indian water rights assigned to the pueblo Indians times region's irrigable Pueblo Indian lands as a percent of total Irrigable Pueblo land.

allocated to the Pueblos in each of the Upper Basin regions was subtracted from the Baseline available surface supplies for each region, and then made available for lease by the Pueblos in Regions One and Two (i.e., 90,040 acre-feet in Region One and 101,127 acre-feet in Region Two under the maximum quantification scenario).

The market pricing of the water by the Pueblo's would likely be based on some economic maximization principal, but unfortunately the model is unable to describe the revenue (i.e., market price times quantity leased) generated by the leasing of water which accrues to each Pueblo. What is described accurately by the pricing of water in this model is the maximum willingness of society to pay for the use of surface water in the Upper Rio Grande Basin. That is, as an input to the production process society will be willing to purchase a specific quantity of water at a price related to the benefits derived by the resource's use. Agriculture may be willing to purchase water at $5 per acre-foot, but at $500 per acre-foot it may be more feasible to import that agricultural (i.e., cost society less) than to produce that same commodity in the Upper Basin when the water must be purchased. At some specific price the product of the quantity of water purchased and its social cost will describe society's maximum total willingness to pay for the surface water resource. It will be interesting to note whether, under different quantification scenarios, the water price at which this maximum total willingness to pay occurs remains constant.

Finally, before presentation of the results obtained under this leasing scenario it should be noted that no compensation is paid to the non-Indian farmers losing their water rights under this scenario. There is legal justification for this specification of the leasing scenario,[146] but there is also practical considerations which lead to this scenario form. It seems unlikely that the Federal Courts would assign an aboriginal water right to the Pueblo's which would allow the lease of the water off-reservation, and then also provide compensation to the affected parties so they might lease the water to which they just lost title. The net effect would be to, on paper, change title to the water rights, while allowing the former users continued use of these rights with a federal subsidy. The combination of leasing and compensation thus appears highly unlikely and therefore receives no further consideration herein.

Table 5.11 summarizes the leasable water available under the two levels of Pueblo Indian water right quantification modeled. The 100 percent scenario describes the quantification such that all non-Indian agricultural surface water rights are assigned to the Pueblos; while the 50 percent scenario describes the judicial resolution where half

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146 See DuMars, et al., supra, Note 22 at 97 to 103; in brief, the argument relies on the reservation of a property right under Winters (supra note) which is severable from the land (see United States v. New Mexico, 438 U.S. 696 (1978) (see also Charles T. DuMars and Helen Ingram, "Congressional Quantification of Indian Reserved Water Rights: A Definitive Solution or a Mirage?" Natural Resources Journal, 20(1)(1980).

the non-Indian agricultural surface water rights are reassigned to the Upper Basin Pueblos. Clearly, <u>any</u> other specific quantification scenario could be postulated (between the zero and the 100 percent resolution), but for analytical simplicity and expository clarity these other possible quantification scenarios were ignored in the results presented here. It should also be noted that even the extreme resolution describes a leasable quantity of water less than the total Baseline Upper Basin agricultural use of water due to the assumed levels of Pueblo Indian irrigation. Thus, even under this extreme scenario there will be <u>no</u> price sufficiently high to eliminate <u>all</u> Upper Basin irrigated agriculture.

TABLE 5.11

TOTAL QUANTITY OF WATER AVAILABLE FOR LEASING SCENARIOS

(acre-feet)

Region 1	50% Scenario	100% Scenario
Pueblos	45,020	90,040
Region 2		
Pueblos	50,563	101,127
Albuquerque*	16,345	16,345
Region Total	66,908	117,472
Upper Basin Total	111,928	207,512

* Estimated surplus City of Albuquerque San Juan-Chama water entitlement.

This is not to say that Upper Basin agriculture is not significantly affected by the specific lease price of water. Figures 5.21 though 5.24 show significant changes in the total output of irrigated agriculture as the lease price of water increases from $0 to $100 per acre-foot. The level of scenario quantification (i.e. 50 or 100 percent) changes the solution as well. The reason for the differences between the 50 percent and 100 percent scenario can be best explained by example. Under the 100 percent scenario there is eliminated all surface water rights in Region Three associated with irrigated agriculture, with the rights formerly found in this region having been transferred into Regions One and Two by the Pueblo water rights

FIGURE 5.21
AGRICULTURAL OUTPUT AND WATER USE
UNDER PUEBLO INDIAN LEASING SCENARIOS AT SELECTED PRICES
Region One

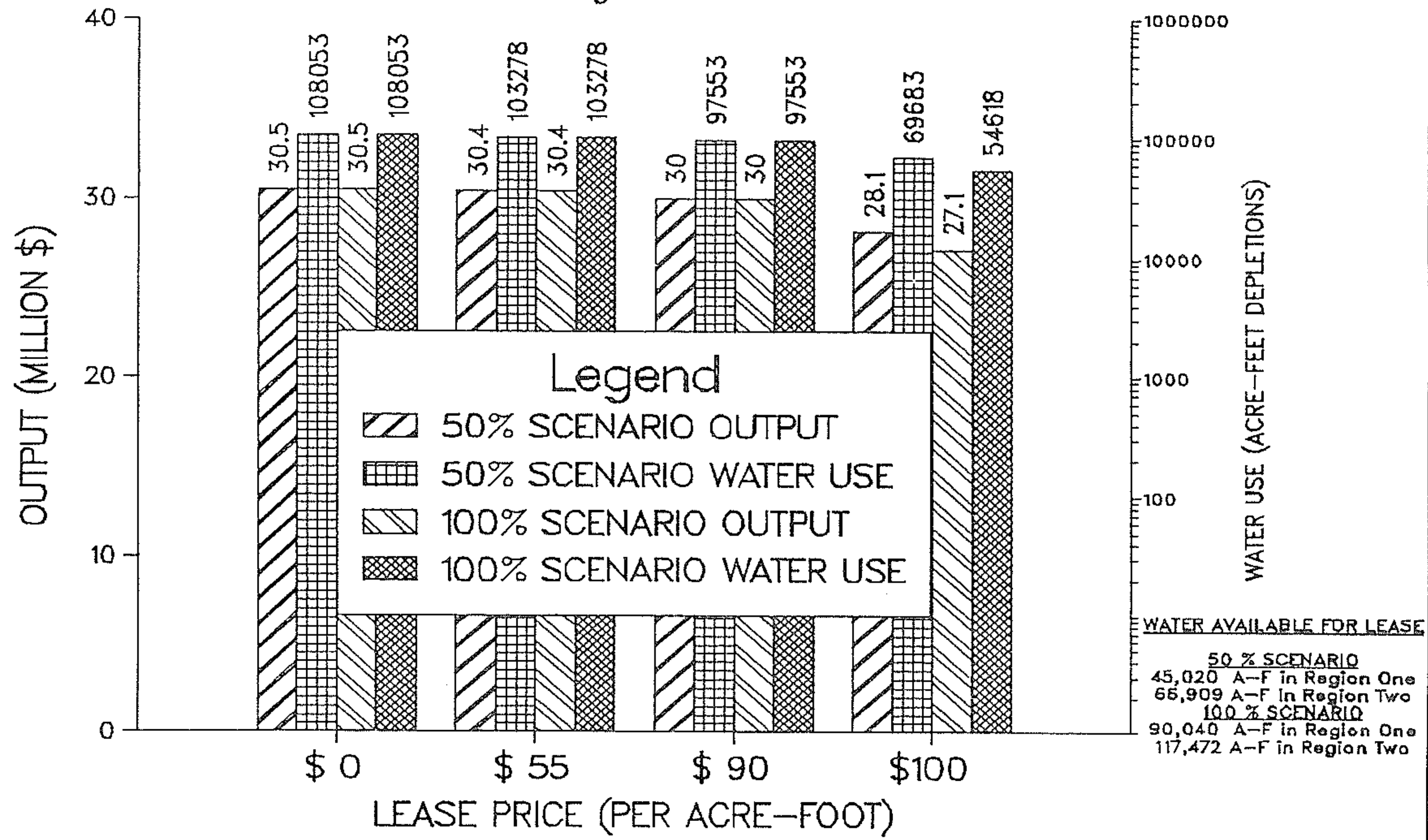


FIGURE 5.22
AGRICULTURAL OUTPUT AND WATER USE
UNDER PUEBLO INDIAN LEASING SCENARIOS AT SELECTED PRICES
Region Two

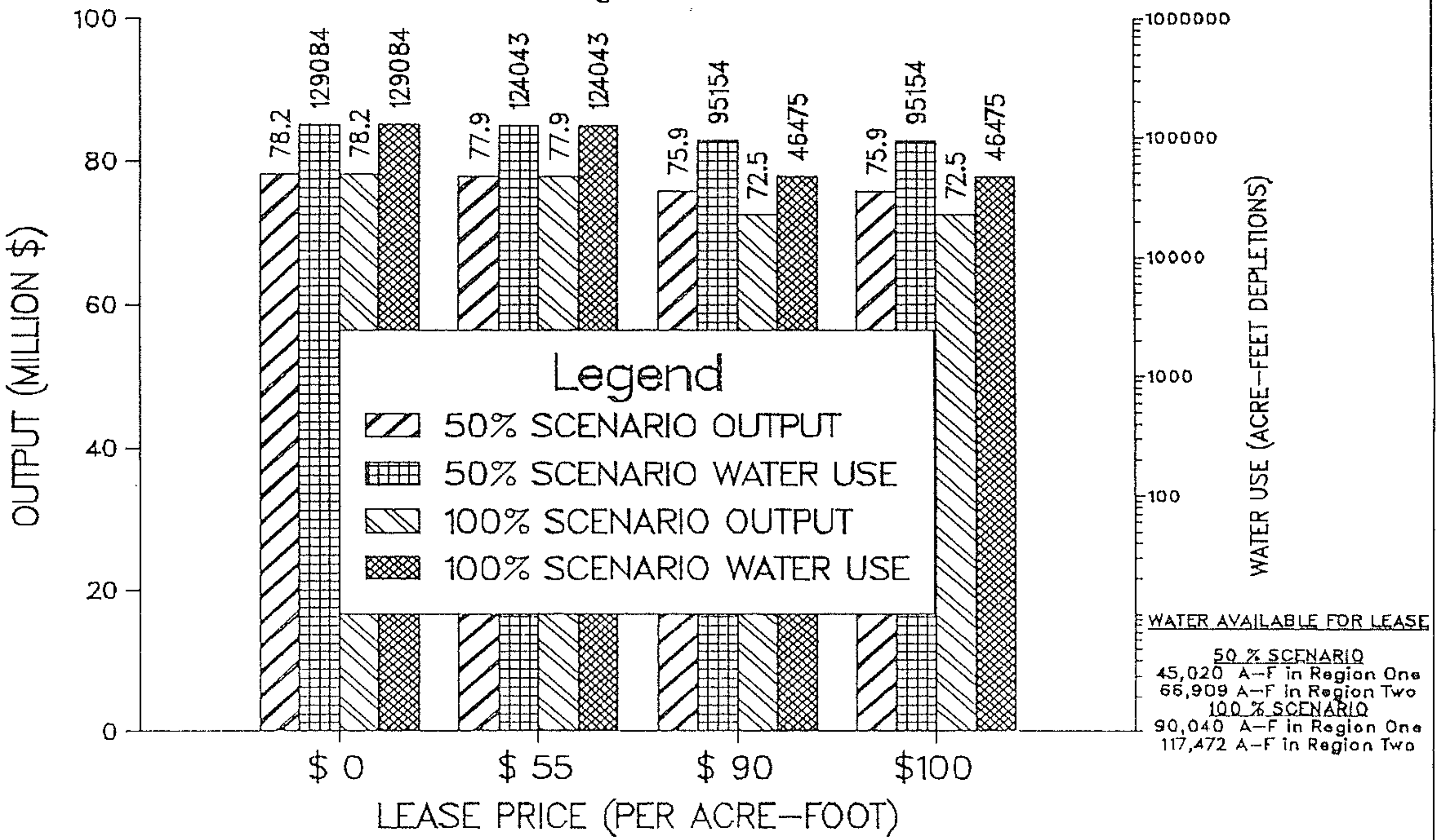


FIGURE 5.23
AGRICULTURAL OUTPUT AND WATER USE
UNDER PUEBLO INDIAN LEASING SCENARIOS AT SELECTED PRICES
Region Three

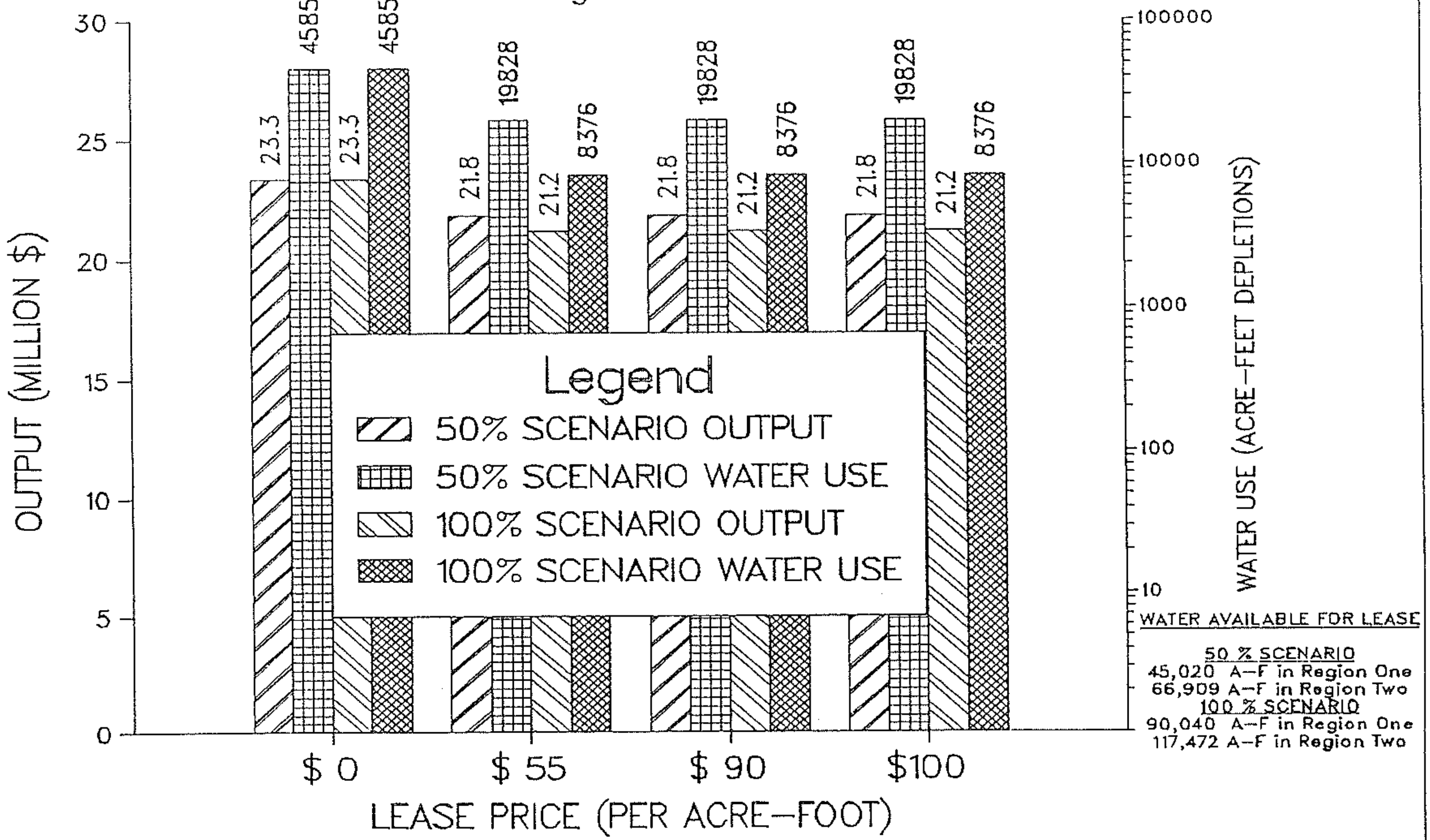
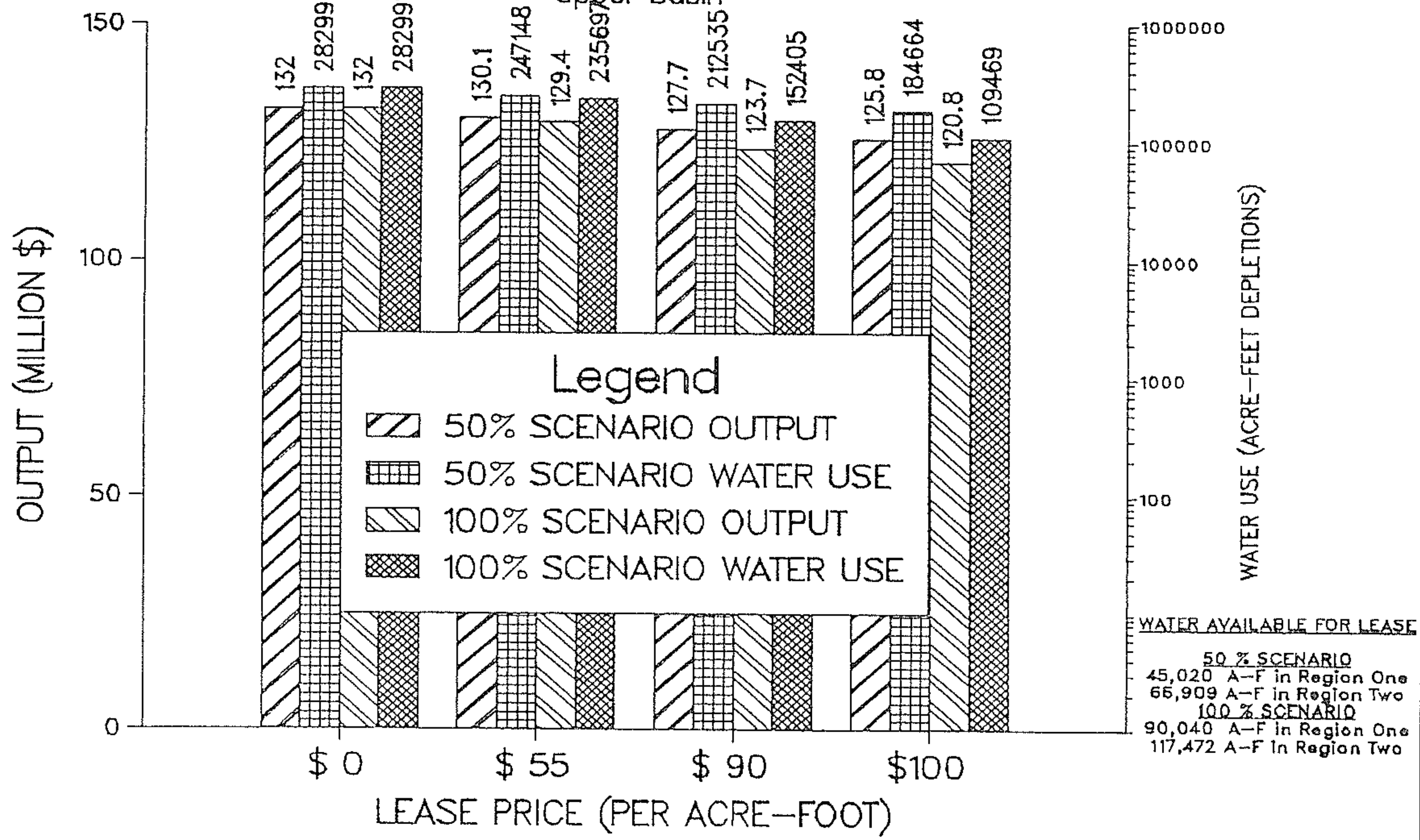


FIGURE 5.24
AGRICULTURAL OUTPUT AND WATER USE
UNDER PUEBLO INDIAN LEASING SCENARIOS AT SELECTED PRICES
Upper Basin



resolution. In the 50 percent scenario half of the surface water agricultural rights remain in Region Three, with the implicit assumption by the model's solution that this remaining water will be utilized in its highest valued agricultural use.[147] It is possible that agricultural output demand in Region Three can be met by transferring water from Region Two (at a price of $10 per acre-foot) under either of the scenarios shown.

As the price of water increases there is elimination of the least efficient water using sector(s) first. This results in rather dramatic changes in the quantity of water used in each region at specific price levels. These significant changes in water use are shown in Figures 5.21 through 5.24 demonstrating the substantial effects of reducing output in the least efficient water using sector(s).

Presenting these results in a more meaningful perspective, the extreme scenario over the $0 to $100 price range describes a nearly 8.5 percent decline in agricultural output, but only a 0.06 percent decline in total output of the Upper Basin. In contrast, over this same range of water prices the Upper Basin agricultural water use declines by more than 60 percent, while total water use in the Upper Basin declines by nearly 45 percent.

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147 That is, the marginal farmers will be the first to leave the profession, with the non-marginal farming enterprises having greater incentive to remain even in light of absolute water scarcity conditions.

The other sectors of the model are to some degree affected by the decline in the agricultural sector associated with increasing water prices, but throughout the range of surface water prices considered here there is no nonagricultural sector whose output declines by as much as three-quarters of a million dollars. Even more to the point, these nonagricultural output changes result in the declines in water use which are less than 10 acre-feet in all cases.

Thus, the basic conclusion is clear regarding this scenario for possible resolution of Pueblo Indian water right claims--if the leasing of Pueblo water right entitlements is allowed, the Pueblos will be able to chose a price which may preclude production of low valued high water using agricultural output without substantially affecting the remainder of the Upper Basin's economy. Indeed, a price could be established which created large surpluses of surface water, water which could be channeled into alternative enterprises capable of producing returns sufficiently high so as to justify purchase of the water input.

An IOLP model is unable to forecast specific structural changes, but it is worthy of note that water availability (i.e., leasable Pueblo rights) could significantly influence a new firm's decision to locate in the Upper Rio Grande Basin. A leasable Pueblo right could thus improve the overall efficiency of water use in the Upper Basin, and at the same time make readily available water for alternative economic development if a sufficiently high price is charged for that water resource.

Of interest to the potential lessor parties are the specific quantity of water sold at the various prices modeled. Figures 5.25 and 5.26 depict the total quantity of water sold at each price, and graphs the total willingness to pay (i.e., total social cost) for the water purchased. The peak in this total willingness to pay schedule at $85 per acre-foot suggests this to be the maximum "price" which can be charged without significantly constraining the use of water in the Upper Basin via the price mechanism. This "welfare price" does not represent the market price charged, but does describe (at the margin) the maximum benefits to society per acre-foot which can be derived from the use of water resources in the Upper basin. It is interesting to note that the changes in quantity of water purchased occur at the same price levels in both the 50 percent scenario and the 100 percent scenario. It is also interesting that even at a zero price there is surplus water in both Regions One and Two, a result which is related to the surplus observed in the Baseline solution to the model.

F. Upper Basin Water Scarcity--An Economic Question

It has been shown in the preceding that the availability of water in the Upper Basin could have significant impact on the specific levels of economic output in several sectors. The question then arises regarding which of the postulated Pueblo water rights resolution scenarios creates the greatest scarcity conditions, and how does the IOLP modeling of the Upper Basin respond to these specific scarcity conditions.

FIGURE 5.25
TOTAL QUANTITY OF WATER SOLD AND TOTAL SOCIAL COST
AT DIFFERENT LEASE PRICES UNDER PUEBLO LEASING SCENARIO
50 PERCENT SCENARIO

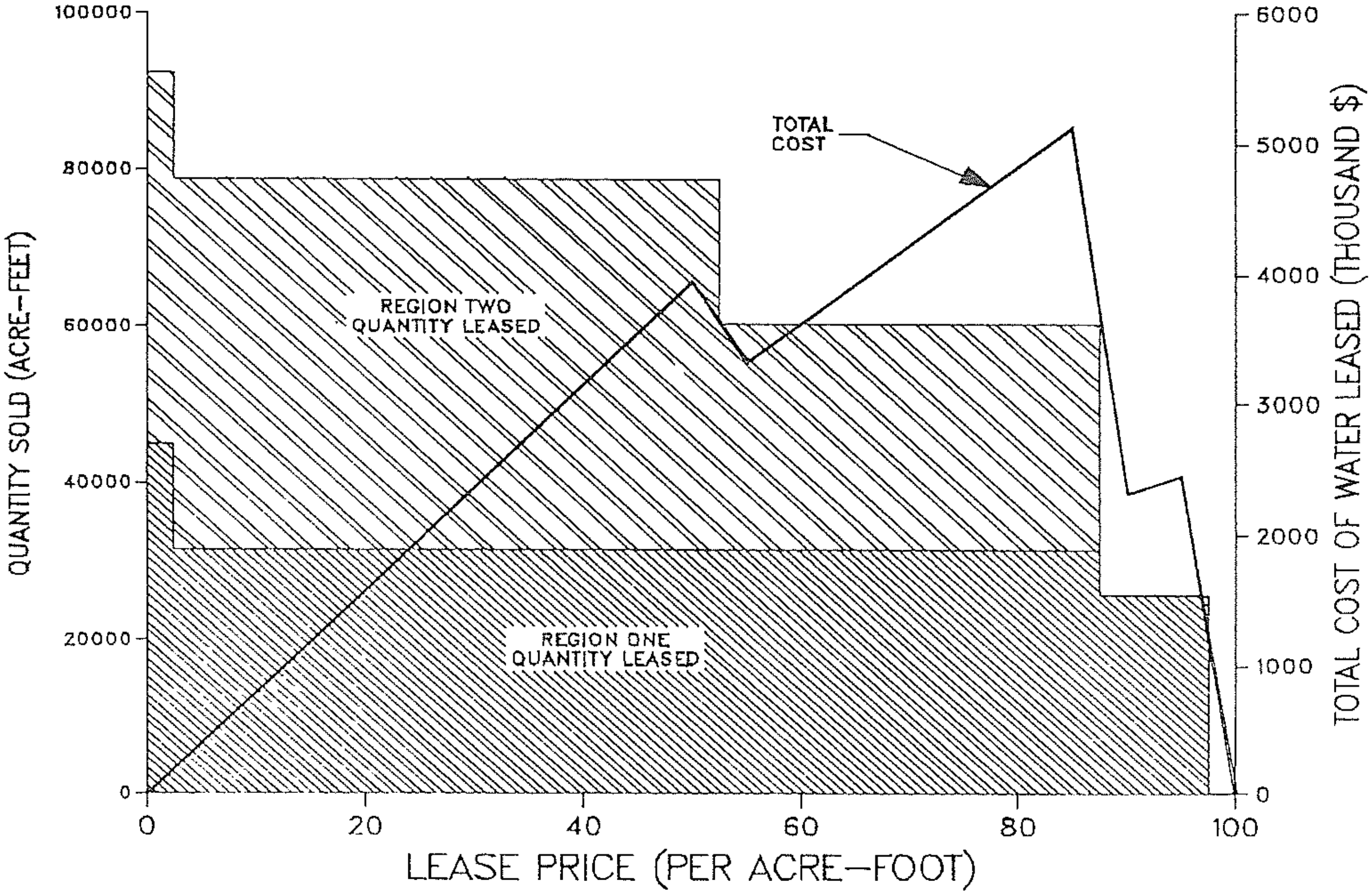
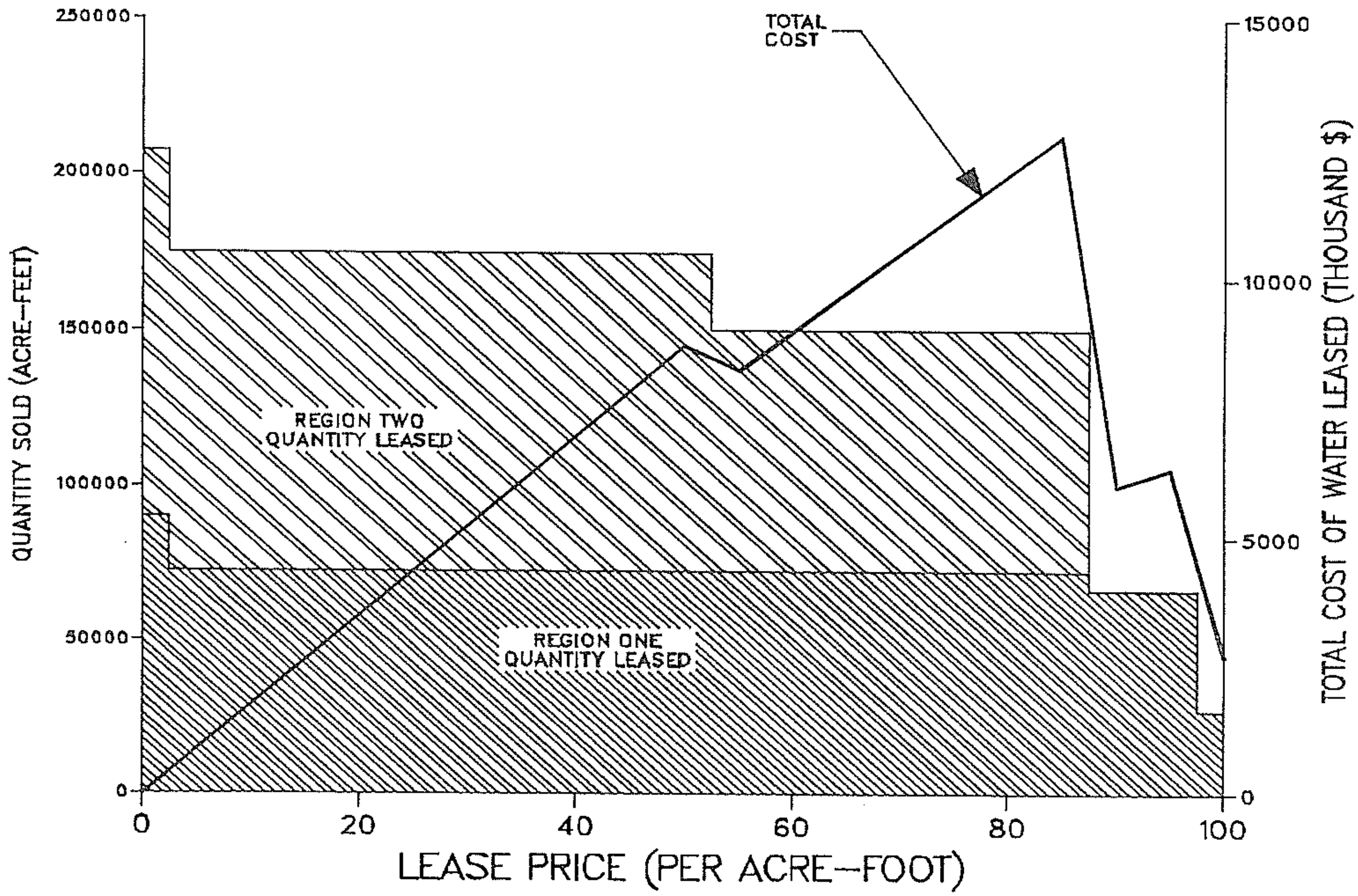


FIGURE 5.26
TOTAL QUANTITY OF WATER SOLD AND TOTAL SOCIAL COST
AT DIFFERENT LEASE PRICES UNDER PUEBLO LEASING SCENARIO
100 PERCENT SCENARIO



The model specifies several different forms of water scarcity measures, including: a) the level of full supply utilization in each of the Upper Basin Regions observed, b) the level of surface water to groundwater transfers observed, c) the level of interregional transfers observed, and d) the quantity of water purchased in a model solution. All four of these scarcity measures provide different information regarding the nature of the scarcity conditions, and their interpretation must rely upon their specifications in each model scenario.

Table 5.12 describes the percentage of available water supplies used. The data shows that in the Baseline solution all Upper Basin regions are utilizing their full level of groundwater rights (which includes an increase over 1975 associated with the Brutsaert model), and nearly all the available surface water including the augmentation provided by the San Juan-Chama project. The Baseline solution shows no critical water supply shortage, and indeed there are surplus supplies of surface water in the year 2000 under this "status quo" growth projection. The Pueblo Agricultural Use scenario shown in Table 5.12 includes compensation to the effected non-Indian water right holders. Since the projection including compensation is only slightly greater than the scenario without compensation (as previously described) it is the only Pueblo agriculture scenario summarized here.

The Pueblo agriculture scenario shows basically that agriculture is increased in the Upper Basin to the point where the full available

TABLE 5.12

PERCENTAGE OF AVAILABLE WATER SUPPLY CONSTRAINT USED*

	Region One		Region Two		Region Three		Upper Rio Grande Basin	
	Percent of Available Surface Water	Percent of Available Groundwater	Percent of Available Surface Water	Percent of Available Groundwater	Percent of Available Surface Water	Percent of Available Groundwater	Percent of Available Surface Water	Percent of Available Groundwater
Baseline Solution	96 %	100 %	88 %	100 %	99 %	100 %	92 %	100 %
Pueblo Agriculture Sceanrio**								
0 %	100 %	100 %	100 %	100 %	100 %	10 %	100 %	86 %
10 %	100 %	100 %	100 %	100 %	100 %	10 %	100 %	86 %
20 %	100 %	100 %	100 %	100 %	100 %	10 %	100 %	86 %
30 %	100 %	100 %	100 %	100 %	100 %	10 %	100 %	86 %
40 %	100 %	100 %	100 %	100 %	100 %	9 %	100 %	86 %
50 %	100 %	100 %	100 %	100 %	100 %	9 %	100 %	86 %
60 %	100 %	100 %	100 %	100 %	100 %	9 %	100 %	86 %
70 %	100 %	100 %	100 %	100 %	100 %	9 %	100 %	86 %
80 %	100 %	100 %	100 %	100 %	100 %	9 %	100 %	86 %
90 %	100 %	100 %	100 %	100 %	100 %	9 %	100 %	86 %
100 %	100 %	100 %	100 %	100 %	100 %	8 %	100 %	86 %
Pueblo Leasing Sceanrio								
50 % $ 0	93 %	100 %	90 %	100 %	100 %	100 %	92 %	100 %
50 % $ 5	88 %	100 %	90 %	100 %	100 %	100 %	90 %	100 %
50 % $ 55	88 %	100 %	81 %	100 %	100 %	38 %	85 %	90 %
50 % $ 90	84 %	100 %	67 %	100 %	100 %	38 %	74 %	90 %
50 % $100	62 %	87 %	67 %	100 %	100 %	38 %	67 %	89 %
Pueblo Leasing Sceanrio								
100 % $ 0	90 %	100 %	93 %	100 %	100 %	100 %	92 %	100 %
100 % $ 5	85 %	100 %	93 %	100 %	100 %	100 %	90 %	100 %
100 % $ 55	85 %	100 %	81 %	100 %	100 %	10 %	83 %	86 %
100 % $ 90	81 %	100 %	45 %	100 %	100 %	10 %	58 %	86 %
100 % $100	48 %	79 %	45 %	100 %	100 %	10 %	46 %	84 %

* Includes both available water constraint plus any additional surface water available for lease from private holders (i.e., Pueblo Indians or City of Albuquerque)
** Pueblo Agriculture scenario with compensation
Note: Pueblo Indian water right quantification scenarios are expressed as a percent of maximum scenario quantities, and Leasing scenarios indicate lease price of Pueblo Indian water rights.

supplies are being utilized, with the exception of groundwater in Region Three. It may be recalled that with each percentage increase in this agricultural use scenario there is a reduction in Region Three's surface water supply, which is then transferred to Region One and Two. Thus, output continuously declines in Region Three as is reflected in the level of groundwater utilization in the region. Under this agricultural use scenario water supplies are absolutely scarce in all regions of the Upper Basin, with the exception of Region Three's groundwater.

The two levels of the Pueblo Leasing scenarios described in Table 5.12 show significant differences in the level of water supply use, depending on both the quantity of water leasable and the lease price of that water. Groundwater use in the Leasing scenarios mirrors the Baseline solution up to the point where the lease price reaches $55 per acre-foot, when the lease price constrains output in Region Three. This appears to be a much more significant change in the 100 percent quantification scenario; but it should also be recalled that surface water remains available in Region Three under the 50 percent scenario which may influence the level of groundwater use due to generally higher production levels in the region (than observed in the 100 percent scenario). It is interesting and significant that under the 50 percent quantification scenario water resources are more scarce (according to this measure of scarcity) than under the 100 percent quantification scenario.

Under either of the Pueblo Leasing scenarios there can be observed <u>lesser</u> scarcity of water resources than under the Baseline solution even at a $0 per acre-foot lease price in the Upper Basin as a whole, although the slightly more than 300 acre-feet of surface water cannot be considered a significant difference. The more significant decline in Region One surface water scarcity is largely attributed to an increase in available water supply of the region associated with the scenario and only a slight increase in output. However, the increased water scarcity observed in Region Two is much more difficult to explain. This Region Two scarcity condition relates to a need to transfer water to Region Three which can be "afforded" at a lease price up to $55 per acre-foot.

In summary, it can generally be said that surface water becomes absolutely scarce in the Upper Basin with the imposition of a Pueblo Indian Agricultural Use scenario, although there is a lesser degree of groundwater use associated with the decline of Region Three output. The effects of Pueblo Indian Leasing scenarios can be said to be more complex, but effecting approximately the same degree of water scarcity in the Upper Basin as is observed in the Baseline solution.

A more detailed description of the specific types and nature of water scarcity conditions associated with these general scarcity conditions is provided by the quantities of water transfers observed in the various model solutions shown in Table 5.13. The Baseline solution describes only surface to groundwater transfers in the Upper

Table 5.13

PURCHASES AND TRANSFERS EFFECTING UPPER BASIN WATER SUPPLIES
(Acre-Feet Depletions)

	Surface to Groundwater Transfers			Interregional Surface Water Transfers				Purchased Surface Water		
								Albuquerque San Juan-Chama Water	Leased Pueblo Water Rights	
	Region One	Region Two	Region Three	Region One to Region Two	Region Two to Region Three	Region Two to Region One	Region Three to Region Two		Region One	Region Two
Baseline Solution	2,403	47,648	206	0	0	0	0	0	na	na
Pueblo Agricultural Scenario*										
0 %	2,449	48,368	0	0	0	0	19,878	16,345	na	na
10 %	2,461	48,363	0	0	0	0	17,898	16,345	na	na
20 %	2,472	48,358	0	0	0	0	15,918	16,345	na	na
30 %	2,484	48,354	0	0	0	0	13,938	16,345	na	na
40 %	2,496	48,349	0	0	0	0	11,957	16,345	na	na
50 %	2,508	48,344	0	0	0	0	9,977	16,345	na	na
60 %	2,519	48,340	0	0	0	0	7,997	16,345	na	na
70 %	2,531	48,335	0	0	0	0	6,017	16,345	na	na
80 %	2,543	48,330	0	0	0	0	4,036	16,345	na	na
90 %	2,576	48,323	0	0	0	0	2,056	16,345	na	na
100 %	3,011	48,519	0	0	0	0	76	16,345	na	na
Pueblo Leasing Scenario										
50 % $ 0	2,403	47,648	0	0	13,361	0	0	0	45,020	47,349
50 % $ 5	435	47,648	0	0	13,361	0	0	0	31,492	47,349
50 % $ 55	435	43,719	0	0	0	0	0	0	31,492	28,799
50 % $ 90	0	43,669	0	0	0	0	0	0	25,751	0
50 % $100	0	43,669	0	0	0	0	0	0	0	0
Pueblo Leasing Scenario										
100 % $ 0	2,403	47,648	0	0	27,307	38	0	16,345	90,040	101,127
100 % $ 5	435	47,648	0	0	27,307	38	0	1,049	72,249	101,127
100 % $ 55	435	43,718	0	0	8,014	38	0	0	72,249	77,694
100 % $ 90	0	43,586	0	0	8,014	38	0	0	66,508	110
100 % $100	0	43,586	0	0	8,014	38	0	0	26,757	110

na Not Applicable
* Pueblo Agriculture scenario with compensation
Note: Pueblo Indian water right quantification scenarios are expressed as a percent of maximum scenario quanties, and Leasing scenarios indicate lease price of Pueblo Indian water rights.

Basin. Only in the case of Region Two does there appear a significant discrepancy between the quantity of groundwater demanded and its availability (as constrained in the Baseline solution). The surplus of water in the Baseline solution is manifested in the City of Albuquerque's inability to sell their surplus San Juan-Chama water. By comparing the Pueblo Indian Agriculture Use scenario to the Baseline solution it is apparent that the increased economic activity of Regions One and Two increases the scarcity of groundwater slightly. However, more significant is the City of Albuquerque's ability to sell the full estimates surplus San Juan-Chama water and the substantial transfers of surface water from Region Three to Region Two.

The expression of water scarcity associated with the two Pueblo Indian Leasing scenarios represents a complex set of relationship between the sectors and regions of the Upper Basin. Clearly, the lease price is significant to the quantity of both surface to groundwater transfers and to the interregional transfers observed in the leasing solutions. The competition between the City of Albuquerque and the Pueblos for sale of leaseable water is also interesting -- the City only able to sell water under the 100 percent quantification scenario at a price of up to $5 per acre-foot. It is also apparent that the Region One Pueblos face a less price elastic demand for water; or more simply stated, the quantity of water leased in Region One seems less affected by the specific price charged.

The pressure on water supplies resulting from the various forms of development and Pueblo water rights resolutions modeled show clear sensitivity to specific parameters (e.g., "price") employed in the scenarios. In the case of the Pueblo Agriculture scenarios it is clear that there is increased scarcity of water resources in the Upper Basin. In the case of the Pueblo Leasing scenarios there is less clear changes in the scarcity of water resources, although it is apparent that as the lease price of water increases there is a decrease in the scarcity measures just described.

CHAPTER VI

SUMMARY OF IMPACTS AND GENERALIZATION OF CONCLUSIONS

A. Summary of the Analytical Parameters

The analysis of economic impacts associated with Pueblo Indian water right resolutions relies on three basic parameters which both define and structure the questions addressed. The three can be summarized as: 1) an empirically defined water constraint on economic activity, 2) a model which explicitly describes the economy of the Upper Rio Grande Basin, and 3) a set of scenarios which describe anticipated economic growth and the specific alternative judicial resolutions of Pueblo Indian water right claims within this modeled economic system. The interaction of these three basic parameters are herein asserted to describe the array of economic impacts which can be anticipated to occur within the Upper Basin economy as a result of specific resolution of Pueblo Indian water right claims.

The water constraint assumes that the social and economic activities observed require water, and that there is a limit to the water resources which can support these activities. It is asserted that the water supply conditions observed in 1975 define a normal (average) water supply for the region, and the patterns of water use reported in that year thus define actual water right entitlements within the Upper Basin. That is, "paper water rights" may or may not be subject to actual appropriation, but <u>actual use</u> clearly demonstrates a users' ability to appropriate the available water resources of the Upper Basin. This empirical specification of existing water rights also incorporates all downstream obligations (i.e., international and interstate delivery conventions) in its definition of water supply.

By this definition of existing water rights, without identification of specific individual users, many thorny legal questions regarding the validity of these individual entitlements have been avoided. The 25-year projection of economic conditions, constrained by water availability, allows for the possibility of significant water right transfer activity in that interim without the encumberment of defining the individual rights transferred. It is simply asserted that, over the 25-year interim, changes in economic activity which also result in changes of water right ownership <u>can</u> occur within the structure of New Mexico water law as is required for the projected economic growth. Recognized explicitly is the augmentation of the available water supplies as a result of the San Juan-Chama transbasin diversion which will satisfy much of the increased water requirements associated with this economic growth. Also explicit in the model are changes in water use efficiency attributed to perceptions of scarcity, including increased actual costs of use (e.g., municipal water system prices) and other incentives for conservation activity.

The economic model which structures this analysis is also of empirical base, and reflects both the observed patterns of economic activity in 1975 and the actual rate of water use in those activities. The interactive structure of the regional economies is defined by activity observed in 1975, thereby providing for specific projection of sectoral economic growth over a 25-year period. This Baseline projection of growth allows the expansion of existing economic activities, but does not anticipate the introduction of new industries which did not exist in the region in 1975 (e.g., a ship building firm).

The analysis specifies possible judicial resolutions of Pueblo Indian water right claims, based on the investigation of these alternatives done by DuMars, O'Leary and Utton, and interpretes these resolution scenarios within the structure of the analytical economic model specified for the Upper Rio Grande Basin. It is assumed for the purposes of this analysis that the specific resolution will be completed during the 25-year interim and that the construction of any necessary facilities for the implementation of the specific resolution will have occurred by 2000.[147] The Baseline scenario of economic

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147 It is recognized that this assumption represents a <u>very</u> optimistic scenario for resolution and implemen- tation of all Pueblo Indian water right claims in the Upper Rio Grande Basin. The use of the 25-year time horizon reflects my discomfort and uncertainty with projection of economic growth and change over any longer period, and also recognizes the limitation of a input/output modeling of the structure of the New Mexico econo-

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growth describes either no resolution, or a specific resolution which does not (by judicial decree) increase the water rights of the Pueblo Indians in the Upper Rio Grande Basin. This does not preclude the acquisition of addition water rights by the Pueblo Indians, but asserts that their acquisition must be through normal market processes and as justified by new economic enterprises undertaken by this sub-group of Upper Basin society.

Two forms of judicial resolution are investigated which would result in the increase in Pueblo Indian water right entitlements exogeneous to thse normal market processes -- 1) the possibility that the Pueblos will be granted additional water rights in accord with actual use on the presently un-irrigated "irrigable acres" of the Pueblos, and 2) the possibility that the Pueblo Indians will be assigned title to the water with the ability to lease the entitlements to other users within the Upper Basin. The specification of increased water rights by agricultural use on the reservations <u>does not</u> modify agricultural market structures of the Upper Basin by introduction of new high-valued crops (e.g., large acreages of Christmas trees or strawberries), although the specific resolution modifies the geograph-

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my. It is felt no significant distortions of the state's dynamic economic growth and structural change are likely in the 25-year projection made, and that this is particularly true of a projection made with a 1975 starting point which relies on observations of growth and change through 1984.

ic location of agricultural enterprises within the Upper Basin in conformity with the location of the Pueblo Indian lands. The analysis of impacts associated with this Agricultural Use scenario looks at a broad range of quantifications which, at the extreme, would eliminate all non-Indian agriculture in the Upper Rio Grande Basin. In the discussion of economic impacts associated with the leasing of water right entitlements an equally broad range of quantifications are considered; and, in addition, there is investigation of the effects of differing pricing policies which could be exercised by the Pueblo Indians.

B. A Summary of the Results

1. Baseline Scenario

The Baseline scenario can be characterized as describing normal economic growth for the specific sectors which comprise the analytical model employed. It is worth repeating that the growth rates used in this projection are not intended for quantitative analysis of this growth, but rather are specified for qualitative analysis of the relative magnitude of this anticipated growth. The growth projected for a particular sector is intended to be accurate relative to the growth projections for the other sectors; however, no quantitative accuracy is professed except in the general magnitude of the growth rates used. More specifically, I do not wish to quibble about whether Sector 12 in Region One will grow at an annual rate of 4.463 percent or 4.963 percent. Rather, the projections are of a relative magnitude (with empirical basis) between sectors of a region and across the Upper Basin as a whole.

Likewise, projection of changes in water use efficiency are in a sector-relative sense, with recognition that the agricultural sectors are much more likely to institute conservation measures than are the other economic sectors of the Upper Basin modeled. The Baseline projections shows significant increases in economic activity, with some sectors tripling their 1975 output by 2000 (in real dollar terms).

Most significant of the Baseline results is the anticipation that water will <u>not</u> be scarce, in a total supply/demand sense, by the year 2000 in the Upper Rio Grande Basin. This is due to the augmentation of the water supply provided by the San Juan-Chama project, with projections showing a surplus of more than 25,000 acre-feet of surface water in 2000. It is worthy of note that the projection shows significant pressure on the use of groundwater resources, and results in the transfer of over 50,000 acre-feet of surface water rights to allow for the required groundwater depletions.[148] It is clear that these

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148 The specific magnitude of these surpluses are effected principally by the projected rates of population growth and, more importantly, growth of agricultural output. I assume, based on observed trends, that growth in agricultural output in the Upper Rio Grande Basin is very limited. I assert that the only potential for substantial change in this assumption must be the result of judicially <u>imposed</u> new Pueblo Indian agricultural enterprises, and have incorporated this in the modeling.
In regard to the transfer of 50,000 acre-feet of surface water

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transfers will provide for a perception of water scarcity, but that economic activity is not constrained by scarcity of water supplies.

The Baseline solution to the model must be interpreted to suggest that water scarcity issues, and particularly steady-state groundwater management issues, will receive increasing attention in the Upper Rio Grande Basin even if no resolution of Pueblo Indian water rights is realized. The concern regarding these issues can only be thought to be exacerbated by the uncertainty of water right title resulting from the non-resolution of Pueblo Indian water right claims. If the Baseline scenario is thought of as describing the resolution of these claims which results in no increase in Pueblo Indian water right entitlements, then the concern regarding these issues maybe somewhat lessened.

2. Pueblo Indian Agricultural Use Scenario

The possibility that the courts will assign increased Pueblo Indian water rights based on the ability to use the water in new agricultural enterprises leads to the most interesting of the results obtained in the analysis. It should be recalled that the model employed divides the Upper Basin into three regions, with the Pueblo

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to allow for increased groundwater use, it must be noted that more than 90 percent of these transfers occur in Region Two and are largely the result of growth in the Albuquerque urban area.

Indian lands found in the northern two of the three regions. Thus, this scenario describes increases in the agriculture sectors of Regions One and Two associated with the Pueblo Indians, with corresponding decrease in Region Three's agriculture. Rather than postulate dramatic structural changes in agricultural economy of the Upper Basin by introduction of new crops, cropping patterns, or average yields (per acre), I chose to defer to the wisdom of the existing agriculturalists and describe this new Pueblo Indian agriculture as serving the same patterns of output demands found in the Baseline solution.

Whereas in the Baseline solution agricultural output was constrained to be no more than 110 percent of its 1975 level, in this scenario minimum levels of agriculture output associated with Pueblo agriculture were set and any additional production which could be "economically justified" in the model's solution was allowed.[149] The results thus obtained have intuitive interpretation as describing the fullest utilization of the water resource justified by output

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149 In the framework of an IOLP solution (as used here) "economically justified" describes the condition were unsatisfied intermediate and final demands can be met more cheaply by "internal" output production (including any necessary input purchases) than by "external" output importation (with its incumbant cost). The minimum levels of Pueblo Indian agriculture represents the agricultural output imposed by specific judicial resolution of Pueblo Indian water rights, and output levels beyond this minimum may be the result of farming by either Indians or non-Indians in the Upper Basin. For discussion of the agricultural output constraint see supra note 148.

demands with the imposition (by the courts) of new Pueblo Indian agriculture. The non-Indian farmers are displaced only when they can not find buyers for their outputs or when the effective water constraint is realized.

The model solutions reveal that specific quantification of Pueblo Indian water right claims based on this agricultural servitude may result in an increased average productivity per acre-foot of water used in agriculture, full utilization of the available water resources, and an increase in the total agricultural output of the Upper Basin. This may seem somewhat remarkable in light of the declining trends in Upper Basin agriculture observed and described herein. However, at an intuitive level the solution describes the motivation, sensibility and wisdom of intransigent, centuries-old agricultural enterprises forced to adapt to and compete with a new, judicially imposed, market structure. Faced with the dramatic changes modeled under this scenario -- which in the extreme contemplates the elimination of all non-Indian agriculture in the Upper Basin -- there can be little question that the non-Indians farmers which remain in business under the non-extreme resolutions will seriously re-think their production practices.

Even under the non-extreme Pueblo Indian Agricultural Use scenarios solutions are obtained which result in absolute water scarcity conditions. The surplus water supply conditions observed in the Baseline solution are supplanted by competition for the available supplies amount economic sectors. However, this increased competition for water has little effect on the output of the nonagricultural sectors modeled.

Indeed, it can be said that the specific resolution of Pueblo Indian water right claims under this scenario results in the elimination of the uncertainty of title, with corresponding increase in the total economic output of the Upper Basin. The changes observed are simply distributional in both geographic location and ethnic beneficiaries. If the specific judicial resolution includes compensation for water rights lost to the affected non-Indians displaced by the new Pueblo Indian agriculture, the results are the same. Most important of the results, though, is the emergence of critical water scarcity conditions which would otherwise not be found in the Upper Rio Grande Basin in the year 2000.

3. Pueblo Indian Leasing Scenario

The final scenario which was investigated focused on the possibility that the courts would assign a particular quantity of water right entitlements to the Pueblo Indians with the specific allowance for leasing these entitlements to non-Indians throughout the Upper Basin. Thus, both the specific quantity and lease price are significant to the results obtained under this scenario. Without precise specification of either of these parameters the general results under this scenario are apparent -- as the price increases the economically marginal users of water will be eliminated, with the potential that at some price no economic sector will be able to afford the lease cost of the Pueblo Indian water rights. This extreme is unlikely though as the water resource would serve neither the Indians or non-Indians of the Upper Basin, and would result in "unintentional" delivery of additional water to Texas.

In fact the result would be to eliminate the marginal agriculture of the Upper Basin, and make water available to other more economically productive uses. The elimination of this marginal agricultural would have the corresponding effect of increasing the overall efficiency of use of the Upper Basin's water resources, an effect which may in itself be desirable and inevitable. Thus, one can characterize the results obtained under this leasing scenario as accelerating water scarcity conditions which result in more efficient use of the resource by explicit expression of a water scarcity value through the pricing of a water commodity.

This scarcity characterization is substantially different from the absolute water supply scarcity previously described. In this case the Pueblo Indians become brokers of a water commodity of specific quantitative dimension which is allocated by market price mechanisms. The management of the clearly defined water resource commodity may actually reduce the perception of water scarcity in the basin. The laissez faire market for perpetual water right entitlement transfers is, in this case, augmented by a leased (non-perpetual) water right market controlled by 17 separate Pueblo Indian administrations throughout Regions One and Two of the Upper Basin.

The specific results obtained show that over a range of lease prices from \$0 to \$100 per acre-foot[150] more than 90 percent of the agricultural output remains viable in the Upper Basin. Thus the effect of this leasing scenario in the extreme quantification resolution (i.e., the reassignment of <u>all</u> non-Indian agricultural water

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150 The \$100 per acre-foot lease price can be expressed as a perpetual water right value by use of a discount rate and the following present value calculation:

$$\lim \int_0^{\infty} PVe^{-rt}\, dt = \frac{PV}{r}$$

where PV is the present value of the income stream (i.e., the lease price) and r is the discount rate. Thus, at a \$100 lease price the value of the water right would be \$1,000 per acre-foot with a 10 percent discount rate, \$2,000 per acre-foot with a 5 percent discount rate, and \$10,000 per acre-foot at a 1 percent discount rate. The choice of a specific discount rate is very difficult and important to Indian water right questions, with an excellent discussion of the issues presented in Report of Teno Ronocalio, Special Master, In Re: The General Adjudication of All Rights to Use Water in the Big Horn River System and All Other Sources, State of Wyoming (Concerning Reserved Water Right Claims By and On Behalf of the Tribes of the Wind River Reservation, Wyoming), Civil No. 4993 (Wyoming District Court, 5th District, December 15, 1982) at 198.

Regardless of the specific discount rate used it is clear that a \$100 per acre-foot lease price provides for a high, but relevant range value for the Pueblo Indian water rights (<u>see</u> Rahman Khoshakhlagh, F. Lee Brown, and Charles DuMars, <u>Forecasting Future Market Values of Water Rights in New Mexico</u>, Report No. 92, New Mexico Water Resources Research Institute, Las Cruces, New Mexico: New Mexico State University, 1977).

rights to the Pueblos), and with pricing in a relevant range, there is found nominal impacts with respect to the economic output of the region. This extreme resolution (quantification and pricing) has dramatic effect on total water resource use, with a nearly 45 percent reduction in total water depletions.

The general effect of this leasing resolution is simply the substantially increased efficiency of water use resulting from the elimination of high water using low productivity sectors by the lease price mechanism. There is little reason to belabor the economic benefits derived by Upper Basin society which can be associated with this leasing resolution. Yet one must certainly be sensitive to the sociological effects of placing one ethnic sub-group of Upper Basin society in such a powerful position as a dominant water broker.

C. Conclusions

Several themes and generalized conclusions must be drawn from this analysis. Most important of these is clear even without the rigor of the preceding -- it is the simple conclusion that resolution of Pueblo Indian water right claims, regardless of the specific form of the resolution, must be encouraged. It is apparent from the analysis of the alternative forms of possible Pueblo Indian water right resolution that the detrimental economic consequences are nominal, and that under certain resolution scenarios the economic benefits substantially outweigh the corresponding costs. To drag the proceedings out any longer than is absolutely necessary is beneficial only to the attorneys and expert witnesses who are employed by the litigation.

This conclusion should not be interpreted to suggest that the proceedings should be haphazard or incomplete, but rather that there is no economic justification to fear or resist the outcomes. Yet it is admitted here that concerns for economic efficiency may not be persuasive relative to the vocal clamorings of the entrenched and powerful non-Indian agricultural community of the Upper Rio Grande Basin. One is forced by the economic analysis provided herein to simply question whether the economically marginal agricultural life-styles which form the predominant water use sectors have a "social desirability" which outweigh the economic questions addressed herein.

The question can alternatively stated as to whether the net economic benefits of a specific resolution (as assessed here or by some other analytical technique) are greater than the nebulous "social costs" affected by impacts on non-Indian agriculture. I can only point to a class of social costs associated with specific resolutions, and state that these "costs" reflect changes in an "agrarian life-style". There can be more precise identification of a group of benefits and costs which relate to the increased certainty of property title associated with final resolution of Pueblo Indian water right questions in the Upper Rio Grande Basin.

In looking at the specific results which form the basis for these conclusions one is drawn to the economic responses to water scarcity conditions which result from specific resolution scenarios. It is possible to conclude that resolutions can be consciously pursued which have either a) net economic benefit and accelerate water resource scarcity in the Upper Basin (i.e., by imposition of new Pueblo Indian agriculture), or b) resolutions which have nominal economic costs and significantly improves the control of water scarcity circumstances (i.e., Pueblo Indian leasing scenario). No attempts were made to project long-term (i.e., more than 25 years) changes in economic activity and water scarcity conditions in the Upper Basin, yet it is clear that at some future time water supplies will constrain additional economic growth.

Upper Basin society may deliberately encourage water use efficiency and incorporate these motivations in the specific resolution of the Pueblo Indian water right question; or may defer to a laissez faire market mechanism which responds only to the relative market powers of its participants, ignoring the non-economic questions faced by Upper Basin society as a whole which are not expressed in actual water right market transactions. Indeed, one of these non-economic questions is whether or not it is desirable to encourage a resolution which places the Pueblo Indians of the region in a position of water broker with substantial control over a vital water resource commodity.

It is precisely this question of deliberate economic and social consequences affected by specific resolution of Pueblo Indian water rights which sets this analysis apart from all previous economic investigations of Indian water right questions. The conclusions are not definitive in a benefit/cost sense, and there is no advocacy of a specific quantification. Relative differences between alternative forms of Pueblo Indian water right resolutions are investigated and described, and the economic questions which can be associated with each of the alternatives described are addressed. In conclusion, I simply reiterate a question asked earlier in this investigation -- can specific judicial resolution of Pueblo Indian water right claims in the Upper Rio Grande Basin ignore the regional economic consequences which result from the alternative legal theories upon which these claims are based?

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