AN ECONOMIC ANALYSIS OF WATER USE IN COLORADO'S ECONOMY

by

S. Lee Gray
John R. McKean

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COLORADO WATER RESOURCES RESEARCH INSTITUTE

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by

S. Lee Gray and John R. McKean

with contributions by

Edward W. Sparling and Joseph C. Weber

Department of Economics
Colorado State University
Fort Collins, CO 80523

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Colorado Water Resources Research Institute
Colorado State University
Fort Collins, Colorado 80523

Norman A. Evans, Director

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2. Gray, S. L. and McKean, J. R. "1970 Labor Inputs into Colorado Agri-Business," Colorado Agricultural Roundup. Cooperative Extension Service, Colorado State University, Fort Collins, Colorado. Summer, 1973.

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CHAPTER I

INTRODUCTION

STATEMENT OF THE PROBLEM

Any well-developed economy is likely to be characterized by a high degree of interdependence among the various producing sectors. Those who produce goods and services for final consumption are dependent to some extent upon other producers for a portion of their supply of productive inputs; i.e., for intermediate products. Those who supply the intermediate products are similarly dependent upon others for their productive ingredients. Producers must also rely on those who provide primary factors of production such as labor, natural resources, government services and goods and services which are produced elsewhere and which must be imported. Because of these type of interdependencies, changes in production activities in one sector of a developed economy may well have significant indirect as well as direct impacts upon the remaining economic activities. Such impacts will be found both in terms of stimulus to intermediate production activities and in the requirements exerted on primary factors of production.

Recent concern, particularly in the semi-arid and arid West, has been expressed by policy makers, planning authorities and the general public over the adequacy of water supplies to sustain increasing population and economic growth. Policy makers are understandably concerned with several questions which need to be addressed in order to provide input into the policy formulation process. Among these are questions pertaining to the amounts of water currently withdrawn and consumed in a particular economy, the impact of changes in economic activity upon the water resources (in both the direct and indirect sense), and the question of how much economic growth can be accommodated with assumed levels of water resource availability. Information of this type, to be most useful, must be obtained within the context of the entire relevant economy rather than for isolated economic sectors.

The purpose of this study is to analyze the relationships between the economic sectors of the Colorado State economy and to relate economic activity in the state to the requirements placed on the state's water resources. In meeting this overall purpose, several specific objectives will be addressed: 1) estimation of the interdependent economic structure of the state's economy; 2) estimation of sector-by-sector withdrawal and consumptive water requirements; 3) estimation of direct and indirect water requirements accompanying changes in economic activity; and 4) a suggested method for assessing the optimal organization of economic activity and water use given an objective of maximizing the gross state product. The major thrust of the research effort lies in the collection, tabulation and analysis of primary and secondary data necessary to satisfy the first three objectives above. This provides a rather detailed descriptive analysis of Colorado's economy. The fourth objective reflects an attempt to convert the descriptive analysis in the first three into a conditionally normative statement of what the economy should look like given a specified state objective function and certain resource constraints. While it is not contended that satisfying the last objective is, at present, a key input into the policy question it is intended that the method suggested can be refined and developed into an effective short-term policy tool.

Objectives one through three will be satisfied through the use of the Leontief input-output analysis, the first such analysis of the entire Colorado economy. The fourth objective will be met through the use of a linear programming model. The linear programming technique allows constraints to be placed on intermediate processing activities while the basic input-output model must be controlled through changes (or limits on the changes) in the final demand sectors. The input-output and linear programming tools will be discussed in detail in subsequent chapters of the report.

In addition to the analysis of water use in relation to sector-by-sector economic activity, several useful extensions of the model are considered. Specifically, an analysis of income and employment for the base year of the study (1970) is included. The input-output model is driven by changes in final demands and projects consistent changes in sector-by-sector outputs to achieve the assumed changes in final demands. The new levels of output by sector are consistent in that they are a unique set of outputs which mutually and simultaneously satisfy all requirements for intermediate and final production. The model is used to project the impact of alternative rates of growth in final consumption on water use, income, and employment to the year 1980. These forecasts are not to be interpreted as actual predictions of the expected economic activity in the state but rather as examples of the "if-then" type of conditional forecasting in which assumed scenarios for change in final demands are introduced into the input-output model resulting in consistent projections of sector-by-sector production requirements. Water use and employment is then calculated on the basis of these new sector production outputs.

The current concern with actual, or potentially severe, energy shortages is suggestive of still further extensions of the basic analysis. Specifically, the model is used to examine the economic impact of rapid growth and/or restricted deliveries to final demand in certain energy related sectors. The analytical framework employed in this study provides a means of addressing both issues. In Colorado, rapid expansion in the coal producing sector seems most likely while restricted deliveries by the natural gas sector are, in some parts of the state, a current reality. We analyze, briefly, the economic impacts on income, employment, and output of both of these cases. Again, the emphasis is on a demonstration of the flexibility of the analytical tool in addressing these questions.

PLAN OF THE REPORT

Chapter II develops the conceptual interindustry or input-output model. This development includes the use of a hypothetical example to explain the basic components of the analytical technique and the solution to the input-output problem. This chapter also includes a discussion of the use of the model to estimate the direct plus indirect water use coefficients and direct plus indirect employment coefficients, business and income multipliers, and consistent forecasts. The chapter concludes with a conceptual statement of the optimization model.

Chapter III identifies the economic sectors contained in the analysis by Standard Industrial Classification (SIC) number and provides a brief description of the major industries included in each sector. Secondary data sources used in estimating the value of total output for each sector are also included in this chapter.

Chapter IV contains the results of the input-output analysis presented in the three basic tables of the Leontief system: the transactions or commodity flows table, the table of direct production requirements or direct coefficients table, and the table of direct plus indirect production requirements. Chapter IV also contains the analysis of the various multiplier effects, income, employment and water use in the Colorado economy.

Chapter V is entitled "Extensions of the Analysis." Included here is an empirical example of the use of the model in consistent forecasting, an assessment of economic impacts of rapid expansion in coal mining and an assessment of the potential income and employment losses associated with limited growth of sales of natural gas to business firms which sell to the final consumer. Chapter V also presents an empirical application of a linear programming model of existing economic activity. The model employs an objective function of maximizing the value of final demand subject to constraints placed on existing economic sectors, water, and household employment.

Chapter VI presents a summary of major findings and some recommendations for future research which would aid in the planning process.

CHAPTER II

THE ANALYTICAL FRAMEWORK:

A CONCEPTUALIZATION AND HYPOTHETICAL EXAMPLE

INTRODUCTION

Modern day interindustry or input-output analysis is based upon early works by Francois Quesnay and later extensions by Leon Walras, Gustav Cassel, and Vilfredo Pareto. The culmination of these early developments is found in the statement of an interdependent production model developed in the 1930's by W. W. Leontief of Harvard University.

THE BASIC MODEL

The key to Leontief's analytical system is the input-output or transactions table. This table describes the flow of commodities, typically in dollar terms, from each of a number of producing sectors to all other consuming sectors for intermediate and final consumption. From this basic description of flows among economic sectors are derived the two other essential components of the Leontief system; namely, the direct and direct-plus-indirect production requirements. Each is discussed below.[1/]

THE TRANSACTIONS TABLE

Table II-1 depicts a highly simplified version of a hypothetical transactions table. The basic data are described in three major portions of the table termed the processing sector, the final demands sector and the payments sector.

[1/] An acceptable nonmathematical treatment of the subject matter of input-output economics may be found in Miernyk, W. H., The Elements of Input-Output Analysis, Random House, New York, 1965.

Table II-1: Hypothetical Transactions Table

		Purchasing Sector			Final Demand	Total Output
		X_1	X_2	X_3		
Processing Sector	X_1	1.00	2.25	.20	1.55	5.00
	X_2	2.00	6.00	1.00	16.00	25.00
	X_3	.20	3.00	1.80	15.00	20.00
Payments Sector		1.80	13.75	17.00	3.00	35.55
Total Outlays		5.00	25.00	20.00	35.55	85.55

In Table II-1 the sectors denoted X_1, X_2 and X_3 are the producing sectors making up the processing sector of the economy. Each of these sectors may deliver its output for intermediate use; i.e., a sale from X_1 at the left of the table to X_1, X_2 or X_3 at the column heads, and also to the final demand or final consumption sectors. Thus, in our example, X_1 delivers or sells $1.00 of its own output to itself, $2.25 worth of output to sector X_2 and $.20 worth of output to sector X_3. Sector X_1 also sells $1.55 worth of output to final consumption.

Any column within the transactions table describes the purchases made by the sector at the column head from each of the producing sectors as well as the purchase of primary inputs. Thus, sector X_2 purchases $2.25 worth of output from X_1, $6.00 worth of output from itself, $3.00 worth of output from X_3 and $13.75 worth of primary inputs. The system is basically a system of double entry accounting in which every sale constitutes a purchase and we purposely double count. The entries in the column headed "total output" are the sum of the corresponding row entries. Similarly, the entries in the total outlays row are the sum of the corresponding column entries. Since each sale and each purchase is accounted for, the column and row totals for the sectors X_1, X_2 and X_3 are equal. Equality between column and row totals for disaggregated final demand, and payments sectors is not required. However, in aggregate the equality between the sum of payments and the sum of final demands must hold.

We have, for simplicity in explanation, restricted our example to an aggregate final demand and payments sector. The final demand sector would generally consist of sales to households, sales to governments, sales to export markets, inventory change and investment while the payments sector would consist of payments to households in the form of wages and salaries, payments of taxes to governments, depreciation, rents, interest, dividends and payments for imports. The extent of disaggregation in these sectors and in the processing sector will depend largely upon the purposes of the study, the availability of data, and the time and money available to the researcher.

Once the basic economic data presented in the transactions table have been collected, the second table of the model, the direct or technical coefficients table,can be computed.

THE TECHNICAL COEFFICIENTS TABLE

Table II-2 is the table of direct coefficients for our hypothetical example. The entries in this table are to be interpreted as the requirements from each of the processing sectors at the left of the table in order for each sector at the top to produce one dollar's worth of output.

Table II-2: Hypothetical Direct Coefficients Table

		Purchasing Sector		
		X_1	X_2	X_3
Processing Sector	X_1	.20	.09	.01
	X_2	.40	.24	.05
	X_3	.04	.12	.09

The entries in this table are computed by dividing each column entry in the processing sector of the transactions table, Table II-1, by the respective column total. Thus, for each dollar of output produced by X_1, X_1 requires \$1.00/\$5.00 = \$.20 from itself, \$2.00/\$5.00 = \$.40 from X_2 and \$.20/\$5.00 = \$.04 from X_3. Each of the other columns has a like interpretation.

The information on final demands and total outputs obtained from Table II-1 can be combined with the information contained in Table II-2 to obtain the system of equations expressed in equations (1) below:

1.
$$X_1 = .20\ X_1 + .09\ X_2 + .01\ X_3 + Y_1$$
$$X_2 = .40\ X_1 + .24\ X_2 + .05\ X_3 + Y_2$$
$$X_3 = .04\ X_1 + .12\ X_2 + .09\ X_3 + Y_3$$

where X_1, X_2 and X_3 are the total outputs of the three sectors, Y_1, Y_2 and Y_3 are the respective deliveries to final demand by the three sectors and the coefficients are the entries in the direct coefficients table.

In matrix notation our system becomes that shown in equation (2):

2.
$$\begin{bmatrix} X_1 \\ X_2 \\ X_3 \end{bmatrix} = \begin{bmatrix} .20 & .09 & .01 \\ .40 & .24 & .05 \\ .04 & .12 & .09 \end{bmatrix} \begin{bmatrix} X_1 \\ X_2 \\ X_3 \end{bmatrix} + \begin{bmatrix} Y_1 \\ Y_2 \\ Y_3 \end{bmatrix}$$

or more simply stated as in (3):

3.
$$\underline{X} = A\underline{X} + \underline{Y}$$

where $\underline{X}$ is the vector of total outputs, A is the matrix of direct coefficients and $\underline{Y}$ is the vector of final demands.

Proceeding to a solution for Y from (1) above we may write:

4.
$$X_1 - .20\ X_1 - .09\ X_2 - .01\ X_3 = Y_1$$
$$-\ .40\ X_1 + X_2 - .24\ X_2 - .05\ X_3 = Y_2$$
$$-\ .04\ X_1 - .12\ X_2 + X_3 - .09\ X_3 = Y_3$$

or:

5. $$(1 - .20)\ X_1 - .09\ X_2 - .01\ X_3 = Y_1$$
$$- .40\ X_1 + (1 - .24)\ X_2 - .05\ X_3 = Y_2$$
$$- .04\ X_1 - .12\ X_2 + (1 - .09)\ X_3 = Y_3$$

Again writing the above system in matrix form we have equations (6):

6. $$\begin{bmatrix} (1 - .20) & - .09 & - .01 \\ - .40 & (1 - .24) & - .05 \\ - .04 & - .12 & (1 - .09) \end{bmatrix} \begin{bmatrix} X_1 \\ X_2 \\ X_3 \end{bmatrix} = \begin{bmatrix} Y_1 \\ Y_2 \\ Y_3 \end{bmatrix}$$

The matrix on the left of equation (6) is the Leontief matrix as shown in equations (7) and (8) below:

7. $$\left(\begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix} - \begin{bmatrix} .20 & .09 & .01 \\ .40 & .24 & .05 \\ .04 & .12 & .09 \end{bmatrix} \right) \begin{bmatrix} X_1 \\ X_2 \\ X_3 \end{bmatrix} = \begin{bmatrix} Y_1 \\ Y_2 \\ Y_3 \end{bmatrix}$$

which in matrix notation reduces to:

8. $$(I - A)\ \underline{X} = \underline{Y}$$

where I is the identity matrix, (I-A) is the Leontief matrix and A, $\underline{X}$ and $\underline{Y}$ are as defined previously.

THE DIRECT AND INDIRECT REQUIREMENTS TABLE

We now have the ingredients necessary to solve the Leontief system; i.e., to find the vector of outputs required to sustain a given vector of final demand, through the use of matrix inversion techniques which need not be dwelt on here.[2/] The mechanical process followed is first to find the inverse of the Leontief or (I-A) matrix. This matrix, identified as $(I-A)^{-1}$, is defined as a matrix C which, in our example, is given in Table II-3.

2/ See Miernyk, op. cit., Chapter 7.

Table II-3: Hypothetical Direct and Indirect Requirements Per Dollar Delivered to Final Demand

	X_1	X_2	X_3
X_1	1.3319	.1614	.0235
X_2	.7110	1.4135	.0855
X_3	.1523	.1935	1.1112

Each element in Table II-3 represents the total direct and indirect requirements from each sector at the left of the table which are necessary in order for the sector at the top of the table to deliver an increase of one dollar of output to final demand. Thus, if there is an increase of one dollar in the final demand for the output of sector X_1, there will be a total direct plus indirect production increase of \$1.33 in sector X_1, a direct plus indirect impact of \$.71 in sector X_2 and a direct plus indirect impact of \$.15 for the output of sector X_3. Using the information contained in Table II-3 in conjunction with the previous information we proceed to solution by premultiplying both sides of (8) above by the Leontief inverse as in:

9. $$(I-A)^{-1} (I-A) \underline{X} = (I-A)^{-1} \underline{Y}$$

which reduces to:

10. $$\underline{X} = (I-A)^{-1} \underline{Y}$$

or:

11. $$X_1 = 1.3319 Y_1 + .1614 Y_2 + .0235 Y_3$$
$$X_2 = .7710 Y_1 + 1.4135 Y_2 = .0855 Y_3$$
$$X_3 = .1523 Y_1 + .1935 Y_2 + 1.1112 Y_3$$

Table II-3 illustrates the concept of economic interdependence referred to early in Chapter I. An alteration in the quantities of any good demanded may be expected to stimulate production in other sectors which in turn stimulates still more production elsewhere in the economy. Table II-3 shows the magnitudes of all direct and indirect effects after the initial stimulation of demand has worked itself out.

FORECASTING WITH INPUT-OUTPUT MODELS

In addition to its usefulness in describing the structure of an economy at one period in time, the input-output model has applicability in making short-run projections of economic activity given certain assumptions as to the levels of final demand. Its use as a forecasting tool is limited by the assumptions of constant production coefficients and technical nonsubstitutability among productive inputs. These assumptions are not likely to be met over the long run. Thus, the ideal use of the model in forecasting is to project for short-run situations followed by an updating of the basic model and subsequent forecasts. The mechanics of forecasting with the input-output model are discussed briefly below.

As a first step in projecting a future level of output and a future flow of commodities among sectors, each element in the final demand sector of the original transactions table is projected. These projections form a single projected final demand vector. In our hypothetical model the projected final demands are \$3.00, \$19.00 and \$17.00, respectively, for sectors X_1, X_2 and X_3. Each row of the transpose of the $(I-A)^{-1}$ matrix is then multiplied by the projected final demand for a particular sector and the resulting columns are summed to obtain the projected gross outputs.[3/]

[3/] Transposing the matrix simply refers to interchanging the rows and columns of the inverse matrix. Thus column one of Table II-3 becomes row one and vice versa.

The process in our example is shown in the following computation:

$$(I-A)_T^{-1} = \begin{bmatrix} 1.3319 & .7110 & .1523 \\ .1614 & 1.4135 & .1935 \\ .0235 & .0855 & 1.1112 \end{bmatrix}$$

$$\begin{bmatrix} 1.3319 & .7110 & .1523 \\ .1614 & 1.4135 & .1935 \\ .0235 & .0855 & 1.1112 \end{bmatrix} \begin{bmatrix} 3.00 \\ 19.00 \\ 17.00 \end{bmatrix} = \begin{bmatrix} 3.9957 & 2.1330 & .4569 \\ 3.0666 & 26.8565 & 3.6765 \\ .3995 & 1.4535 & 18.8904 \end{bmatrix}$$

The projected gross outputs are the sums of the columns of the right hand side matrix above; i.e., \$7.5, \$30.4 and \$23.0, respectively, for X_1, X_2 and X_3. These gross output figures are then multiplied by each respective column entry in the direct coefficients table (Table II-2) to obtain the projected transactions table as follows:

.20 x 7.5 = 1.5   .09 x 30.4 = 2.7   .01 x 23.0 = .2

.40 x 7.5 = 3.0   .24 x 30.4 = 7.3   .05 x 23.0 = 1.2

.04 x 7.5 = .3   .12 x 30.4 = 3.6   .09 x 23.0 = 2.1

and the projected transactions table is that shown in Table II-4.

Table II-4: <u>Hypothetical Projected Transactions Table</u>

	X_1	X_2	X_3	Final Demand	Total Output
X_1	1.5	2.7	.2	3.0	7.4
X_2	3.0	7.3	1.2	19.0	30.5
X_3	.3	3.6	2.1	17.0	23.0
Payments	2.6	16.9	19.5		39.0
Total Outlay	7.4	30.5	23.0	39.0	99.9

THE CONCEPTUAL WATER USE ANALYSIS

Given the previous construct, the model's extension to an analysis of sector-by-sector water use requires additional information concerning water withdrawals (or consumptive use) per dollar of output in each sector. Denote the withdrawal requirements per dollar output in sector i, (i=1 . . . n), by W_i. For any single sector, total current water use by that sector is given by W_iX_i; i.e., the product formed by multiplying water withdrawn per dollar output times the sector's total output. Aggregate water withdrawn in the entire economy for a given period of time is then given by:

12. $$\sum_{i=1}^{n} W_iX_i = [W_1 \; . \; . \; . \; W_n] \begin{bmatrix} X_1 \\ . \\ . \\ . \\ X_n \end{bmatrix}$$

From a planning perspective, the projection of aggregate changes in water withdrawals, given exogenous changes in final demands, may be obtained quite simply in the following manner:

13. $$\sum_{i=1}^{n} W_i\Delta\hat{X}_i = [W_i \; . \; . \; . \; W_n] \begin{bmatrix} \Delta\hat{X}_1 \\ . \\ . \\ . \\ \Delta\hat{X}_n \end{bmatrix}$$

where $\Delta\hat{X}_i$ are the projected changes in output required to achieve the exogenous changes in final demands.

Another relationship of interest to planners may be obtained directly from expression (13) by isolating the individual $W_i\Delta\hat{X}_i$ products. Each $W_i\Delta\hat{X}_i$ reflects the total direct plus indirect water withdrawn in the single sector i as a result of meeting the assumed increases in final demand in all sectors. This is to be distinguished from $\sum_{i=1}^{n} W_i\Delta\hat{X}_i$ which is the total direct plus indirect increase in water withdrawals in the entire economy.

A third item of information on water use is found in the derivation of sector-by-sector direct plus indirect water requirements which allow planning agencies to assess the impacts on total water use throughout the economy as a single sector's deliveries to final demand are expanded. This derivation employs the Leontief inverse matrix, $[C_{ij}]$, and the vector of direct water requirements in the following manner:

14. $$\sum_{i=1}^{n} W_i C_{ij} = [W_1 \ . \ . \ . \ W_n] \begin{bmatrix} C_{1j} \\ \cdot \\ \cdot \\ \cdot \\ C_{nj} \end{bmatrix}$$

The C_{ij} elements in (14) are column vectors taken directly from the Leontief inverse matrix. The W_i are the direct water requirements. As sector j increases its deliveries to final demand by one dollar, the total water withdrawn in all sectors is $\sum_{i=1}^{n} W_i C_{ij}$. If $\Delta\hat{Y}_j$ is the assumed increase in deliveries to final demand by sector j, then the total direct plus indirect increase in water withdrawals in all sectors is:

15. $$\sum_{i=1}^{n} W_i C_{ij} \cdot \Delta\hat{Y}_j$$

The scalar values represented in (15) may be summed to obtain the increase in total water withdrawn as all sectors expand deliveries to final demand simultaneously as in:

16. $$\sum_{j=1}^{n} \sum_{i=1}^{n} W_i C_{ij} \cdot \Delta\hat{Y}_j$$

The result in (16) is the same as in (13); i.e.,

17. $$\sum_{j=1}^{n} \sum_{i=1}^{n} W_i C_{ij} \cdot \Delta\hat{Y}_j = \sum_{i=1}^{n} W_i \Delta\hat{X}_i$$

but the information displayed in the sector-by-sector analysis is obviously much more detailed. The analysis of direct and indirect employment impacts parallels this statement and is not repeated here.

DERIVATION OF INCOME MULTIPLIERS

One other issue remains to be discussed in concluding our conceptual discussion of the basic input-output system and that is the use of the input-output model in deriving estimates of various multiplier effects. Three such effects will be considered here: the simple business multipliers, Type I income multipliers and Type II income multipliers. Since the Type I and Type II multipliers depend upon the manipulation of a specific household sector, we will make no attempt to derive them for our hypothetical example. Rather, we will address the procedure followed in their derivation and their meaning.

The business multiplier for each individual sector within an economy is an estimate of the total business activity generated per dollar of output delivered to final demand by a sector. This type of multiplier effect is obtained directly from the inverse of the Leontief matrix or $(I-A)^{-1}$ and is the sum down the individual columns of that matrix. A column sum for a sector equal to 1.95 indicates that every dollar delivered to final demand by that sector yields \$1.95 worth of economic activity throughout the economy. These multipliers relate specifically to changes in the levels of final demands for individual sectors.

Of interest to this study is the development of the Type I and Type II income multipliers. The Type I multiplier, or simple income multiplier, takes into account the direct and indirect income changes which result from additional direct income paid to households by all industries of the processing sector. The Type II income multiplier explicitly recognizes the induced income effects in addition to the direct and indirect income effects; i.e., it shows the chain reaction beginning with increased demands, increased output, increased income, increased consumption induced by increased household income, increased output and so on. It is thus the total direct, indirect and induced income change resulting from a one dollar increase in direct income.

As a first step in computing the Type I and Type II multipliers the households sector is included within the processing sector. A second set of direct and direct plus indirect requirements tables is then computed in the same manner described previously. The Type I income multiplier is calculated by first reading the direct income change (payments to household per dollar output in each sector) from the household row of the direct coefficients table with households included in the processing sector. The direct-plus-indirect income change is found by summing the product of each column entry of the $(I-A)^{-1}$ matrix (with households excluded from the processing sector) times the corresponding household row entries of the direct coefficients table (households included in the processing sector). The Type I income multiplier is computed by dividing the direct plus indirect income change by the direct income change. A Type I sectoral income multiplier of 2.10 tells us that for every dollar of direct income paid by that sector a total direct plus indirect income of $2.10 is generated; i.e., $2.10 of direct plus indirect income is created for every $1.00 direct income.

The Type II income multiplier is computed by dividing the total direct plus indirect plus induced income change by the direct income change. The direct plus indirect plus induced income effect for a given sector is read directly from the household row of the $(I-A)^{-1}$ matrix with households included in the processing sector. The direct income effect, again, is obtained from the household row of the direct coefficients table. A Type II income multiplier of 6.49 means that for every one dollar of direct income payed to households by a specific sector, a total direct, indirect, and induced income of $6.49 is generated in the economy.

RESOURCE LIMITATIONS AND LINEAR PROGRAMMING

In order to attach constraints on the processing sectors of the input-output model we must utilize the linear programming technique. This is so because the input-output model is driven by final demand. It is the nature of the I-O model that changes must initially be introduced in the final demand sector in order to project consistent estimates of the production requirements in each sector. In order to use the input-output model to study the effects of bottlenecks or constraints on economic growth the effects of the constraints must be introduced through limitations on growth assumed for the final demand sectors. If the linear programming technique is used no such restriction exists, as this latter technique allows constraints to be placed on any sector of the economy.

In order to formulate the linear programming model the primary structural requirement is the set of linear equations which make up the input-output model. Given an $\underline{n}$ industry processing sector these $\underline{n}$ equations may appear in the linear programming model in various ways. For example they may be used to introduce a constraint that the total output in any sector is greater than or equal to the base year level of production or simply that all $\underline{n}$ sectors have a positive level of production, etc. Other constraint functions may be introduced into the linear programming model. For instance, an equation showing the water requirements per dollar of output produced in each sector and indicating a maximum level for total water use may be included. The other important component of the linear programming model is the objective function. This function relates the variables in the model (output in each sector) to some desired goal. Procedures to find the best level of output for each sector in order to maximize the objective function taking account of other constraints contained in the model is the principal concern of the theory of mathematical programming and need not concern us here. It is sufficient that computerized techniques exist which select the best solution without evaluating all possible solutions thus greatly reducing the computational expenses. No direct method for finding an optimal solution to a linear programming problem is known. The lack of direct solutions forces us to resort to interactive step-by-step procedures that converge toward an optimal solution in a finite number of steps. These interactive processes, sometimes called algorithms, are ideally suited for computerized processing. Formally, then, the addition of resource rows to an input-output model necessitates its conversion to an optimization problem or a linear program. Without resource restraints the input-output model amounts to the solution of a set of n linear equations in n unknowns. This set of equations is represented in matrix form by $(I-A)X=d$, the solution of which is $X=(I-A)^{-1}d$. Addition of resource restraints requires that the $(I-A)$ matrix be modified to include one row of resource use constraints for each resource. With this addition, the new matrix of coefficients will appear as $\frac{I-A}{B}$. It is no longer possible for all restrictions to be met as equalities (to solve n+r equations in n unknowns), hence the problem is usually specified $\begin{bmatrix} I-A \\ \hline B \end{bmatrix} X \leq \begin{bmatrix} d \\ \hline R \end{bmatrix}$ where d is the vector of n final demands and R is a vector of r resource restraints. (The horizontal lines in the matrices represent partitions delineating types of variables appearing in the matrices.) As long as no resource is limiting there will be no restriction on final demands, and for a given set of final demands the first n restrictions will be satisfied as equalities, and the last r restrictions as inequalities. But if one or more resource restraints are binding, then there will be a corresponding restriction on one or more final demands. This choice of which final demand is not satisfied as an equality must depend upon some criterion. Therefore, a complete linear programming formulation requires that an objective function be specified giving values to unit levels of each sector output. The actual function used for this study was the sum of final demands which can be expressed as (1, 1, . . ., 1) (I-A)X. The complete linear program is then:

maximize (1, 1, 1, . . ., 1) (I-A)X

such that $\begin{bmatrix} I-A \\ \hline B \end{bmatrix} X \leq \begin{bmatrix} d \\ \hline R \end{bmatrix}$

This type of linear programming extension of a standard input-output model has several attractive features. First, linear programs are easily and efficiently soluable using standard computer techniques. Secondly, the linear programming solution furnishes approximate values at which a given resource becomes limiting while identifying sectors which use these resources (directly or indirectly) least effectively to achieve the desired objective. Third, this framework can be extended to include alternative technologies for each sector, allowing substitution of various resources for scarce resources. Finally, it is possible to incorporate supply and demand relationships and subregional relationships which give the model a considerably more realistic structure, although computational costs of solution are increased because the model becomes nonlinear.

CHAPTER III

THE SECTORAL STRUCTURING OF THE COLORADO I-O MODEL

INTRODUCTION

The input-output model requires the separation of the economy into various economic divisions or "sectors." Total output, by input-output accounting procedures, is the combined value of all sales that take place, or, total sales during a year. Total output must be divided up into sectors in order to study the structural interdependence that prevails. As has been shown previously, input-output models structure economic activity into two major components, suppliers or sellers and purchasers or users. Each of these is further subdivided in accordance with the following scheme. Suppliers include: 1) intermediate or processing suppliers who are producers who must purchase inputs to be processed into outputs which they sell to final users or as inputs to other processors, and 2) primary suppliers whose output is not directly dependent on purchased inputs. Purchasers include: 1) intermediate or processing purchasers who buy the outputs of suppliers for use as inputs for further processing, and 2) final purchasers who buy the outputs of suppliers in their final form and for final use. The level of demand by final purchasers and its composition are determined exogenously outside of the input-output system. Production to meet the exogenously determined final demand generates intermediate purchases of inputs. Primary suppliers and final purchasers may or may not be one and the same. However, the activities of primary suppliers and final purchasers are treated in the I-O model as if they were completely independent of each other. This is apparent from the differing sector structuring of the primary suppliers and the final purchasers. The two major divisions of the suppliers are then the intermediate suppliers which we will label as the processing sector and the primary suppliers which we will designate as the final payments sector. (The suppliers are conventionally shown along the left side of an input-output table.) The two major divisions of the purchasers are the intermediate purchasers which we will label as the processing sector (just as with the intermediate suppliers) and the final purchasers which we will designate as final demand. (The purchasers are conventionally shown along the top of an I-O table.) It is within this general framework that a further sector disaggregation must be accomplished.

A disaggregation within the broad categories delineated above would ideally consist of industries or producer groups which provide a homogeneous good or service. This ideal is very difficult to achieve because of the large amounts of time and finances that are required for detailed disaggregation and also because of a paucity of data. Any of these factors, or a combination of them lead to a violation of the homogeneous product ideal.

Sector selection, in addition to dependence upon financing, time, and data availability, should be determined to a large extent by the objectives of the study. The present study is particularly concerned with demands placed upon water resources as a result of changes in the economic activity in Colorado. Thus, the sector classification attempts to identify major water using sectors as well as sectors which are an important part of the state's economic activity but are not particularly heavy water users.

SECTORS OF THE STUDY

The sectors of the study were defined to follow the Standard Industrial Classifications of 1972. Aggregation across SIC numbers was made in order to provide that all sectors are of sufficient size to have a significant impact on the Colorado economy. In some cases data could not be further disaggregated because of disclosure rules. Table III-1 presents the sectors identified in the study and provides a short sector description. Table III-2 shows the related 1972 SIC numbers contained within each sector. It should be noted that some SIC industry divisions do not exist in Colorado or are too small to appear in the Census of Manufacturers. Hence, only the relevant SIC industries are shown in Table III-2. Because of incomplete primary and secondary data for certain sectors and because not all economic activity is allocated to SIC classification by the Census it was necessary and appropriate to include a miscellaneous sector in both the final demand and the final payments portions of the model. Table III-3 shows the relative size of each of the sectors. Data sources for the sector control totals are shown in Appendix A.

SECTOR DESCRIPTION

NATURAL GAS DISTRIBUTION

Establishments engaged in the distribution of natural gas for sale.

THE AGRICULTURAL SECTORS

Many input-output studies identify only a single agricultural sector. However, given our interest in pressures exerted on the state's water resources, the relatively large size of agricultural production in Colorado and the high rate of water use exhibited by agriculture, further disaggregation of the agricultural sector is desirable. Consequently, we have divided the sector into three components: livestock and livestock products, irrigated agriculture and dryland agriculture.

Table III-1: Short Sector Description

Sector Number	Short Sector Description
Processing Sectors	
1	Natural Gas Distribution
2	Livestock and Livestock Products
3	Irrigated Crops and Pasture
4	Dryland Crops and Pasture
5	Meat, Dairy, Grain and Other Food and Kindred Products
6	Metal Mining
7	Petroleum Production and Natural Gas Processing
8	Industrial Minerals Production, Cement and Concrete
9	Bituminous Coal Mining
10	Services to All Extractive Industries
11	Petroleum and Gas Pipelines
12	Petroleum Refining
13	Metal Smelting and Processing
14	Electric Power Generation and Transmission
15	Fabricated Metal, Metal Fixtures, Machinery, Transportation Equipment, Industrial and Household Wiring and Lighting
16	Electronic Components, Computers, Scientific and Medical Testing and Measuring Devices, Photographic and Optical Goods
17	Transportation, Communication and Public Utilities (Except Pipeline Transportation)
18	Textiles, Leather and Apparel

Table III-1: Short Sector Description (Continued)

Sector Number	Short Sector Description
19	Paper and Allied Products
20	Printing and Publishing
21	Chemicals, Explosives and Rubber Products
22	Lumber and Wood Products, Wood Furniture and Fixtures
23	All Other Manufacturing, Tobacco, Jewelry, Glass Products, Sporting Goods, Pencils, Etc.
24	Wholesale and Retail Trade
25	Services, Hotels, and Lodging Places, Personal and Business Services, Automotive Repair, Miscellaneous Repair, Motion Pictures, Amusement and Recreation, Health, Legal and Social Services, Membership Organizations
26	Primary and Secondary Level Education
27	University Level Education
28	The Final Individual Consumer
Final Demand Sectors	
29	Local, State and National Government Purchases
30	Exports from Colorado
31	Other Final Demand
Final Payments Sectors	
29	Local, State and National Government Receipts
30	Other Final Payments
31	Construction
32	Imports to Colorado

Table III-2: Sector Identification by Standard Industrial Classification

Sector Numbers	Sector Name	1972 SIC Codes
Processing Sectors		
1	Natural Gas Distribution	4924, 4931 (part)
2	Livestock and Livestock Products	02
3	Irrigated Agriculture	01
4	Dryland Agriculture	01
5	Food and Kindred Products	20
6	Metal Mining	1011, 1021, 1031, 1041, 1044, 1061, 1094, 1099
7	Petroleum Production	1311, 1321
8	Industrial Minerals Production	14 (except 148), 324, 325, 327
9	Coal Mining	1211
10	Mining Services	1081, 1213, 1381, 1382, 1389, 1481
11	Pipeline Transportation	4612, 4613, 4922, 4923
12	Petroleum Refining	2911, 295, 299
13	Primary Metal	33
14	Electric Power Generation	4911, 4931 (part)
15	Fabricated Metal, Machinery and Electrical	2514, 2515, 2522, 2542 2591, 2599, 34 (except 3482 and 3483), 35 (except 3573 and 3574), 362, 363, 364, 3691, 3692, 3694, 3699, 37
16	Electronic and Scientific Products	3573, 3574, 361, 365, 366, 367, 3693, 38
17	Transportation, Communication, and Utilities	40, 41, 42, 45, 47, 48, 49, (except 4922, 4923, 4924, and parts of 491 and 4931)

Table III-2: Sector Identification by Standard Industrial Classification (Continued)

Sector Numbers	Sector Name	1972 SIC Codes
18	Textiles, Leather, Apparel	22, 23, 31
19	Paper and Allied Products	26
20	Printing and Publishing	27
21	Chemicals, Explosives and Rubber Products	28, 30, 3482, 3483
22	Lumber and Wood Products	24, 2511, 2512, 2519, 2521, 2531, 2541
23	All Other Manufacturing	21, 323, 326, 328, 329, 39
24	Trade	50-59
25	Services	70, 72, 73, 75, 76, 78-81, 84, 86, 89
26	Other Education	821
27	University Education	822
28	Households	-
Final Demand Sectors		
29	Government	91-94
30	Exports	-
31	Other Final Demand	-
Final Payments Sectors		
29	Government	-
30	Other Final Payment	-
31	Construction	15, 16, 17
32	Imports	-

Table III-3: Relative Size of Sectors

Sector Numbers	Sector Name	Gross Output $ X 1000
1	Natural Gas Distribution	89,623
2	Livestock and Livestock Products	951,256
3	Irrigated Agriculture	320,982
4	Dryland Agriculture	135,271
5	Food and Kindred Products	1,787,260
6	Metal Mining	222,015
7	Petroleum Production	128,925
8	Industrial Minerals Production	195,068
9	Coal Mining	42,308
10	Mining Services	59,412
11	Pipeline Transportation	267,650
12	Petroleum Refining	89,900
13	Primary Metal	239,580
14	Electric Power Generation	112,802
15	Fabricated Metal, Machinery and Electrical	1,062,756
16	Electronic and Scientific Products	528,697
17	Transportation, Communication, and Utilities	1,081,292
18	Textiles, Leather and Apparel	108,940
19	Paper and Allied Products	53,240
20	Printing and Publishing	208,600
21	Chemicals, Explosives, and Rubber Products	327,360

Table III-3: Relative Size of Sectors (Continued)

Sector Numbers	Sector Name	Gross Output $ X 1000
22	Lumber and Wood Products	117,700
23	All Other Manufacturing	94,615
24	Trade	5,807,247
25	Services	1,975,044
26	Other Education	480,580
27	University Education	317,198
28	Households	8,084,834
29	Government (receipts)	4,527,410
30	Other Final Payments	3,228,268
31	Construction	2,037,522
32	Imports	3,745,223
	TOTAL GROSS OUTPUT	38,428,578

THE LIVESTOCK AND LIVESTOCK PRODUCTS SECTOR

This sector consists of all beef cattle and calves, dairy cattle and calves, hogs, sheep, goats, horses, poultry and all nonprocessed products of livestock.

THE IRRIGATED AGRICULTURAL SECTOR

This sector consists of a number of agricultural crops produced in the state. Table III-4 shows the principal irrigated crops listed in order of value of production for Colorado in 1970.

THE DRYLAND AGRICULTURAL SECTOR

Dryland agriculture is also of major importance in Colorado. In total, dryland agriculture accounts for about 30 percent of the value of production from crop lands in Colorado in 1970. Table III-5 shows the principal dryland crops listed in order of value of production for Colorado in 1970.

THE FOOD AND KINDRED PRODUCTS SECTOR

The food processing sector is one of the largest sectors in Colorado due, in the main, to the well-developed livestock and agricultural crops sectors. The food and kindred products sector includes meat packing plants, prepared meat products, processing of dairy products, prepared animal feed, cereal preparations, fruit and vegetable processing, bakery products, sugar and beverages.

METAL MINING

Exploration, development and production from metal mines. Iron, copper, lead and zinc, gold, silver ferroalloy ores, and uranium-radium-vanadium ores are included in this sector.

Table III-4: Colorado Irrigated Crops Ranked by Value of Production, 1970

Rank	Crop	Value of Production (in dollars)
1	Alfalfa Hay	52,326,000
2	Corn	43,441,200
3	Corn for Silage	37,220,000
4	Sugar Beets	35,507,000
5	Potatoes	18,868,000
6	Vegetables	17,991,000
7	Dry Beans	11,347,500
8	Barley	8,925,120
9	Sorghum for Grain	7,737,180
10	Fruits	5,931,000
11	Winter Wheat	4,269,720
12	Broomcorn	1,517,000
13	Oats	1,465,800
14	Sorghum for Silage	1,184,000
15	Spring Wheat	406,980
16	Rye	250,000
17	Alfalfa Seed	118,000
	TOTAL	247,071,500 [1/]

[1/] Total shown in Gross Flows Table is slightly larger due to the inclusion of other miscellaneous irrigated agricultural production.

Table III-5: Colorado Dryland Crops Ranked by Value of Production, 1970

Rank	Crop	Value of Production (in dollars)
1	Winter Wheat	73,734,780
2	Wild Hay	28,943,000
3	Barley	4,942,080
4	Sorghum for Grain	3,970,620
5	Dry Beans	3,637,500
6	Millet for Grain	2,654,000
7	Oats	2,118,200
8	Rye	1,248,000
9	Spring Wheat	942,480
10	Corn	910,800
11	Sorghum for Silage	363,200
	TOTAL	123,101,460 1/

1/ Total shown in Gross Flows Table is slightly larger due to the inclusion of other miscellaneous dryland agricultural production.

PETROLEUM PRODUCTION

Exploration, operation and maintenance of crude oil and gas producing wells and natural gas liquids production are included in this sector.

INDUSTRIAL MINERALS PRODUCTION

Dimension stone, crushed and broken stone, including riprap, sand and gravel, clay, ceramic and refractory minerals, chemical and fertilizer mining and other miscellaneous nonmetallic minerals except fuels are included in this sector. Also included is the processing of hydraulic cement, structural clay products, concrete, gypsum and plaster products.

COAL MINING

The coal mining sector includes mining, cleaning, crushing, screening, and sizing of bituminous coal.

MINING SERVICES

Metal mining services, bituminous coal mining services, drilling for oil and gas, oil and gas field exploration services, other oil and gas field services, nonmetallic minerals (except fuels) services are included in this sector.

PIPELINE TRANSPORTATION

Crude and refined petroleum pipelines and the transmission and storage of natural gas are included in this sector. The distribution of natural gas to a few large users is also carried out by the pipeline sector.

PETROLEUM REFINING

This sector includes the production of gasoline, kerosene, distillate fuel oils, residual fuel oils, lubricants and other products from crude petroleum.

PRIMARY METAL

This sector includes the manufacture of pig iron, silvery pig iron and ferroalloys from iron ore and iron and steel scrap, converting pig iron, scrap iron and scrap steel into steel, and hot rolling iron and steel into basic shapes.

ELECTRIC POWER GENERATION

The generation and transmission of electric energy.

FABRICATED METAL, MACHINERY AND ELECTRICAL

This sector includes office and household metal furnishings, fabricated metal products except ammunition, electrical and nonelectrical machines except electronic calculators and accounting machines, lighting and wiring, batteries, other miscellaneous electrical machinery, and transportation equipment.

ELECTRONIC AND SCIENTIFIC PRODUCTS

Electronic calculating and computing equipment, transformers, switches, electric motors, controls, etc., radio, television, communications electronics and electronics components, x-ray and electromedical apparatus, measuring, analyzing and controlling instruments, photographic, medical and optical goods, watches and clocks are included in this sector.

TRANSPORTATION, COMMUNICATION AND PUBLIC UTILITIES

This sector includes railroad transportation, local and suburban transit and interurban highway passenger transportation, motor freight and warehousing, air transportation, transportation services, communication services, electric energy distribution, and sanitary services except for natural gas transmission and distribution, water supply systems except irrigation.

TEXTILES, LEATHER AND APPAREL

This sector includes the preparation of fiber and the manufacturing of yarn, thread, braids, twine, and cordage; the manufacture of woven fabric, knit fabric, and carpets and rugs from yarn; dyeing and finishing fiber, yarn, fabric and knit apparel; coating, waterproofing or otherwise treating fabric; the manufacture of knit apparel and other finished articles from yarn; the manufacture of felt or lace goods, nonwoven fabrics and miscellaneous textiles; the production of clothing by cutting and sewing woven or knit textiles and related materials such as leather, rubberized fabric, plastics and furs, tanning, currying and finishing hides and skins and the manufacture of finished leather and artificial leather products and similar products made of other materials.

PAPER AND ALLIED PRODUCTS

The manufacture of pulps from wood and other cellulose fibers, and from rags, the manufacture of paper and paperboard, paper bags, paper boxes and envelopes are included in this sector.

PRINTING AND PUBLISHING

Printing by one or more of the common processes and printing services such as bookbinding, typesetting, engraving, photoengraving and electro typing, newspaper, book, and periodical publishing are included in this sector.

CHEMICALS, EXPLOSIVES AND RUBBER PRODUCTS

This sector includes the production of basic chemicals and the manufacturing of products by predominantly chemical processes, the manufacture of natural and synthetic or reclaimed rubber, gutta percha, balata or gutta siak rubber products such as tires, rubber footwear, mechanical rubber goods, heels and soles, flooring and rubber sundries, molding of plastics and the manufacture of finished plastic products. Also included are ammunition for small and large arms, bombs, torpedoes, grenades, depth charges, chemical warfare projectiles and component parts.

LUMBER AND WOOD PRODUCTS

This sector includes logging camps cutting timber and pulpwood, sawmills, lath mills, shingle mills, cooperage stock mills, planing mills, plywood mills, and veneer mills, establishments engaged in producing lumber and wood basic materials, and the manufacture of finished articles made mainly of wood or wood substitutes including wood furniture and fixtures for home, office, and public buildings, wood partitions, shelving, lockers and store fixtures.

ALL OTHER MANUFACTURING

This sector includes the manufacture of glass products made of purchased glass, pottery and related products, cut stone and stone products, miscellaneous manufacturing such as jewelry, silverware and plated ware, musical instruments, toys, sporting and atheletic goods, pens, pencils, office and artists materials, buttons, costume novelties, notions, brooms and brushes, caskets and other miscellaneous goods.

TRADE

Wholesale trade includes establishments primarily engaged in selling merchandise to retailers, to industrial, commercial, institutional, farm, or professional business users, to other wholesalers or acting as agents or brokers in buying merchandise for or selling merchandise to such persons or companies. Retail trade includes establishments engaged in selling merchandise for personal or household consumption, and rendering services incidental to the sale of the goods. This sector contains establishments engaged in selling to the general public.

In input-output accounting it is often the practice to attribute to the trade sector only the value of sales that represents gross margin (sales less cost of goods sold). If the goods sold by the trade sector are treated as inputs, other processing sectors will show less sales to final demand. A large share of sales to final demand would be registered in the trade sector because a large part of the sales of many industries reach consumers, and many intermediate users as well, through wholesalers and retailers. We have not followed the practice of measuring trade in terms of gross margins here because of the desire to trace the flows more precisely and in order to show the trade sector linkages. However, in order to reduce the "blowing-up" of the trade sector relative to other sectors we have adjusted the sales of trade to trade (sales of wholesale to retail and among wholesalers and retailers) to reflect the gross margin which is estimated to be 13 percent of sales volume.

SERVICES

This sector includes hotels, rooming houses, camps and other lodging places, personal services, business services, automotive repair services and garages, miscellaneous repair services, motion pictures, amusement and recreation services, health services, legal services, private art galleries, botanical and zoological gardens, business and professional membership organizations, private domestic services and other miscellaneous services.

OTHER EDUCATION

Elementary and secondary schools, both public and private make up this sector.

UNIVERSITY EDUCATION

Junior colleges, technical institutes, colleges, universities and professional schools, both public and private make up this sector.

HOUSEHOLDS

Purchases from households include wages, interest payments, and salaries paid by a firm which accrue to the individual. Purchases by households in general are the revenues accruing to the firm which are not obtained through the sale of goods and services to governments, to foreign (out-of-state) markets, or to other intermediate users. Thus, the household is the final individual consumer.

GOVERNMENT

Local, state and federal government including executive, legislative, justice, public order and safety, public finance, taxation, monetary regulators, and the administration of human resource programs make up this sector.

OTHER FINAL PAYMENTS

Finance, insurance and real estate and rent, interest and profit (except for agriculture which includes rent, interest, and profit in payments to households) plus unallocable payments. This sector includes banking, credit agencies other than banks, security and commodity brokers, dealers, exchanges, and services, insurance, insurance agents, brokers and services, real estate, combinations of real estate, insurance, loan and law offices, holding and other investment trusts. For the final payments group rent, interest and profit accruing to business and individuals except agriculture is included in this sector.

CONSTRUCTION (final payments sector)

This sector contains building construction, general contractors and operative builders, general contractors, special trade contractors, building, highway, bridge, tunnel, pipe and power line construction, interior and exterior building trades, well drilling and all other construction.

IMPORTS (final payments sector)

Purchases by Colorado firms or households from firms or households outside Colorado.

EXPORTS (final demand sector)

Sales by Colorado firms or households to households or firms outside Colorado.

OTHER FINAL DEMANDS

(As described in other final payments except that capital formation in Colorado is also included.) Unallocable sales, these numbers reflect residual discrepancies between input and output totals. These are sales or purchases which cannot be distributed among the sectors because of data imperfections or disclosure laws.

CHAPTER IV

DESCRIPTIVE ANALYSIS OF THE STATE ECONOMY

INTRODUCTION

This chapter presents results of the positive (or descriptive) analysis of the Colorado economy. Included in the discussion are: the description of the economy as it existed in 1970; an analysis of the nature and magnitude of economic interdependence among producing sectors; estimated business and income multipliers; the analysis of water use as it relates to aggregate economic activity and sector-by-sector levels of output; and the analysis of current employment and income.

THE DESCRIPTIVE ANALYSIS

The description of the Colorado economy rests on the construction and interpretation of three primary sources of information. These are the transactions table, the table of direct production requirements and the table of direct plus indirect production requirements. These three sources of information are closely related but each serves to describe the interrelationships among sectors in a different manner. We discuss each in turn.

THE TRANSACTIONS TABLE

The basic source of information in the input-output model is the transactions table, Table IV-1. This table depicts the estimated dollar value of flows of goods and services from each producing sector to all other sectors of the economy. It thus describes, simultaneously, the distribution of output to satisfy intermediate and final demands and the purchases by each sector necessary to produce its products. For purposes of explanation it is convenient to separate Table IV-1 into several components. The rows and columns numbered 1-28 constitute the processing sector. This portion of the table describes the flow of goods and services, in dollar terms which satisfy intermediate demands.[4/] In addition to the processing or intermediate demands portion of the table are final demands (columns 29, 30 and 31) and final payments (rows 29, 30, 31 and 32). Final demand or final consumption represents the final bill of goods; i.e., deliveries to sectors which do not further process the goods. The final payments sectors consist of payments in the form of taxes paid to governments, payments for construction, and payments made for goods and services not produced within the state. The sectors identified as Other Final Demands and Other Final Payments are essentially balance accounts whose individual components were not satisfactorily identified from the survey responses.

The last row and column of Table IV-1 are respectively the total gross outlay and total gross output by each sector of the economy. Each entry in the last row of the transactions table is the sum of the entries in the respective columns and each entry in the last column is the sum of the components in the respective rows. The final entry of Table IV-1 represents the total value of production for the Colorado economy, estimated at $38.4 billion for 1970.

Discussion of the distribution of output and purchases for a specific sector of the economy will aid in interpreting the information presented in Table IV-1. Consider sector 2 in the table, the livestock sector. Reading across the livestock row shows that the sector's output was distributed

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[4/] The households sector is often included in the final demand sector of the table. However, for the development of various multiplier impacts households is included as a processing sector. Thus, in this initial discussion we close the model with respect to households. The water use analysis requires some modification of this procedure which is explained subsequently.

TABLE IV-1

COLORADO GROSS FLOWS TABLE, 1970, IN THOUSAND:

	1 Nat. Gas	2 Live-stock	3 Irr. Ag.	4 Dry. Ag.	5 Food Proc.	6 Met. Min.	7 Pet. Prod.	8 Ind. Min. Prod.
1. Nat. Gas	0	1,450	670	167	2,894	13	31	2,539
2. Livestock	2	265,585	0	0	585,110	0	0	0
3. Irr. Ag.	0	192,276	0	0	77,127	0	0	0
4. Dry. Ag.	0	46,431	0	0	33,275	0	0	0
5. Food Proc.	0	0	34,529	5,741	54,599	0	0	0
6. Met. Min.	0	0	0	0	0	0	0	0
7. Pet. Prod.	0	0	0	0	0	0	3,733	0
8. Ind. Min. Prod.	10	0	0	0	1,108	3,289	0	0
9. Coal Min.	0	0	0	0	0	0	0	0
10. Min. Serv.	0	0	0	0	0	16,667	13,519	301
11. Pipe. Trans.	48,424	0	0	0	1,529	374	270	264
12. Pet. Ref.	0	0	0	0	136	208	17	360
13. Prim. Met.	0	0	0	0	0	2,375	0	0
14. Elec. Pow. Gen.	0	0	0	0	0	0	0	0
15. Fab. Met.	37	271	526	71	9,644	7,372	589	6,034
16. Electronics	25	0	0	0	365	0	0	0
17. Trans., Com., Put. Ut.	635	1,429	8,244	1,613	44,518	23,954	4,437	40,648
18. Textiles	0	616	3,712	0	0	0	0	0
19. Paper	0	0	572	34	6,182	63	46	222
20. Printing	180	138	0	0	82	144	176	21
21. Chem.	24	18,118	35,870	7,443	253	5,549	259	861
22. Wood Prod.	0	0	55	37	17	4,123	31	84
23. Oth. Mfg.	0	0	0	0	632	344	41	1,022
24. Trade	2,101	19,055	25,747	11,892	2,305	2,084	6	7,934
25. Serv.	171	67,307	67,472	26,808	851	462	905	962
26. El., Sec. Ed.	0	0	0	0	0	0	0	0
27. Univ. Ed.	8	1,845	0	210	270	0	0	0
28. Households	13,570	151,330	61,586	30,016	161,333	52,731	48,337	35,593
29. Govts.	7,304	13,232	13,348	7,667	43,638	24,699	24,583	8,848
30. Oth. Fin. Pay.	16,135	104,569	64,057	41,118	354,977	47,615	31,922	62,496
31. Const.	204	3,086	4,040	1,625	43,000	4,814	0	9,251
32. Imports	793	64,518	554	829	363,415	25,135	23	17,628
33. T. G. O.	89,623	951,256	320,982	135,271	1,787,260	222,015	128,925	195,068

	9 Coal Min.	10 Min. Serv.	11 Pipe. Trans.	12 Pet. Ref.	13 Prim. Met.	14 Elec. Pow. Gen.	15 Fab. Met.	16 Elec-tron-ics	17 Trans., Com., Pub. Ut.
1. Nat. Gas	0	0	0	224	89	0	751	472	2,827
2. Livestock	0	0	0	0	0	0	0	0	33
3. Irr. Ag.	0	0	0	0	0	0	0	0	0
4. Dry. Ag.	0	0	0	0	0	0	0	0	0
5. Food Proc.	0	0	0	0	0	0	0	0	2,451
6. Met. Min.	0	0	0	0	1,442	0	811	0	0
7. Pet. Prod.	0	0	107,426	0	0	0	0	0	0
8. Ind. Min. Prod.	1,631	442	0	0	1,852	0	521	0	1,002
9. Coal Min.	0	0	0	0	6,630	10,260	0	0	0
10. Min. Serv.	1,880	0	14,395	0	0	0	1,210	0	0
11. Pipe. Trans.	0	0	0	56,413	3,949	8,139	0	3,047	0
12. Pet. Ref.	27	35	0	0	170	57	152	0	3,569
13. Prim. Met.	0	0	0	0	17,376	0	88,593	0	1,342
14. Elec. Pow. Gen.	0	0	0	0	0	0	0	0	110,500
15. Fab. Met.	917	518	935	2,692	5,591	1,577	54,365	5,626	3,380
16. Electronics	0	29	1	1	0	37	7,868	30,818	25,002
17. Trans., Com., Put. Ut.	4,806	1,878	1,939	121	4,377	7,892	10,972	7,360	51,108
18. Textiles	0	0	0	0	0	0	0	0	429
19. Paper	18	7	0	11	29	29	1,717	788	260
20. Printing	21	17	75	14	0	34	914	1,161	4,989
21. Chem.	383	60	157	63	3006	0	2,230	5,441	777
22. Wood Prod.	251	72	0	0	623	191	543	0	1,510
23. Oth. Mfg.	38	544	453	394	3,481	246	1,338	5,773	156
24. Trade	260	3,000	2,691	1,024	4,362	1,093	9,327	211	40,300
25. Serv.	230	2,398	814	22	1,212	116	3,650	10,708	28,611
26. El., Sec. Ed.	0	0	0	0	0	0	0	0	0
27. Univ. Ed.	0	0	0	0	0	0	810	993	67
28. Households	13,017	23,220	2,891	5,873	68,145	14,300	162,957	119,980	384,263
29. Govts.	3,439	4,000	5,442	7,606	14,420	19,113	52,750	75,068	120,857
30. Oth. Fin. Pay.	10,524	23,192	22,601	9,729	25,920	35,678	81,016	113,748	256,676
31. Const.	180	0	0	0	23,243	2,342	28,982	37,632	974
32. Imports	4,686	0	107,830	5,713	53,663	11,698	551,279	109,871	40,209
33. T. G. O.	42,308	59,412	267,650	89,900	239,580	112,802	1,062,756	528,697	1,081,292

DOLLARS

18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
Tex-tiles	Paper	Print-ing	Chem.	Wood Prod.	Oth. Mfg.	Trade	Serv.	El., Sec. Ed.	Univ. Ed.	House-holds	Govts.	Exports	Oth. Fin. Dem.	T. G. O.
105	85	84	239	153	179	5,047	8,266	2,777	1,848	50,178	3,476	0	5,059	89,623
0	0	0	0	0	4	38,203	5,870	0	1,819	12,454	2,893	32,688	6,595	951,256
0	0	0	0	0	257	23,550	2,955	0	285	144	7,515	9,816	7,057	320,982
0	0	0	0	0	0	0	0	0	0	0	20,163	34,260	1,142	135,271
0	0	0	0	0	407	640,097	5,750	14,700	3,411	172,410	147,797	667,613	37,755	1,787,260
0	0	0	150	0	0	0	0	0	0	0	0	189,540	30,072	222,015
0	0	0	134	0	0	0	0	0	0	0	0	16,298	1,334	128,925
0	0	0	1,564	0	955	17,030	22,435	663	0	0	32,569	8,716	101,281	195,068
0	0	0	0	0	0	0	439	20	0	40	0	18,904	6,015	42,308
0	0	0	0	0	0	0	0	0	0	0	0	11,351	89	59,412
0	0	0	215	98	104	1,168	0	0	0	0	2,753	105,471	35,432	267,650
0	12	0	64	45	0	40,234	0	0	0	0	0	33,678	11,136	89,900
0	0	0	0	0	4,125	73	3,185	0	0	0	0	113,417	9,094	239,580
0	0	0	0	0	0	0	0	0	0	0	1,500	0	802	112,802
941	0	0	8,900	5,190	3,752	34,134	89,022	2,627	257	9,381	9,596	763,996	34,815	1,062,756
108	0	315	0	0	220	7,525	69,848	4,535	1,359	0	758	379,883	0	528,697
820	1,514	2,472	6,920	3,605	2,422	313,214	65,124	9,765	9,983	237,963	58,976	94,177	58,406	1,081,292
1,225	0	0	0	0	4,795	12,508	42,028	0	0	10,415	0	33,053	159	108,940
497	461	2,778	1,482	894	2,363	12,263	6,377	1,071	171	0	0	4,556	10,349	53,240
616	20	8,177	618	83	1,289	43,904	28,119	12,057	4,232	21,006	1,390	41,057	38,066	208,600
264	1,067	180	10,148	0	7,944	56,234	69,165	773	186	0	2,945	97,513	447	327,360
0	0	0	1,366	8,337	1,661	17,691	399	1,242	50	46	163	17,617	61,591	117,700
0	326	0	62	233	5,774	24,853	18,995	600	86	13,194	313	15,717	0	94,615
431	185	1,676	2,308	2,797	4,171	1,438,967	163,177	8,038	9,615	2,295,000	208,728	1,341,255	197,507	5,807,247
560	470	4,514	4,697	39	3,808	277,955	243,794	4,251	6,385	850,000	38,026	266,000	61,846	1,975,044
0	0	0	0	0	0	0	0	4,483	0	0	416,667	0	59,430	480,580
9	0	0	90	422	0	196	786	0	854	105,300	160,890	26,880	17,568	317,198
35,378	9,385	68,777	76,646	22,433	38,195	895,859	443,739	283,913	168,600	850	1,854,487	0	2,837,430	8,084,834
6,916	3,438	16,852	26,205	5,958	3,855	184,460	199,213	0	334	2,563,400	685,000	0	385,765	4,527,410
8,824	6,974	32,397	48,777	9,313	4,485	205,652	354,261	58,115	51,545	1,085,901	50,979	9,072	0	3,228,268
1,000	1,600	7,600	12,551	2,893	158	140,708	118,798	50,000	11,802	379,055	600,490	68,689	482,805	2,037,522
51,246	27,703	62,778	124,224	55,207	3,692	1,375,722	13,299	20,950	44,376	278,097	0	0	330,085	3,745,223
08,940	53,240	208,600	327,360	117,700	94,615	5,807,247	1,975,044	480,580	317,198	8,084,834	4,308,074	4,401,217	4,829,132	38,428,578

in the following manner: $2 thousand to natural gas; $265.6 million worth of output was sold to the livestock sector itself; $585.1 million was sold to food processing; $33 thousand to transportation, communication, and public utilities; $4 thousand to other manufacturing; $38.2 million to trade; $5.9 million to services; $1.8 million to university education; $12.5 million to households; $2.9 million to governments; $32.7 million to exports; and $6.6 million to other final demands. Summing these sales yields the total gross output of $951.3 million for the livestock sector.

Reading down column 2 identifies the purchases made by the livestock sector from each of the other sectors in the economy. The livestock sector purchased $1.5 million from the natural gas sector; $265.6 million from itself; $192.3 million from irrigated agriculture; $46.4 million from dry-land agriculture; $271 thousand from fabricated metals; $1.4 million from transportation, communication, and public utilities; $616 thousand from textiles; $138 thousand from printing; $18.1 million from chemicals; $19.1 million from trade; $67.3 million from services; $1.8 million from university education; $151.3 million from households; $13.2 million from governments; $104.6 million from other final payments (including rents, profits, depreciation, finance, insurance, etc.); $3.1 million from construction; and $64.5 million from imports. The sum of the column 1 entries yields the total gross outlay of $951.3 million. It is noted that the row and column sums for each processing sector must be equal since all purchases and all sales are accounted for.

Several other items can be obtained directly from the information presented in Table IV-1. The household row represents payments to the labor sector of the economy and thus approximates the contribution to personal income by each sector listed at the top of the table. An examination of the household row indicates that for the processing sectors (1-27), the leading contributors to household income are: trade ($896 million); services ($444 million); transportation, communications, and public utilities ($384 million); elementary and secondary education ($284 million); university education ($169 million); fabricated metals ($163 million); food processing ($161 million); livestock ($151 million); and electronics ($120 million).

Gross state income and gross state product may also be approximated from Table IV-1. Gross state product is defined as the sum of deliveries to final demand net of imports. For the Colorado economy in 1970, gross state product is estimated at $17.9 billion. Gross state income is computed directly from the final payments sector of Table IV-1 and is identical to gross state product. The procedure followed in estimating gross state income is to sum all entries in final payments (excluding imports).[5/] Individual sector contributions to gross state income and gross state product may, of course, be estimated by summing the appropriate final payments and final demands for the individual sectors.

THE TABLE OF DIRECT (TECHNICAL) PRODUCTION COEFFICIENTS

The second basic component of the interindustry analysis is the direct or technical coefficients table, Table IV-2. The elements of Table IV-2 are derived by dividing the entries in each column of the transactions table by the respective column totals. The coefficients presented in Table IV-2 describe the purchases necessary from each sector at the left of the table in order for the sector at the column head to produce one dollar's worth of output. Thus they are the direct requirements per dollar of output.

[5/] The calculation of both gross state product and gross state income, as presented in the text, include households as a final consumer and as a primary payments sector.

TABLE IV-2

DIRECT PRODUCTION REQUIREMENTS, PER DOLLAR OUTPUT, COLORADO, 1970

	1 Nat. Gas	2 Live-stock	3 Irr. Ag.	4 Dry. Ag.	5 Food Proc.	6 Met. Min.	7 Pet. Prod.	8 Ind. Min. Prod.	9 Coal Min.	10 Min. Serv.	11 Pipe. Trans.
1. Nat. Gas	.0000	.0015	.0021	.0012	.0016	.0001	.0002	.0130	.0000	.0000	.0000
2. Livestock	.0000	.2792	.0000	.0000	.3274	.0000	.0000	.0000	.0000	.0000	.0000
3. Irr. Ag.	.0000	.2021	.0000	.0000	.0432	.0000	.0000	.0000	.0000	.0000	.0000
4. Dry. Ag.	.0000	.0488	.0000	.0000	.0186	.0000	.0000	.0000	.0000	.0000	.0000
5. Food Proc.	.0000	.0000	.1076	.0424	.0305	.0000	.0000	.0000	.0000	.0000	.0000
6. Met. Min.	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
7. Pet. Prod.	.0000	.0000	.0000	.0000	.0000	.0000	.0290	.0000	.0000	.0000	.4014
8. Ind. Min. Prod.	.0001	.0000	.0000	.0000	.0006	.0148	.0000	.0000	.0386	.0074	.0000
9. Coal Min.	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
10. Min. Serv.	.0000	.0000	.0000	.0000	.0000	.0751	.1049	.0015	.0444	.0000	.0538
11. Pipe. Trans.	.5403	.0000	.0000	.0000	.0009	.0017	.0021	.0014	.0000	.0000	.0000
12. Pet. Ref.	.0000	.0000	.0000	.0000	.0001	.0009	.0001	.0018	.0006	.0006	.0000
13. Prim. Met.	.0000	.0000	.0000	.0000	.0000	.0107	.0000	.0000	.0000	.0000	.0000
14. Elec. Pow. Gen.	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
15. Fab. Met.	.0004	.0003	.0016	.0005	.0054	.0332	.0046	.0309	.0217	.0087	.0035
16. Electronics	.0003	.0000	.0000	.0000	.0002	.0000	.0000	.0000	.0000	.0005	.0000
17. Trans., Com., Pub. Ut.	.0071	.0015	.0257	.0119	.0249	.1079	.0344	.2084	.1136	.0316	.0072
18. Textiles	.0000	.0006	.0116	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
19. Paper	.0000	.0000	.0018	.0003	.0035	.0003	.0004	.0011	.0004	.0001	.0000
20. Printing	.0020	.0001	.0000	.0000	.0000	.0006	.0014	.0001	.0005	.0003	.0003
21. Chem.	.0003	.0190	.1118	.0550	.0001	.0250	.0020	.0044	.0091	.0010	.0006
22. Wood Prod.	.0000	.0000	.0002	.0003	.0000	.0186	.0002	.0004	.0059	.0012	.0000
23. Oth. Mfg.	.0000	.0000	.0000	.0000	.0004	.0015	.0003	.0052	.0009	.0092	.0017
24. Trade	.0234	.0200	.0802	.0879	.0013	.0094	.0000	.0407	.0061	.0505	.0101
25. Serv.	.0019	.0708	.2102	.1982	.0005	.0021	.0070	.0049	.0054	.0404	.0030
26. El., Sec. Ed.	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
27. Univ. Ed.	.0001	.0019	.0000	.0016	.0002	.0000	.0000	.0000	.0000	.0000	.0000
28. Households	.1514	.1591	.1919	.2219	.0903	.2375	.3749	.1825	.3077	.3908	.0108

	12 Pet. Ref.	13 Prim. Met.	14 Elec. Pow. Gen.	15 Fab. Met.	16 Elec-tron-ics	17 Trans., Com., Pub. Ut.	18 Tex-tiles	19 Paper	20 Print-ing	21 Chem.
1. Nat. Gas	.0025	.0004	.0000	.0007	.0009	.0026	.0010	.0016	.0004	.0007
2. Livestock	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
3. Irr. Ag.	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
4. Dry. Ag.	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
5. Food Proc.	.0000	.0000	.0000	.0000	.0000	.0023	.0000	.0000	.0000	.0000
6. Met. Min.	.0000	.0060	.0000	.0008	.0000	.0000	.0000	.0000	.0000	.0005
7. Pet. Prod.	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0004
8. Ind. Min. Prod.	.0000	.0077	.0000	.0005	.0000	.0009	.0000	.0000	.0000	.0048
9. Coal Min.	.0000	.0277	.0910	.0000	.0000	.0000	.0000	.0000	.0000	.0000
10. Min. Serv.	.0000	.0000	.0000	.0011	.0000	.0000	.0000	.0000	.0000	.0000
11. Pipe. Trans.	.6275	.0165	.0722	.0000	.0058	.0000	.0000	.0000	.0000	.0007
12. Pet. Ref.	.0000	.0007	.0005	.0001	.0000	.0033	.0000	.0002	.0000	.0002
13. Prim. Met.	.0000	.0725	.0000	.0834	.0000	.0012	.0000	.0000	.0000	.0000
14. Elec. Pow. Gen.	.0000	.0000	.0000	.0000	.0000	.1022	.0000	.0000	.0000	.0000
15. Fab. Met.	.0299	.0233	.0140	.0512	.0106	.0031	.0086	.0000	.0000	.0272
16. Electronics	.0000	.0000	.0003	.0074	.0583	.0231	.0010	.0000	.0015	.0000
17. Trans., Com., Pub. Ut.	.0013	.0183	.0700	.0103	.0139	.0473	.0075	.0284	.0119	.0211
18. Textiles	.0000	.0000	.0000	.0000	.0000	.0004	.0112	.0000	.0000	.0000
19. Paper	.0001	.0001	.0003	.0016	.0015	.0002	.0046	.0087	.0133	.0045
20. Printing	.0002	.0000	.0003	.0009	.0022	.0046	.0057	.0004	.0392	.0019
21. Chem.	.0007	.0125	.0000	.0021	.0103	.0007	.0024	.0200	.0009	.0310
22. Wood Prod.	.0000	.0026	.0017	.0005	.0000	.0014	.0000	.0000	.0000	.0042
23. Oth. Mfg.	.0044	.0145	.0022	.0013	.0109	.0001	.0000	.0061	.0000	.0002
24. Trade	.0114	.0182	.0097	.0088	.0004	.0373	.0040	.0035	.0080	.0071
25. Serv.	.0002	.0051	.0010	.0034	.0203	.0265	.0051	.0088	.0216	.0143
26. El., Sec. Ed.	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
27. Univ. Ed.	.0000	.0000	.0000	.0008	.0019	.0001	.0001	.0000	.0000	.0003
28. Households	.0653	.2844	.1268	.1533	.2269	.3554	.3247	.1763	.3297	.2341

22 Wood Prod.	23 Oth. Mfg.	24 Trade	25 Serv.	26 El., Sec. Ed.	27 Univ. Ed.	28 House-holds
.0013	.0019	.0009	.0042	.0058	.0058	.0062
.0000	.0000	.0066	.0030	.0000	.0057	.0015
.0000	.0027	.0041	.0015	.0000	.0009	.0000
.0000	.0000	.0000	.0000	.0000	.0000	.0000
.0000	.0043	.1102	.0029	.0306	.0108	.0213
.0000	.0000	.0000	.0000	.0000	.0000	.0000
.0000	.0000	.0000	.0000	.0000	.0000	.0000
.0000	.0101	.0029	.0114	.0014	.0000	.0000
.0000	.0000	.0000	.0002	.0000	.0000	.0000
.0000	.0000	.0000	.0000	.0000	.0000	.0000
.0008	.0011	.0002	.0000	.0000	.0000	.0000
.0004	.0000	.0069	.0000	.0000	.0000	.0000
.0000	.0436	.0000	.0016	.0000	.0000	.0000
.0000	.0000	.0000	.0000	.0000	.0000	.0000
.0441	.0397	.0059	.0451	.0055	.0008	.0012
.0000	.0023	.0013	.0354	.0094	.0043	.0000
.0306	.0256	.0539	.0330	.0203	.0315	.0294
.0000	.0507	.0022	.0213	.0000	.0000	.0013
.0076	.0250	.0021	.0032	.0022	.0005	.0000
.0007	.0136	.0076	.0142	.0251	.0133	.0026
.0000	.0840	.0097	.0350	.0016	.0006	.0000
.0708	.0176	.0030	.0002	.0026	.0002	.0000
.0020	.0610	.0043	.0096	.0012	.0003	.0016
.0238	.0441	.2478	.0826	.0167	.0303	.2839
.0003	.0402	.0479	.1234	.0088	.0201	.1051
.0000	.0000	.0000	.0000	.0093	.0000	.0000
.0036	.0000	.0000	.0004	.0000	.0027	.0130
.1906	.4037	.1543	.2247	.5908	.5315	.0001

For purposes of interpretation, consider the metal mining sector of Table IV-2 (column 6). For every dollar of output produced in the metal mining sector, \$.015 worth of output is required from the industrial minerals production sector; \$.075 from mining services; \$.002 from pipeline transportation; \$.001 from petroleum refining; \$.011 from primary metals; \$.033 from fabricated metals; \$.108 from transportation, communication, and public utilities; and so forth down the column. Each of the remaining columns is interpreted in this manner. The sums of all entries in any single column indicate the total direct value of production in all processing sectors of the economy necessary for the sector at the column head to produce one dollar's worth of output.

These direct production impacts, however, represent only a portion of the total impacts of exogenous changes in an economy. Indirect impacts also exist and may be quite sizable depending upon the degree of interdependence among the various processing sectors. The third analytical component of the accounting system, the table of direct plus indirect production coefficients, provides an assessment of the extent and magnitude of economic interdependence.

THE TABLE OF DIRECT PLUS INDIRECT PRODUCTION COEFFICIENTS

Table IV-3 presents the direct plus indirect production coefficients, by sector, as estimated for the Colorado economy in 1970. The table shows the direct plus indirect production in each sector of the economy necessary to sustain the delivery of one dollar's worth of output in a particular sector to final consumption. Consider column 5, food processing. Assume that the final demand for the output of the food processing sector increases by one dollar. Given this exogenous change, we wish to estimate its total impact on the other sectors of the economy. This estimated impact may be obtained directly from Table IV-3 by reading down the food processing column.

TABLE IV-3

DIRECT PLUS INDIRECT PRODUCTION REQUIREMENTS PER DOLLAR OUTPUT DELIVERED TO FINAL DEMAND, COLORADO, 1970

(Households in Processing Sector)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
	Nat. Gas	Live-stock	Irr. Ag.	Dry. Ag.	Food Proc.	Met. Min.	Pet. Prod.	Ind. Min. Prod.	Coal Min.	Min. Serv.	Pipe. Trans.	Pet. Ref.	Prim. Met.	Elec. Pow. Gen.	Fab. Met.	Elec-tron-ics	Trans., Com. Pub. Ut.	Tex-tiles
1. Nat. Gas	1.0029	.0078	.0074	.0061	.0059	.0040	.0047	.0167	.0047	.0047	.0024	.0048	.0041	.0024	.0028	.0037	.0071	.0042
2. Livestock	.0160	1.4291	.0787	.0472	.4922	.0180	.0217	.0186	.0200	.0255	.0119	.0122	.0187	.0115	.0107	.0130	.0249	.0161
3. Irr. Ag.	.0054	.2940	1.0247	.0153	.1469	.0060	.0072	.0062	.0067	.0086	.0040	.0041	.0063	.0038	.0036	.0044	.0083	.0053
4. Dry. Ag.	.0013	.0713	.0069	1.0040	.0441	.0015	.0018	.0015	.0017	.0021	.0010	.0010	.0016	.0010	.0009	.0011	.0021	.0013
5. Food Proc.	.0293	.0811	.1617	.0925	1.0774	.0329	.0395	.0341	.0366	.0465	.0218	.0223	.0343	.0210	.0195	.0236	.0457	.0293
6. Met. Min.	.0000	.0001	.0001	.0001	.0000	1.0001	.0000	.0001	.0001	.0000	.0000	.0001	.0066	.0000	.0014	.0000	.0000	.0000
7. Pet. Prod.	.2248	.0027	.0028	.0024	.0024	.0030	1.0326	.0062	.0024	.0021	.4147	.2612	.0092	.0312	.0017	.0038	.0065	.0014
8. Ind. Min. Prod.	.0019	.0047	.0057	.0050	.0031	.0174	.0028	1.0020	.0409	.0102	.0019	.0017	.0116	.0047	.0024	.0016	.0037	.0014
9. Coal Min.	.0005	.0007	.0009	.0007	.0007	.0019	.0008	.0025	1.0016	.0008	.0005	.0005	.0305	.0920	.0030	.0005	.0103	.0004
10. Min. Serv.	.0528	.0007	.0007	.0006	.0006	.0760	.1087	.0032	.0452	1.0006	.0975	.0614	.0041	.0115	.0019	.0009	.0020	.0004
11. Pipe. Trans.	.5437	.0064	.0067	.0056	.0056	.0073	.0067	.0151	.0058	.0052	1.0033	.6318	.0223	.0756	.0042	.0092	.0158	.0035
12. Pet. Ref.	.0015	.0023	.0026	.0025	.0015	.0029	.0021	.0042	.0028	.0029	.0012	1.0012	.0025	.0018	.0012	.0011	.0056	.0013
13. Prim. Met.	.0012	.0027	.0034	.0028	.0020	.0162	.0018	.0045	.0036	.0028	.0014	.0042	1.0826	.0024	.0957	.0025	.0032	.0016
14. Elec. Pow. Gen.	.0048	.0061	.0084	.0063	.0062	.0155	.0080	.0256	.0168	.0079	.0047	.0039	.0061	1.0109	.0033	.0040	.1123	.0036
15. Fab. Met.	.0096	.0207	.0264	.0216	.0165	.0454	.0142	.0407	.0331	.0204	.0113	.0405	.0359	.0222	1.0606	.0185	.0151	.0150
16. Electronics	.0043	.0127	.0152	.0138	.0073	.0073	.0062	.0096	.0080	.0081	.0036	.0035	.0050	.0051	.0110	1.0661	.0319	.0049
17. Trans., Com., Pub. Ut.	.0471	.0594	.0821	.0620	.0611	.1516	.0778	.2505	.1641	.0768	.0459	.0381	.0596	.1068	.0320	.0391	1.0985	.0353
18. Textiles	.0025	.0120	.0208	.0084	.0060	.0030	.0037	.0031	.0034	.0051	.0021	.0022	.0038	.0019	.0018	.0032	.0045	1.0140
19. Paper	.0011	.0031	.0053	.0030	.0053	.0018	.0017	.0025	.0018	.0020	.0010	.0012	.0018	.0011	.0025	.0028	.0019	.0056
20. Printing	.0063	.0088	.0097	.0090	.0050	.0056	.0069	.0054	.0059	.0068	.0039	.0037	.0048	.0035	.0035	.0061	.0109	.0098
21. Chem.	.0068	.0800	.1364	.0749	.0366	.0329	.0101	.0118	.0170	.0120	.0062	.0067	.0225	.0053	.0077	.0177	.0102	.0082
22. Wood Prod.	.0009	.0017	.0022	.0020	.0010	.0214	.0015	.0019	.0077	.0028	.0009	.0009	.0047	.0032	.0015	.0009	.0030	.0007
23. Oth. Mfg.	.0038	.0054	.0061	.0057	.0034	.0054	.0046	.0084	.0047	.0137	.0047	.0083	.0196	.0044	.0045	.0145	.0043	.0024
24. Trade	.1824	.2961	.3227	.3198	.1760	.1961	.2299	.2155	.2153	.2908	.1323	.1375	.2064	.1263	.1169	.1359	.2669	.1704
25. Serv.	.0643	.2804	.3304	.3072	.1367	.0761	.0982	.0733	.0875	.1342	.0552	.0509	.0771	.0469	.0447	.0759	.1161	.0689
26. El., Sec. Ed.	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
27. Univ. Ed.	.0046	.0094	.0062	.0074	.0055	.0057	.0072	.0049	.0064	.0071	.0036	.0036	.0058	.0035	.0041	.0063	.0070	.0055
28. Households	.3414	.4817	.4410	.4239	.3192	.4169	.5426	.3618	.4787	.5313	.2705	.2643	.4328	.2602	.2485	.3233	.5150	.4065

19	20	21	22	23	24	25	26	27	28
Paper	Print-ing	Chem.	Wood Prod.	Oth. Mfg.	Trade	Serv.	El., Sec., Ed.	Univ. Ed.	House-holds
.0037	.0040	.0035	.0039	.0081	.0054	.0089	.0121	.0115	.0092
.0100	.0177	.0134	.0136	.0333	.0992	.0317	.0458	.0428	.0457
.0033	.0059	.0045	.0046	.0140	.0344	.0117	.0147	.0139	.0151
.0008	.0015	.0011	.0011	.0028	.0083	.0025	.0039	.0033	.0038
.0182	.0322	.0243	.0249	.0615	.1849	.0503	.0892	.0656	.0835
.0000	.0000	.0005	.0001	.0004	.0000	.0001	.0000	.0000	.0000
.0013	.0015	.0021	.0019	.0039	.0046	.0032	.0037	.0036	.0034
.0012	.0018	.0063	.0012	.0149	.0067	.0155	.0042	.0028	.0038
.0005	.0005	.0006	.0007	.0024	.0012	.0013	.0008	.0008	.0008
.0003	.0004	.0005	.0006	.0011	.0012	.0009	.0009	.0009	.0008
.0032	.0035	.0040	.0047	.0092	.0112	.0076	.0090	.0087	.0081
.0011	.0015	.0014	.0017	.0028	.0109	.0025	.0026	.0025	.0036
.0010	.0010	.0035	.0053	.0564	.0028	.0088	.0022	.0017	.0021
.0049	.0044	.0048	.0059	.0090	.0116	.0085	.0077	.0085	.0078
.0049	.0072	.0354	.0548	.0631	.0211	.0652	.0175	.0120	.0153
.0033	.0066	.0042	.0040	.0120	.0109	.0491	.0177	.0123	.0096
.0479	.0434	.0474	.0574	.0884	.1134	.0836	.0754	.0827	.0764
.0021	.0032	.0024	.0021	.0602	.0081	.0286	.0051	.0050	.0071
1.0096	.0150	.0056	.0092	.0299	.0052	.0062	.0046	.0025	.0024
.0031	1.0453	.0055	.0041	.0234	.0161	.0229	.0338	.0211	.0105
.0252	.0080	1.0373	.0050	.1065	.0283	.0519	.0137	.0122	.0151
.0007	.0008	.0053	1.0770	.0223	.0055	.0020	.0043	.0016	.0020
.0081	.0028	.0024	.0043	1.0710	.0096	.0157	.0060	.0047	.0064
.1064	.1893	.1437	.1548	.3474	1.5074	.3101	.3344	.3244	.4794
.0495	.0934	.0680	.0490	.1623	.1522	1.2227	.1326	.1351	.1813
.0000	.0000	.0000	.0000	.0000	.0000	.0000	1.0094	.0000	.0000
.0032	.0058	.0046	.0078	.0091	.0054	.0064	.0102	1.0119	.0158
.2434	.4328	.3217	.2905	.6712	.3847	.4360	.7622	.6886	1.1920

The assumed change in final demand for food processing output generates a total direct plus indirect production of \$.006 in the natural gas sector; \$.492 in the livestock sector; \$.147 in the irrigated agriculture sector, \$.044 in the dryland agriculture sector; \$1.077 in the food processing sector; and so forth down the column. Reading down any column of Table IV-3 gives the direct plus indirect production generated in each sector at the left of the table as the sector at the column head expands its deliveries to final demand by one dollar.

An additional piece of information may be derived by reading across any row of Table IV-3. The situation addressed here is that of estimating the total direct plus indirect production generated in a single sector as all sectors of the economy simultaneously expand their deliveries to final demand. Take row 2, the livestock sector, for example. As the natural gas sector expands its deliveries to final consumption by one dollar, a total direct plus indirect production of \$.016 is generated in the livestock sector. As the livestock sector expands its deliveries to final demand a total direct plus indirect production of \$1.429 is generated in the livestock sector. As irrigated agriculture expands its deliveries to final demand by one dollar, a total direct plus indirect production of \$.079 is generated in the livestock sector. A like interpretation attaches to each entry in the second row of Table IV-3. Every other row may be interpreted in this same manner.

BUSINESS MULTIPLIERS

The sums of the column entries in the direct plus indirect production requirements table have a particular significance in the system. These column sums yield the sector-by-sector business multipliers or total business activity generated for each additional dollar's worth of output delivered to final demand by each of the sectors identified. Thus, if a desired policy objective is to stimulate economic activity, these multipliers provide an indication of those sectors which will generate the greatest dollar value of production for each dollar's worth of output delivered to final consumption. Table IV-4 presents the business multipliers for the Colorado economy, by sector, as estimated for 1970.[6/]

The results presented in Table IV-4 indicate that in terms of business activity generated per dollar of final consumption the livestock sector ranks first in order of importance with a multiplier of (3.18). This is followed by other manufacturing (2.89), irrigated agriculture (2.72), trade (2.65), elementary and secondary education (2.62), food processing and petroleum refining (2.57), university education (2.48), and services and dryland agriculture (2.45). These are the sectors which exhibit the greatest interdependence with other sectors in the state economy and thus which would generate the greatest business activity per dollar of output delivered to final demand.

THE INCOME MULTIPLIERS

Other types of multiplier effects may also be estimated from the inter-industry analysis. Two of the most common are the Type I and Type II income multipliers. These multipliers, as distinct from the business multipliers, relate not to output, but rather to changes in income paid to the household sector. The Type I, or simple income multiplier, describes the direct plus indirect income increases stemming from an additional dollar of direct income paid to households. The simple income multiplier is derived as the ratio of direct plus indirect income to the direct income paid to households.

[6/] These estimates, and the elements of Table IV-4 are derived assuming a 13 percent margin in the cell showing sales among wholesalers and retailers in the trade sector.

Table IV-4: Business Multipliers for the Colorado Economy, by Sector, 1970

(in dollars of business activity generated per dollar delivered to final demand)

Sector	Business Multiplier
1. Natural Gas	2.56
2. Livestock	3.18
3. Irrigated Agriculture	2.72
4. Dryland Agriculture	2.45
5. Food Processing	2.57
6. Metal Mining	2.17
7. Petroleum Production	2.24
8. Industrial Minerals Production	2.13
9. Coal Mining	2.22
10. Mining Services	2.23
11. Pipeline Transportation	2.11
12. Petroleum Refining	2.57
13. Primary Metals	2.12
14. Electric Power Generation	1.86
15. Fabricated Metals	1.69
16. Electronics	1.78
17. Transportation, Communication, and Public Utilities	2.33
18. Textiles	1.82
19. Paper	1.56
20. Printing	1.93
21. Chemicals	1.75
22. Wood Products	1.79
23. Other Manufacturing	2.89
24. Trade	2.65
25. Services	2.45
26. Elementary and Secondary Education	2.62
27. University Education	2.48

The Type II multiplier takes into account not only the direct plus indirect changes in income, but also the induced income increases generated by additional consumer spending. The Type II income multiplier thus shows the direct plus indirect plus induced income generated by an additional dollar of income paid directly to households. Table IV-5 presents the two types of income multipliers for each sector of the economy. The reader must note with care that the income multipliers are ratios, respectively, of direct plus indirect income to direct income and direct plus indirect plus induced income to direct income. Thus, they must not be interpreted as the income generated in response to production changes in any given sector.

The preceding description of the state's economy provides the data input necessary to complete analyses of specific items of interest in this study. The following sections of the chapter relate the results of the water use analysis and the employment analysis. In each case the analysis is done for each sector of the economy with the results summarized in tabular form.

THE WATER USE ANALYSIS

The analysis of water use in the Colorado economy contains estimates of consumptive use requirements on a sector-by-sector basis. Water withdrawals in the manufacturing sectors are available from secondary sources such as the Census of Water Use in Manufacturing,[7/] on a regional basis. However, there are rather significant differences in the mix and composition

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7/ United States Geological Survey, Estimated Use of Water in the United States in 1970. Geological Survey Circular 676, by C. R. Murray and E. Bodette Reeves, Washington, 1972. Water for Tomorrow, Colorado State Water Plan, Phase I, Bureau of Reclamation in Cooperation with the State of Colorado, February, 1974.

Table IV-5: Type I and Type II Income Multipliers, Colorado, by Sector, 1970

(in dollars of income generated per dollar of direct income paid to households)

Sector		Type I	Type II
1.	Natural Gas	1.90	2.26
2.	Livestock	2.54	3.03
3.	Irrigated Agriculture	1.93	2.30
4.	Dryland Agriculture	1.60	1.91
5.	Food Processing	2.97	3.54
6.	Metal Mining	1.47	1.76
7.	Petroleum Production	1.21	1.45
8.	Industrial Minerals Production	1.66	1.98
9.	Coal Mining	1.31	1.56
10.	Mining Services	1.14	1.36
11.	Pipeline Transportation	*	*
12.	Petroleum Refining	3.39	4.05
13.	Primary Metals	1.28	1.52
14.	Electric Power Generation	1.72	2.05
15.	Fabricated Metals	1.36	1.62
16.	Electronics	1.20	1.42
17.	Transportation, Communication, and Public Utilities	1.22	1.45
18.	Textiles	1.05	1.25
19.	Paper	1.16	1.38
20.	Printing	1.10	1.31
21.	Chemicals	1.15	1.37
22.	Wood Products	1.28	1.52
23.	Other Manufacturing	1.40	1.66
24.	Trade	2.09	2.49
25.	Services	1.63	1.94
26.	Elementary and Secondary Education	1.08	1.29
27.	University Education	1.09	1.30

* The very small amount of direct income paid to households by pipelines makes the income multipliers for this sector misleading. Hence, they are not reported.

of sectors and products between individual states and broad, aggregate regions. Since this is the case, water withdrawal estimates in the manufacturing sectors defined in this study were derived from primary data collected in personal interviews and mail questionnaires. Estimates of water withdrawals (and consumptive use) in the agricultural sectors were derived from data from the United States Geological Survey, the Bureau of Reclamation, and the Colorado Water Conservation Board.

Consumptive use estimates were obtained, where possible, from personal interviews and mail questionnaires. However, the majority of these estimates were derived from published secondary sources.[8,9] Table IV-6 presents the sector-by-sector withdrawal and consumptive use requirements used in this study. The coefficients for water use are in gallons per dollar output. These estimates provide the means for estimating the total water withdrawals and total consumptive use of water in the state for the year 1970. Multiplying the water coefficients in Table IV-6 by the respective total output levels given in Table IV-2 gives total withdrawal and consumptive use for each sector of the economy. Summing these products yields the estimate of total withdrawals and consumptive use in the processing sectors of the economy. Households are treated as a residual water using sector as will be explained subsequently. Table IV-7 presents the estimates of water withdrawals and consumptive use in acre-feet.

The total consumptive use of water in the 27 producing sectors identified is 4,307,884 acre-feet. To this total is added 658,000 acre-feet of

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8/ Ibid.

9/ Census of Water Use in Manufacturing, U.S. Bureau of Census, Census of Manufacturing, 1972.

Table IV-6: Water Withdrawal and Consumptive Use Requirements Per Dollar of Output, Colorado, 1970

(in gallons per dollar)

	Sector	Withdrawal	Consumptive Use
1.	Natural Gas	1.06	.11
2.	Livestock	13.37	11.90
3.	Irrigated Agriculture	7,450.00	4,241.00
4.	Dryland Agriculture	.00	.00
5.	Food Processing	3.68	.35
6.	Metal Mining	108.40	53.75
7.	Petroleum Production	14.30	5.08
8.	Industrial Minerals Production	137.00	4.80
9.	Coal Mining	3.80	3.42
10.	Mining Services	6.30	.63
11.	Pipeline Transportation	5.00	.50
12.	Petroleum Refining	14.60	3.80
13.	Primary Metals	37.60	9.78
14.	Electric Power Generation	632.70	31.60
15.	Fabricated Metals	6.70	1.60
16.	Electronics	1.50	.27
17.	Transportation, Communication, and Public Utilities	25.00	1.50
18.	Textiles	3.20	.32
19.	Paper	1.30	.25
20.	Printing	.80	.08
21.	Chemicals	50.10	8.02
22.	Wood Products	27.30	13.98
23.	Other Manufacturing	15.00	2.00
24.	Trade	2.30	.23
25.	Services	6.30	.63
26.	Elementary and Secondary Education	5.90	.59
27.	University Education	5.90	.59

estimated nonbeneficial use.[10/] Also, the household sector use must be included in this total. Household use, which accounts for all uses not identified in the sectors listed in Table IV-7, is assumed to require 130 gallons per capita per day for withdrawal. Applying this figure to the estimated 1970 population of 2,224,000 yields an estimated household withdrawal of 323,600 acre-feet per year. Assuming that consumptive use amounts to 20 percent of total withdrawals, consumptive use equals 64,720 acre-feet per year. Thus, the total estimated consumptive use for Colorado in 1970 is 5,030,604 acre-feet. This estimate is within 4.5 percent of the Colorado Water Conservation Board and Bureau of Reclamation estimates.[11/] While these estimates are of historical interest, the model used in this analysis can be applied to issues of more significance from the planning perspective.

DIRECT PLUS INDIRECT WATER REQUIREMENTS

In the arid and semi-arid west, a contemporary problem to which the model can be applied is that of measuring the relationship between economic activity and water use. Planners are finding it increasingly important to assess the adequacy of the water resource base to support continued population growth and associated increase in economic activity. Efforts in this direction require not only a description of existing relationships between production activities and water use but also a means of projecting potential water requirements to support growth. The input-output model provides a framework within which both issues can be addressed. The key element in assessing the impact of various exogenous changes in the economy on water use is the derivation of the direct plus indirect water requirements accompanying

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10/ Water For Tomorrow, Colorado State Water Plan, Phase I, February, 1974.

11/ Ibid. Total consumptive use was estimated at 5,268,000 acre-feet.

Table IV-7: Water Withdrawals and Consumptive Use, By Sector, Colorado, 1970

(in acre-feet)

	Sector	Withdrawal	Consumptive Use
1.	Natural Gas	291	30
2.	Livestock	39,013	34,739
3.	Irrigated Agriculture	7,338,476	4,177,514
4.	Dryland Agriculture	0	0
5.	Food Processing	20,184	1,920
6.	Metal Mining	73,855	36,621
7.	Petroleum Production	5,658	2,010
8.	Industrial Minerals Production	82,012	2,873
9.	Coal Mining	493	444
10.	Mining Services	1,149	115
11.	Pipeline Transportation	4,107	411
12.	Petroleum Refining	4,028	1,048
13.	Primary Metals	27,644	7,190
14.	Electric Power Generation	219,020	10,939
15.	Fabricated Metals	21,851	5,218
16.	Electronics	2,434	438
17.	Transportation, Communication, and Public Utilities	82,957	4,977
18.	Textiles	1,070	107
19.	Paper	212	41
20.	Printing	512	51
21.	Chemicals	50,331	8,057
22.	Wood Products	9,861	5,050
23.	Other Manufacturing	4,355	581
24.	Trade	40,989	4,099
25.	Services	38,184	3,818
26.	Elementary and Secondary Education	8,701	870
27.	University Education	5,743	574
	TOTALS	8,083,130	4,309,735

these changes. The exogenous forces are changes in the final demands for specific sector outputs. Thus, we develop direct plus indirect consumptive water use requirements for each dollar's worth of output delivered to final demand. This development requires two pieces of information: first, the direct plus indirect production generated in all sectors as a single sector expands its deliveries to final demand, and second, the direct consumptive water use requirements by sector.

The procedure followed in computing the direct plus indirect water requirements is straightforward once the basic data necessary to complete the input-output model have been obtained. However, there is a conceptual issue which the authors feel can lead to some measurement difficulties. The issue revolves around the estimate of direct plus indirect water requirements with the households sector included in the processing sector versus the estimation of requirements with households included as a part of the final demands sector.

When households is treated as an endogenous sector of the economy it becomes simply another producer. Household technical coefficients of production are expressed in terms of requirements per dollar of output (income) and the water use coefficients in the household sector are expressed in terms of water use per dollar of income. The latter means that an expansion in household income will be accompanied by both a direct and indirect increase in household water use. While this procedure is mechanically consistent with the input-output technique, the authors do not feel that it provides a satisfactory means to estimate household water use. It is contended here that household water use is more appropriately expressed as a function of numbers of households than it is as a function of income and that the development of direct and indirect household water requirements for projections purposes can lead to an upward bias in the projections. This upward bias will likely exist not only because of the direct plus indirect household water requirement but also because the direct plus indirect production requirement and thus water requirements in other sectors tend to be larger when households are included in the processing sector. For these reasons, the computation of direct plus indirect water requirements is based on the inclusion of households in the final demand sectors.

The procedure followed in estimating the direct plus indirect consumptive use requirements, by sector, thus involves premultiplying the Leontief inverse matrix, with households exogenous, (Table IV-8) by a diagonal matrix of direct consumptive use requirements (where the elements of the diagonal are the direct consumptive use requirements shown in Table IV-6. The columns of the resulting matrix are summed to obtain the direct plus indirect water requirements per dollar of output delivered to final demand. These requirements are shown in Table IV-9.

The entries in Table IV-9 are interpreted in the following way: each sector at the left of the table delivers output for final consumption. For each dollar of output delivered to final demand there is a total direct plus indirect consumptive water use requirement imposed on the entire economy. Thus, for each dollar of output delivered to final demand by the livestock sector a total of 1,241 gallons of water is used consumptively; for each dollar of output delivered to final demand by irrigated agriculture a total of 4,331 gallons is consumed throughout the economy, etc.

The importance of considering the economic interdependence among sectors becomes apparent when one compares Table IV-6 and Table IV-9. The difference between the consumptive use estimates in these two tables (which is shown in the second column of Table IV-9) is the indirect consumptive use owing specifically to interdependence. In some cases, for example:

TABLE IV-8

DIRECT PLUS INDIRECT PRODUCTION REQUIREMENTS PER DOLLAR OUTPUT DELIVERED TO FINAL DEMAND, COLORADO, 1970

(Households in Final Demand)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
	Nat. Gas	Live-stock	Irr. Ag.	Dry. Ag.	Food Proc.	Met. Min.	Pet. Prod.	Ind. Min. Prod.	Coal Min.	Min. Serv.	Pipe. Trans.	Pet. Ref.	Prim. Met.	Elec. Pow. Gen.	Fab. Met.	Elec-tron-ics	Trans., Com. Pub. Ut.	Tex-tiles
1. Nat. Gas	1.0003	.0041	.0040	.0028	.0034	.0008	.0005	.0139	.0010	.0006	.0003	.0028	.0008	.0004	.0009	.0012	.0031	.0011
2. Livestock	.0029	1.4107	.0618	.0309	.4800	.0020	.0009	.0047	.0017	.0052	.0016	.0020	.0021	.0015	.0011	.0006	.0051	.0005
3. Irr. Ag.	.0010	.2879	1.0191	.0099	.1429	.0007	.0003	.0017	.0006	.0019	.0006	.0007	.0008	.0005	.0004	.0003	.0018	.0002
4. Dry. Ag.	.0002	.0697	.0055	1.0027	.0431	.0002	.0001	.0004	.0001	.0004	.0001	.0002	.0002	.0001	.0001	.0000	.0004	.0000
5. Food Proc.	.0054	.0474	.1308	.0628	1.0550	.0037	.0015	.0088	.0030	.0093	.0029	.0038	.0040	.0028	.0021	.0009	.0096	.0009
6. Met. Min.	.0000	.0001	.0001	.0001	.0000	1.0001	.0000	.0001	.0000	.0000	.0000	.0001	.0065	.0000	.0014	.0000	.0000	.0000
7. Pet. Prod.	.2238	.0013	.0016	.0012	.0015	.0018	1.0311	.0052	.0010	.0006	.4140	.2604	.0080	.0305	.0010	.0029	.0051	.0003
8. Ind. Min. Prod.	.0009	.0031	.0043	.0037	.0020	.0161	.0011	1.0009	.0394	.0085	.0010	.0008	.0102	.0039	.0016	.0006	.0021	.0001
9. Coal Min.	.0003	.0004	.0006	.0004	.0004	.0016	.0004	.0022	1.0013	.0005	.0003	.0003	.0302	.0918	.0028	.0002	.0100	.0001
10. Min. Serv.	.0526	.0004	.0004	.0003	.0004	.0757	.1083	.0029	.0448	1.0002	.0973	.0613	.0038	.0113	.0017	.0007	.0017	.0001
11. Pipe. Trans.	.5414	.0031	.0037	.0027	.0035	.0044	.0030	.0126	.0025	.0015	1.0015	.6300	.0193	.0738	.0025	.0070	.0123	.0007
12. Pet. Ref.	.0005	.0008	.0012	.0012	.0006	.0017	.0004	.0031	.0014	.0013	.0004	1.0004	.0012	.0010	.0004	.0001	.0040	.0001
13. Prim. Met.	.0006	.0018	.0026	.0021	.0014	.0155	.0008	.0039	.0027	.0019	.0009	.0037	1.0819	.0020	.0952	.0020	.0023	.0009
14. Elec. Pow. Gen.	.0026	.0029	.0055	.0036	.0042	.0128	.0044	.0232	.0136	.0044	.0029	.0022	.0033	1.0092	.0016	.0019	.1089	.0009
15. Fab. Met.	.0053	.0145	.0207	.0162	.0124	.0401	.0073	.0360	.0270	.0136	.0079	.0371	.0304	.0188	1.0574	.0144	.0085	.0098
16. Electronics	.0015	.0088	.0116	.0104	.0047	.0040	.0018	.0067	.0041	.0038	.0014	.0013	.0015	.0030	.0090	1.0635	.0278	.0017
17. Trans., Com., Pub. Ut.	.0252	.0285	.0538	.0349	.0407	.1249	.0430	.2273	.1334	.0428	.0285	.0211	.0318	.0901	.0161	.0183	1.0655	.0092
18. Textiles	.0005	.0091	.0182	.0059	.0041	.0006	.0005	.0010	.0005	.0019	.0005	.0007	.0012	.0004	.0004	.0013	.0015	1.0116
19. Paper	.0004	.0022	.0044	.0022	.0046	.0009	.0006	.0018	.0009	.0009	.0004	.0006	.0009	.0006	.0020	.0022	.0008	.0048
20. Printing	.0033	.0046	.0058	.0052	.0022	.0019	.0021	.0022	.0017	.0021	.0015	.0014	.0009	.0012	.0014	.0032	.0063	.0062
21. Chem.	.0025	.0739	.1308	.0696	.0326	.0276	.0032	.0072	.0109	.0052	.0028	.0033	.0170	.0020	.0045	.0136	.0037	.0031
22. Wood Prod.	.0004	.0009	.0015	.0013	.0005	.0207	.0006	.0013	.0069	.0019	.0004	.0005	.0039	.0027	.0011	.0004	.0021	.0001
23. Oth. Mfg.	.0020	.0028	.0037	.0034	.0017	.0032	.0017	.0065	.0021	.0108	.0032	.0069	.0173	.0030	.0032	.0128	.0015	.0002
24. Trade	.0451	.1024	.1453	.1493	.0476	.0284	.0117	.0700	.0228	.0771	.0235	.0312	.0323	.0217	.0169	.0059	.0598	.0069
25. Serv.	.0123	.2071	.2633	.2427	.0881	.0127	.0156	.0183	.0147	.0534	.0140	.0107	.0112	.0073	.0069	.0267	.0377	.0070
26. El., Sec. Ed.	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
27. Univ. Ed.	.0001	.0030	.0003	.0018	.0012	.0001	.0000	.0001	.0001	.0001	.0000	.0000	.0001	.0000	.0008	.0020	.0002	.0001

19	20	21	22	23	24	25	26	27
Paper	Print-ing	Chem.	Wood Prod.	Oth. Mfg.	Trade	Serv.	El., Sec. Ed.	Univ. Ed.
.0018	.0006	.0010	.0017	.0029	.0024	.0056	.0062	.0062
.0006	.0011	.0010	.0025	.0076	.0845	.0150	.0166	.0164
.0003	.0004	.0004	.0009	.0055	.0295	.0062	.0050	.0052
.0001	.0001	.0001	.0002	.0006	.0071	.0011	.0015	.0011
.0011	.0019	.0018	.0046	.0145	.1579	.0197	.0358	.0173
.0000	.0000	.0005	.0001	.0004	.0000	.0001	.0000	.0000
.0006	.0002	.0012	.0011	.0020	.0036	.0019	.0016	.0017
.0004	.0004	.0053	.0003	.0127	.0055	.0141	.0018	.0006
.0003	.0002	.0003	.0005	.0020	.0009	.0010	.0003	.0004
.0002	.0001	.0003	.0003	.0007	.0009	.0006	.0004	.0004
.0015	.0006	.0018	.0027	.0047	.0086	.0047	.0038	.0040
.0004	.0002	.0004	.0008	.0008	.0097	.0012	.0003	.0005
.0005	.0002	.0029	.0048	.0552	.0021	.0081	.0008	.0004
.0033	.0016	.0027	.0040	.0046	.0091	.0057	.0027	.0039
.0018	.0017	.0313	.0511	.0545	.0162	.0596	.0077	.0032
.0013	.0031	.0017	.0016	.0066	.0078	.0456	.0115	.0068
.0322	.0156	.0268	.0388	.0454	.0887	.0557	.0265	.0386
.0007	.0007	.0005	.0004	.0563	.0058	.0260	.0006	.0009
1.0091	.0142	.0050	.0086	.0285	.0044	.0053	.0030	.0011
.0010	1.0414	.0026	.0015	.0175	.0127	.0191	.0270	.0150
.0221	.0025	1.0332	.0014	.0980	.0234	.0464	.0040	.0034
.0003	.0001	.0048	1.0765	.0212	.0049	.0013	.0030	.0004
.0068	.0005	.0007	.0027	1.0673	.0075	.0134	.0019	.0010
.0085	.0152	.0143	.0379	.0775	1.3527	.1347	.0279	.0475
.0125	.0275	.0191	.0048	.0602	.0937	1.1564	.0166	.0304
.0000	.0000	.0000	.0000	.0000	.0000	.0000	1.0094	.0000
.0000	.0000	.0003	.0039	.0002	.0003	.0007	.0001	1.0028

Table IV-9: Direct and Indirect Consumptive Water Use Per Dollar of Output Delivered to Final Demand by Sector, Colorado, 1970

(in gallons per dollar)*

Sector	Direct Plus Indirect Consumptive Use	Indirect Consumptive Use
1. Natural Gas	6.16	6.05
2. Livestock	1,240.57	1,228.67
3. Irrigated Agriculture	4,330.68	89.68
4. Dryland Agriculture	43.62	43.62
5. Food Processing	613.49	613.14
6. Metal Mining	58.25	4.50
7. Petroleum Production	6.95	1.87
8. Industrial Minerals Production	13.26	8.46
9. Coal Mining	7.06	3.46
10. Mining Services	9.05	8.42
11. Pipeline Transportation	5.31	4.81
12. Petroleum Refining	8.89	5.09
13. Primary Metals	15.00	5.22
14. Electric Power Generation	34.95	3.35
15. Fabricated Metals	4.60	3.00
16. Electronics	1.71	1.44
17. Transportation, Communication, and Public Utilities	12.79	11.29
18. Textiles	1.17	.85
19. Paper	1.71	1.46
20. Printing	1.98	1.90
21. Chemicals	10.24	2.22
22. Wood Products	19.14	5.16
23. Other Manufacturing	27.54	25.54
24. Trade	127.69	127.46
25. Services	28.20	27.57
26. Elementary and Secondary Education	22.46	21.87
27. University Education	23.19	22.60

* The direct plus indirect consumptive use requirements are derived using Table IV-8 where households are included in final demand.

natural gas, dryland agriculture, food processing, mining services, transportation, communication, and public utilities, trade, services and education, the indirect effects account for virtually all of the consumptive use requirements. The sectors showing relatively large total consumptive use requirements are sectors which have a significant tie, either directly or indirectly, to irrigated agriculture. This result is certainly reasonable since irrigated agriculture is far and away the heaviest water using sector in the Colorado economy.

From the planning perspective, then, the importance of accounting for both direct and indirect water requirements cannot be overemphasized. Applying only direct requirements to projected levels of economic activity obviously can understate projected water needs. Under certain assumptions regarding the stability of the technical aspects of production, these direct plus indirect consumptive use requirements provide a means of projecting the level of consumptive water use accompanying projected changes in final demands. This aspect of the model's use will be addressed specifically in a subsequent chapter of the report.

THE EMPLOYMENT ANALYSIS

In analyzing sector-by-sector employment in the state's economy, a process analogous to that used in the water use analysis is employed. Employment data were obtained directly from the Colorado Division of Employment and are based on the standard industrial classification of the sectors in the model. The units in the employment analysis are numbers of workers per $1,000 of total gross output. The coefficients are presented in Table IV-10. The direct employment requirements, by themselves, are of limited usefulness in assessing the impacts of various changes in economic activity. The limitations exist for the same reasons discussed in the analysis of water use--direct coefficients alone ignore the effects of sectoral interdependence.

To assess the total employment impacts of exogenous changes in final consumption requires the use of the direct plus indirect production requirements per dollar of output delivered to final demand. The process involves premultiplying the direct plus indirect production requirements table (Table IV-8) by a diagonal matrix of direct employment coefficients taken from Table IV-10. The results are presented in Table IV-11.

The interpretation of the entries in Table IV-11 is shown by the following example. As the final demand for the output of the natural gas sector expands by $1,000 there will be a direct expansion of employment in that sector as well as in those sectors which supply production ingredients to the natural gas sector. Indirect employment increases will also occur in sectors which supply production inputs to those sectors who directly supply the natural gas sector with its inputs. The magnitude of the direct and indirect employment impacts shows the total employment generated in the entire economy as this single sector increases its deliveries to final demand. For the natural gas sector, an increased delivery of $1,000 to final demand results in a total state employment impact of .036. A $1 million increase would lead to the employment of an additional 36 persons in the state. All of the remaining entries have the same interpretation for the respective sectors. Table IV-11 indicates that the leading sectors in terms of direct and indirect employment generation in the Colorado economy are university education, irrigated agriculture, elementary and secondary education, livestock and livestock processing, other manufacturing, services, and textiles.

This concludes the descriptive analysis of the Colorado economy as estimated for the year 1970. The results of this analysis provide the ingredients for extensions of the basic accounting system. In this report the extensions considered are: (1) projections of total gross output by sector under various final demand growth scenarios; (2) projections of consumptive water use and employment consistent with the growth scenarios; (3) consideration of the impacts of restricted natural gas deliveries on the economic growth potential of the state; (4) a scenario in which coal exports expand; and (5) a linear programming model to find the sectors which are impacted by shortages in water and other resources as the economy grows over time.

It must be emphasized, at this point, that the extensions of the basic model are presented somewhat cautiously. With specific reference to alternative futures, it must be recognized that forecasting under ideal conditions is at best a somewhat tenuous undertaking. It becomes even more so in light of the rather unique set of economic conditions prevailing from the early 1970's to the present. Nonetheless, the economic tool of analysis employed here provides a consistent forecasting technique and the results, given time, financial and data limitations, are reasonably indicative of the direction and relative magnitudes of changes in the economy. One appealing feature of the accounting system is that any alternative statement of exogenous changes can be incorporated rapidly and efficiently into the forecasting procedure. It is to the extensions that we now turn.

Table IV-10: Employment Coefficients Per $1,000 of Output and Total Employment by Sector, Colorado, 1970

(in workers per $1,000 output produced and numbers of workers)

Sector	(Workers Per $1,000 Total Output) Direct Employment Requirement	(Number of Workers) Total Employment
1. Natural Gas	.022	1,972
2. Livestock	.031	29,489
3. Irrigated Agriculture	.062	19,901
4. Dryland Agriculture	.032	4,329
5. Food Processing	.012	21,447
6. Metal Mining	.028	6,216
7. Petroleum Production	.033	4,255
8. Industrial Minerals Production	.025	4,877
9. Coal Mining	.027	1,142
10. Mining Services	.039	2,317
11. Pipeline Transportation	.001	268
12. Petroleum Refining	.008	719
13. Primary Metals	.032	7,667
14. Electric Power Generation	.016	1,805
15. Fabricated Metals	.019	20,192
16. Electronics	.026	13,746
17. Transportation, Communication, and Public Utilities	.042	45,414
18. Textiles	.057	6,210
19. Paper	.025	1,331
20. Printing	.045	9,387
21. Chemicals	.027	8,839
22. Wood Products	.034	4,002
23. Other Manufacturing	.059	5,582
24. Trade	.028	162,603
25. Services	.049	96,777
26. Elementary and Secondary Education	.083	39,888
27. University Education	.126	39,967
Total, Processing Sector Employment		560,342

Table IV-11: Direct Plus Indirect Labor Requirements Per $1,000 Delivered to Final Demand, Colorado, 1970

(in workers per $1,000)

Sector	Direct Plus Indirect Employment
1. Natural Gas	.036
2. Livestock	.087
3. Irrigated Agriculture	.092
4. Dryland Agriculture	.056
5. Food Processing	.047
6. Metal Mining	.042
7. Petroleum Production	.042
8. Industrial Minerals Production	.041
9. Coal Mining	.038
10. Mining Services	.048
11. Pipeline Transportation	.022
12. Petroleum Refining	.024
13. Primary Metals	.042
14. Electric Power Generation	.026
15. Fabricated Metals	.026
16. Electronics	.033
17. Transportation, Communication, and Public Utilities	.053
18. Textiles	.060
19. Paper	.028
20. Printing	.050
21. Chemicals	.032
22. Wood Products	.042
23. Other Manufacturing	.083
24. Trade	.057
25. Services	.072
26. Elementary and Secondary Education	.090
27. University Education	.133

CHAPTER V

EXTENSIONS OF THE ANALYSIS

INTRODUCTION

While the primary purpose of this research effort was the development of a state-wide input-output model for the Colorado economy and identification of the related water use on a sector-by-sector basis there are a number of viable uses for the model which extend beyond the purely descriptive discussion of Chapter IV. Our purpose in considering some of these extensions is to demonstrate the flexibility of the input-output system as a tool which can be of substantial aid in the planning process. Once the basic model has been constructed these extensions can be accommodated with a minimum of time and financial input.

The first extension considered here employs several alternative scenarios for economic growth to the year 1980. The discussion centers on the impact of these growth scenarios on the economic variables income, employment, and total gross output and on the associated water use requirements.

The second extension considers the application of the model to cases in which the final demands for the output of specific sectors are restricted. The sector selected for consideration in this extension is the natural gas sector where final demands are, in fact, being restricted in Colorado. The purpose here is to exhibit the use of the model in identifying the negative impacts of such restrictions on employment, income and output in the Colorado economy.

The final extension of the input-output framework consists of converting the Leontief system to a linear programming framework through the introduction of a specific objective function and a constraint on the availability of water for consumptive use.

ALTERNATIVE SCENARIOS FOR ECONOMIC ACTIVITY TO 1980

The projection of economic activity via input-output models involves first, the projections of components of final demand to some future period; and second, applying these assumed values to the direct plus indirect production requirements table to determine new or projected levels of output and other economic variables. The forecasting use of the system is limited to the short run unless the technical production coefficients are adjusted to allow for substitution and technological changes. While the coefficients are not likely to remain constant over the long run, the assumption of constant technical coefficients generally will not present serious problems in short-term analyses.

Forecasting the individual elements of final demand is an expensive and time-consuming process. However, individual components of final demand will likely grow (or decrease) at different rates, thus making a single final demand projection highly suspect. In view of the financial constraints under which this study was undertaken, we have selected a compromise procedure which estimates changes in final demands for two major components, households and governments, with no projected changes in exports and other final demands. To the extent that these two components do change, our projections may understate or overstate the real world futures. Again, the capability for analyzing these other components exists. All that is needed is the data base to include them in the analysis.

The projections model uses several variants of population growth in the Colorado economy coupled with an assumed growth in the government sector of 3.5 percent per year (a 1.411 multiple for the period 1970-1980). All projections are in 1970 dollars. Population growth was varied from a low annual increase of .5 percent to a high of 8 percent per year. It is not likely that either of these extremes will occur. Our judgment is that a narrower range--between 1.5 percent per year and 3 percent per year--is much more reasonable.[12/] However, to at least partially accommodate potential growth in other components of final demand; i.e., exports, capital formation, etc., one variant of the model uses a 4.5 percent growth in households. Tables V-1 through V-4 present the results of the projections for levels of total output, consumptive water use and employment for alternative projected increases in final demands.

While the material presented in Tables V-1 through V-4 is self-explanatory there are several items worthy of consideration. All projections are for the 27 processing sectors shown. They do not include projected water requirements for household use (a residual which includes all use by the final demand sectors) nor employment projections for government, construction and other components of the final demand sector. The projected consumptive water use and employment shown in the tables are determined within the framework of the accounting system; that is, they are consistent projections given the assumed external changes in the final demand sectors. Thus, water use and employment in final demand sectors must be added to projected processing sector water use and employment in order to estimate state totals. The estimated household withdrawal of water is 130 gallons per capita per day and, assuming that 20 percent of this amount is used consumptively, annual per capita consumptive use in 1970 was approximately .03 acre-feet or 9,490 gallons. If it is further assumed that this per

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[12/] This population range is roughly consistent with recent estimates made by: the Colorado Office of State Planning and Budgeting; Survey of Current Business, April, 1974; OBERS, Projections Regional Activity in The U.S., Vol. 4 and 5, 1972; Colorado Population Trends, Regional and County Estimates, 1970-1980, David E. Monarchi, Vol. 3, No. 3, Summer, 1974.

TABLE V-1

1980 Projections of Selected Economic Variables Using a 1.5% Annual Increase in Households Final Demand and 3.5% Growth in Government

Sector	($1,000) Final Demands	($1,000) Total Output	(Acre-Feet) Consumptive Water Use	(No. Workers) Employment
1. Natural Gas	68,195.86	103,369.49	35	2,274
2. Livestock	57,817.24	1,043,884.72	38,105	32,360
3. Irrigated Agriculture	27,640.77	353,581.29	4,599,807	21,922
4. Dryland Agriculture	63,843.90	151,374.00		4,844
5. Food Processing	1,113,939.11	1,964,663.13	2,109	23,576
6. Metal Mining	219,612.00	222,066.74	36,614	6,218
7. Petroleum Production	17,632.00	134,402.44	2,094	4,435
8. Industrial Minerals Production	155,938.79	213,848.48	322	5,346
9. Coal Mining	24,965.42	43,740.05	459	1,181
10. Mining Services	11,440.00	60,824.26	118	2,372
11. Pipeline Transportation	144,786.38	280,876.68	431	281
12. Petroleum Refining	44,814.00	94,942.25	1,107	760
13. Primary Metals	122,511.00	242,957.20	7,289	7,775
14. Electric Power Generation	2,917.90	126,787.47	12,290	2,029
15. Fabricated Metals	823,234.14	1,089,136.78	5,345	20,694
16. Electronics	380,952.23	544,511.58	451	14,157
17. Transportation, Communication, and Public Utilities	511,940.25	1,212,119.30	5,577	50,909
18. Textiles	45,299.03	118,121.29	116	6,733
19. Paper	14,905.00	57,313.91	44	1,433
20. Printing	105,462.05	228,046.93	56	10,262
21. Chemicals	102,114.21	351,988.16	8,659	9,504
22. Wood Products	79,491.31	121,029.65	5,190	4,115
23. Other Manufacturing	31,470.69	103,285.24	634	6,094
24. Trade	4,496,634.65	6,462,465.94	4,559	180,949
25. Services	1,367,945.13	2,213,135.78	4,277	108,444
26. Elementary and Secondary Education	647,179.95	653,273.90	1,182	54,222
27. University Education	393,604.18	400,816.24	725	50,503
Totals		18,592,563.00	4,737,595	633,392

TABLE V-2

1980 Projection of Selected Economic Variables Using a 2.5% Annual Increase in Household Final Demand and 3.5% Growth in Government

Sector	($1,000) Final Demand	($1,000) Total Output	(Acre-Feet) Consumptive Water Use	(No. Workers) Employment
1. Natural Gas	74,194	110,851	37	2,439
2. Livestock	59,306	1,080,957	39,458	33,510
3. Irrigated Agriculture	27,658	365,835	4,759,221	22,682
4. Dryland Agriculture	63,844	154,444		4,942
5. Food Processing	1,134,550	2,032,362	2,182	24,388
6. Metal Mining	219,612	222,092	36,618	6,219
7. Petroleum Production	17,632	137,121	2,137	4,525
8. Industrial Minerals Production	155,939	216,920	3,194	5,423
9. Coal Mining	24,970	44,401	466	1,199
10. Mining Services	11,440	61,513	119	2,399
11. Pipeline Transportation	144,786	287,442	441	287
12. Petroleum Refining	44,814	97,861	1,141	783
13. Primary Metals	122,511	244,659	7,340	7,829
14. Electric Power Generation	2,918	133,121	12,904	2,130
15. Fabricated Metals	824,356	1,101,518	5,406	20,929
16. Electronics	380,952	552,298	457	14,360
17. Transportation, Communication, and Public Utilities	540,387	1,274,094	5,862	53,512
18. Textiles	46,544	123,851	122	7,060
19. Paper	14,905	59,281	45	1,482
20. Printing	107,973	236,570	58	10,646
21. Chemicals	102,114	364,247	8,961	9,835
22. Wood Products	79,497	122,626	5,259	4,169
23. Other Manufacturing	33,048	108,499	666	6,401
24. Trade	4,770,987	6,851,156	4,834	191,832
25. Services	1,469,557	2,360,173	4,561	115,648
26. Elementary and Secondary Education	647,180	653,274	1,182	54,222
27. University Education	406,192	413,635	749	52,118
Totals		19,410,801	4,903,420	660,969

TABLE V-3

1980 Projections of Selected Economic Variables Using a 3% Annual Increase in Households Final Demand and 3.5% Growth in Government

	Sector	($1,000) Final Demands	($1,000) Total Output	(Acre-Feet) Consumptive Water Use	(No. Workers) Employment
1.	Natural Gas	77,397	114,845	39	2,527
2.	Livestock	60,101	1,100,752	40,181	34,123
3.	Irrigated Agriculture	27,667	372,378	4,844,341	23,087
4.	Dryland Agriculture	63,844	156,083	--	4,995
5.	Food Processing	1,145,555	2,068,511	2,221	24,822
6.	Metal Mining	219,612	222,106	36,620	6,219
7.	Petroleum Production	17,632	138,573	2,159	4,573
8.	Industrial Minerals Production	155,939	218,560	3,218	5,464
9.	Coal Mining	24,973	44,753	469	1,208
10.	Mining Services	11,440	61,880	120	2,413
11.	Pipeline Transportation	144,786	290,947	446	291
12.	Petroleum Refining	44,814	99,420	1,159	795
13.	Primary Metals	122,511	245,568	7,367	7,858
14.	Electric Power Generation	2,918	136,503	13,232	2,184
15.	Fabricated Metals	824,954	1,108,130	5,439	21,054
16.	Electronics	380,952	556,455	461	14,468
17.	Transportation, Communication, and Public Utilities	555,577	1,307,187	6,015	54,902
18.	Textiles	47,209	126,911	125	7,234
19.	Paper	14,905	60,322	46	1,508
20.	Printing	109,314	241,120	59	10,850
21.	Chemicals	102,114	370,793	9,122	10,011
22.	Wood Products	79,500	123,478	5,295	4,198
23.	Other Manufacturing	33,890	111,283	683	6,566
24.	Trade	4,917,482	7,058,702	4,980	197,644
25.	Services	1,523,814	2,438,685	4,713	119,496
26.	Elementary and Secondary Education	647,180	653,274	1,182	54,222
27.	University Education	412,914	420,480	761	52,980
	Totals		19,847,699	4,990,453	675,692

TABLE V-4

1980 Projections of Selected Economic Variables Using a 4.5% Annual Increase in Households Final Demand and 3.5% Growth in Government

Sector	($1,000) Final Demands	($1,000) Total Output	(Acre-Feet) Consumptive Water Use	(No. Workers) Employment
1. Natural Gas	87,887	127,928	43	2,814
2. Livestock	62,705	1,165,582	42,547	36,133
3. Irrigated Agriculture	27,697	393,807	5,123,115	24,416
4. Dryland Agriculture	63,844	161,452		5,166
5. Food Processing	1,181,598	2,186,900	2,348	26,243
6. Metal Mining	219,612	222,150	36,627	6,220
7. Petroleum Production	17,632	143,327	2,233	4,730
8. Industrial Minerals Production	155,939	223,932	3,297	5,598
9. Coal Mining	24,981	45,909	482	1,240
10. Mining Services	11,440	63,084	122	2,460
11. Pipeline Transportation	144,786	302,427	464	302
12. Petroleum Refining	44,814	104,525	1,218	836
13. Primary Metals	122,511	248,545	7,456	7,953
14. Electric Power Generation	2,918	147,578	14,305	2,361
15. Fabricated Metals	826,916	1,129,782	5,545	21,466
16. Electronics	380,952	570,071	472	14,822
17. Transportation, Communication, and Public Utilities	605,324	1,415,566	6,513	59,454
18. Textiles	49,386	136,932	134	7,805
19. Paper	14,905	63,772	49	1,594
20. Printing	113,705	256,024	63	11,521
21. Chemicals	102,114	392,232	9,649	10,590
22. Wood Products	79,509	126,268	5,415	4,293
23. Other Manufacturing	36,648	120,401	739	7,104
24. Trade	5,397,258	7,738,426	5,460	216,676
25. Services	1,701,509	2,695,817	5,210	279,095
26. Elementary and Secondary Education	647,180	653,274	1,182	54,222
27. University Education	434,927	442,898	802	54,801
Totals		21,278,609	5,275,490	869,915

capita consumptive use remains constant over the period covered by the projections then the projected household consumptive use may be determined by multiplying the per capita annual consumptive use by the total population. For the projected annual rates of growth assumed in Tables V-1 through V-4 the consumptive use estimates for households are respectively; 77,450 acre-feet at 1.5 percent annual growth; 85,428 acre-feet at 2.5 percent annual growth; 89,687 acre-feet at 3 percent annual growth; and 103,639 acre-feet at 4.5 percent annual growth. These household consumptive use estimates plus the estimated 658,000 acre-feet of estimated nonbeneficial consumptive use added to the projected processing sector consumptive use estimates shown in Tables V-1 through V-4 yield the following range of projected total consumptive use: 5,440,045 acre-feet at 1.5 percent annual growth; 5,646,848 acre-feet at 2.5 percent annual growth; 5,738,140 acre-feet at 3 percent annual growth; and 6,037,129 acre-feet at 4.5 percent annual growth. The last projection of consumptive water use is within 500,000 acre-feet of the total water available in the state for consumptive use as estimated by the Bureau of Reclamation and the Colorado Water Conservation Board.[13/] It must be noted that none of these projections account for dilution or waste assimilative requirements; i.e., quality considerations. They are strictly quantities of water required to sustain the assumed levels of economic activity.

Similar adjustments must be made in projecting total employment resulting from economic growth. Assuming that employment in the government sectors, construction, finance, insurance and real estate and other components of final demand remains as a constant share of total employment to the year 1980, the total projected employment range for the state is as

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13/ Water For Tomorrow, op. cit., page 33.

follows: 1,127,032 at 1.5 percent annual growth in households; 1,176,101 at 2.5 percent annual growth; 1,202,299 at 3.0 percent annual growth; and 1,547,891 at 4.5 percent annual growth.[14/]

Table V-5 represents a slight variation in the projections technique described previously. It is quite possible that the coal mining sector may grow relative to the other sectors of the economy through increased export demands for Colorado coal. In order to address this scenario, coal sector exports were allowed to grow at an annual rate of 8 percent in addition to a 3 percent annual increase in households and a 3.5 percent increase in governments. This modification results in a much larger final demand projection for the coal sector ($46.9 million as compared to $25.0 million in the other projections). It also results in changes in the total output level of sectors which are directly or indirectly tied to the coal mining sector. A comparison of Tables V-3 and V-5 shows the effect on total output in all sectors given the additional export demand for coal mining products.

In addition to the use of the model in addressing specific sector-by-sector water use and employment growth scenarios and the aggregate state projections the capability exists to analyze individual sectors which may be of particular interest to the policy maker. Chapter IV presented the direct plus indirect production requirements, direct plus indirect consumptive use requirements for water and the direct plus indirect employment requirements, which accompany increasing final demands for the outputs of various economic sectors. These direct plus indirect requirements may be employed,

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[14/] These projections compare quite reasonably with the range of 1,146,944 - 1,342,744 presented by Monarchi, Colorado Population Trends, op. cit., Table I.

TABLE V-5

1980 Projections of Selected Economic Variables Using a 3% Annual Increase in Household Final Demand, 3.5% Growth in Governments and 8% Annual Growth in Coal Mining Exports

Sector	($1,000) Final Demands	($1,000) Total Output	(Acre-Feet) Consumptive Water Use	(No. Workers) Employment
1. Natural Gas	77,397	114,867	39	2,527
2. Livestock	60,101	1,100,788	40,182	34,124
3. Irrigated Agriculture	27,667	372,391	4,844,510	23,088
4. Dryland Agriculture	63,844	156,086		4,995
5. Food Processing	1,145,555	2,068,577	2,221	24,823
6. Metal Mining	219,612	222,106	36,620	6,219
7. Petroleum Production	17,632	138,596	2,160	4,574
8. Industrial Minerals Production	155,939	219,424	3,231	5,486
9. Coal Mining	46,881	66,690	700	1,801
10. Mining Services	11,440	62,862	121	2,452
11. Pipeline Transportation	144,786	291,002	446	291
12. Petroleum Refining	44,814	99,450	1,159	796
13. Primary Metals	122,511	245,628	7,369	7,860
14. Electric Power Generation	2,918	136,801	13,260	2,189
15. Fabricated Metals	824,954	1,108,720	5,442	21,066
16. Electronics	380,952	556,545	461	14,470
17. Transportation, Communication, and Public Utilities	555,577	1,310,110	6,028	55,025
18. Textiles	47,209	126,923	125	7,235
19. Paper	14,905	60,350	46	1,509
20. Printing	109,314	241,157	59	10,852
21. Chemicals	102,114	371,032	9,128	10,018
22. Wood Products	79,500	123,628	5,302	4,203
23. Other Manufacturing	33,890	111,329	683	6,568
24. Trade	4,917,482	7,059,201	4,980	197,658
25. Services	1,523,814	2,439,006	4,713	119,511
26. Elementary and Secondary Education	647,180	653,274	1,182	54,222
27. University Education	412,914	420,482	761	52,981
Totals		19,877,025	4,990,928	676,543

along with estimated future levels of final demand, to assess the impact of changes in any economic sector upon the remainder of the economy. We demonstrate this feature of the model through an examination of three energy sectors: sector 1, natural gas; sector 9, coal production; and sector 14, electric power generation.

Consider first the natural gas sector. The business multiplier for this sector was estimated to be 2.56. This indicates that for each dollar of additional output delivered to final demand by natural gas a total of $2.56 of production will be required (generated) throughout all processing sectors of the economy. The projected final demand for natural gas output, using the 2.5 percent annual growth in households, for 1980, is $74.2 million (see Table V-2). This represents an increase in final demand of $15.5 million over the 1970 level.

In satisfying this increase a total of $39.7 million worth of production will be generated throughout the state economy. A similar calculation may be performed on each set of projections. In addition to the business activity generated by the expanded deliveries of natural gas to final demand, it is possible to assess the impacts on employment and water use. Consider the direct plus indirect consumptive use requirement for each dollar of output delivered to final demand by the natural gas sector. This requirement, shown in Table IV-8 is 6.16 gallons per dollar. Again using an increase of $15.5 million for final demand deliveries we ask, What does this mean in terms of additional water use? The estimates indicate that an additional consumptive use of 95.5 million gallons or 293 acre-feet is necessary to sustain this increase in final demand deliveries. It is emphasized that this is not the increased water required by the natural gas sector. Rather it is the total direct plus indirect requirement for water in the whole Colorado economy which results from the increased final demand for natural gas.

Similarly, the direct plus indirect employment requirement generated in the entire economy as a result of the increased delivery of natural gas to final demand is determined by multiplying the increase in final demand by the direct plus indirect employment coefficient for the natural gas sector. This requirement is found in Table IV-10 and is .036 workers per thousand dollars delivered to final demand. Thus, should the increase of $15.5 million occur, a total direct and indirect employment of 558 workers will occur in the economy.

This same analysis may be applied to the coal and electric power generation sectors. Considering first the coal sector, with final demand projected to increase at 3.0 percent per year in households, 3.5 percent per year in governments, and 8 percent per year in exports of coal the final demand is $46.9 million. This is an increase of $21.9 million over the 1970 level of final demand. Multiplying this increase by the business multiplier for the coal mining sector of 2.23 (Table IV-4) shows a total value of production generated in the economy of $48.8 million. Consumptive use of water accompanying this increase would be 168.7 million gallons or 475 acre-feet (7.06 gallons per dollar delivered to final demand, from Table IV-8, times $21.9 million divided by 325,860 gallons). The employment impact is .038 (Table IV-10) times $21,900 or a total direct plus indirect employment of 832 additional workers throughout the economy.

A projected increase in the final demand for the electric power generation sector, consistent with the growth assumed above, of $616 thousand would lead to additional production valued at $1.15 million, additional consumptive use of water of 2.1 million gallons, or a mere 6 acre-feet, and an additional 16 workers.

Table V-6 presents the projected sector-by-sector income projections which accompany three alternative scenarios for growth in final demands.

TABLE V-6

1980 Projected Income Under Alternative Rates of Growth In Final Demand

(in $1,000)

Sector	Income 1.5% Increase in Households	Income 2.5% Increase in Households	Income 3.0% Increase in Households	Income 4.5% Increase in Households	Income 3% Increase in Households 8% Increase in Coal Exports
1. Natural Gas	15,650	16,783	17,388	19,368	17,390
2. Livestock	166,082	171,980	175,130	185,444	175,135
3. Irrigated Agriculture	67,852	70,204	71,459	75,572	71,462
4. Dryland Agriculture	33,590	34,271	34,635	35,826	34,635
5. Food Processing	177,409	183,522	186,787	197,477	186,793
6. Metal Mining	52,741	52,747	52,750	52,761	52,750
7. Petroleum Production	50,387	51,407	51,951	53,733	51,960
8. Industrial Minerals Production	39,027	39,588	39,887	40,868	40,045
9. Coal Mining	13,459	13,662	13,770	14,126	20,521
10. Mining Services	23,770	24,039	24,183	24,653	24,566
11. Pipeline Transportation	3,033	3,104	3,142	3,266	3,143
12. Petroleum Refining	6,200	6,390	6,492	6,825	6,494
13. Primary Metals	69,097	69,581	69,840	70,686	69,857
14. Electric Power Generation	16,077	16,880	17,309	18,713	17,346
15. Fabricated Metals	166,965	168,863	169,876	173,196	169,967
16. Electronics	123,550	125,316	126,260	129,349	126,280
17. Transportation, Communication, and Public Utilities	430,787	452,813	464,574	503,092	465,613
18. Textiles	38,354	40,214	41,208	44,462	41,212
19. Paper	10,104	10,451	10,635	11,243	10,640
20. Printing	75,187	77,997	79,497	84,411	79,509
21. Chemicals	82,400	85,270	86,803	91,822	86,859
22. Wood Products	23,068	23,373	23,535	24,067	23,563
23. Other Manufacturing	41,696	43,801	44,925	48,606	44,944
24. Trade	997,159	1,057,133	1,089,158	1,194,039	1,089,235
25. Services	497,292	530,331	547,973	605,750	548,045
26. Elementary and Secondary Education	385,954	385,954	385,954	385,954	385,954
27. University Education	213,034	219,847	223,485	235,400	223,486
Totals	3,793,448	3,975,521	4,058,606	4,330,709	4,067,404

Table V-7 presents a summary of the output, consumptive water use and employment changes for the scenario employing a household increase in final demand of 3 percent per year, government growth at 3.5 percent per year and coal mining export growth of 8 percent per year. The changes in final demand, denoted "Δ Final Demand" represent changes from 1970-1980 projected under these growth assumptions. The remaining columns represent the changes in output, consumptive water use and employment associated with the projected changes in final demands. In this regard it should be noted that the third column which shows a change in consumptive use of water is the increase in consumptive use throughout the economy as final demands in the particular sector at the left expand to projected levels. The fourth column showing the change in consumptive use reflects the increase in water consumed by the sector at the left as all final demands expand to the projected levels. The same holds for the columns marked "Δ Employment." The fifth column represents the change in total employment throughout the economy which is attributed to the sector at the left as its deliveries to final demand increase to projected levels. The sixth column reflects the increase in employment within a given sector as all final demands reach projected levels. The sum of the two columns for "Δ Consumptive Water Use," should be equal as should the column sums for "Δ Employment." Any discrepancy (.1 percent in the case of consumptive use of water and .6 percent in the case of employment) is due to rounding error.

One interesting and rather important result of the projections made through alternative rates of growth in final demands concerns the question of excess demand for natural gas. Forecasts of natural gas supplies provided by the Future Requirements Committee indicate a 1980 supply of 303,236 million cubic feet of natural gas available for consumption. In value terms this translates to approximately $106.6 million. The projections

TABLE V-7

Projected Changes in Selected Economic Variables, 1970-1980, Assuming 3% Annual Growth in Households, 3.5% Annual Growth in Governments, and 8% Annual Growth in Coal Exports.

	Sector	($1,000) Δ Final Demand	($1,000) Δ Output	(Acre-Feet)[1] Δ Consumptive Water Use	(Acre-Feet)[2] Δ Consumptive Water Use	(# of Workers)[3] Δ Employment	(# of Workers)[4] Δ Employment
1.	Natural Gas	18,684	25,244	353	9	673	555
2.	Livestock	5,471	149,532	20,820	5,458	476	4,635
3.	Irrigated Agriculture	3,135	51,409	41,646	668,790	288	3,187
4.	Dryland Agriculture	8,279	20,815	1,108	--	464	666
5.	Food Processing	119,980	281,317	225,787	302	5,639	3,376
6.	Metal Mining	--	91	--	15	--	3
7.	Petroleum Production	--	9,671	--	151	--	319
8.	Industrial Minerals Production	13,373	24,356	544	359	548	609
9.	Coal Mining	21,922	24,382	475	256	833	658
10.	Mining Services	--	3,450	--	7	--	135
11.	Pipeline Transportation	1,130	23,352	18	36	25	23
12.	Petroleum Refining	--	9,550	--	111	--	76
13.	Primary Metals	--	6,048	--	181	--	194
14.	Electric Power Generation	616	23,999	66	2,326	16	384
15.	Fabricated Metals	7,166	45,964	101	226	186	873
16.	Electronics	311	27,848	2	23	10	724
17.	Transportation, Communication, and Public Utilities	106,055	228,818	4,161	1,053	5,621	9,610
18.	Textiles	3,582	17,983	13	18	215	1,025
19.	Paper	--	7,110	--	5	--	178
20.	Printing	7,795	32,557	47	8	390	1,465
21.	Chemicals	1,209	43,672	38	1,074	39	1,179
22.	Wood Products	83	5,928	5	254	3	202
23.	Other Manufacturing	4,666	16,714	394	103	387	986
24.	Trade	874,992	1,251,954	342,723	883	49,875	35,055
25.	Services	307,942	463,962	26,638	897	22,172	22,734
26.	Elementary and Secondary Education	171,083	172,694	11,787	313	15,397	14,334
27.	University Education	102,276	103,284	7,275	187	13,603	13,014
	Totals			684,001	683,045	116,860	116,199

[1] This column shows the change in consumptive use throughout the economy as each sector at the left expands sales to final demand.

[2] This column shows the change in consumptive use by the sector at the left as all final demands reach projected levels.

[3] This column reflects the change in employment in all sectors of the economy as a single sector expands sales to final demand.

[4] This column shows the change in employment in a single sector as all sectors expand sales to final demands to projected levels.

for the natural gas sector outputs for all but the first variant of the projections model indicate that by 1980 there will be an excess demand for natural gas. Using the assumed rate of growth of 2.5 percent per year in households and 3.5 percent per year in government, an excess demand for natural gas of $4.2 million, equal to 4.1 percent of projected supply, was estimated. A 3.0 percent per year assumed growth in households final demand coupled with a 3.5 percent annual growth in government requires, according to the model, a natural gas output valued at $114.8 million, an excess requirement of 7.7 percent over the estimated available supply. Using the highest assumed rates of growth, the excess demand is valued at $21.3 million or 20 percent of the projected available supply. Thus for all but the lowest growth scenario, our results indicate a projected future shortage of natural gas consistent with the findings of other sources.[15/]

A second observation concerns the impact of allowing export demand in the coal mining sector to expand. The 8 percent per year growth in coal exports requires a total increase in consumptive water use of 475 acre-feet above the level projected in Table V-3 and results in the projected employment of an additional 851 workers over and above the projection found in Table V-3.

The total consumptive use of water in the processing sectors is projected at 4,990,928 acre-feet to which is added 658,000 acre-feet of non-beneficial use and household consumption of 89,687 acre-feet. The total is 5,738,615 acre-feet which is within some 800,000 acre-feet of the estimated total water supply available for consumptive use in the state.

[15/] Future Requirements Committee, Future Gas Consumption of the United States, Vol. 5, November, 1973, University of Denver Research Institute.

IMPACT OF RESTRICTING FINAL DEMANDS FOR SPECIFIC SECTORS

One item of interest to state planners concerns the direct and indirect impacts of restricting deliveries of outputs to final demand. We illustrate the use of the model in addressing this issue by considering again the natural gas sector. Restricted deliveries of natural gas may be expected, through sector interdependence, to effect output, employment, and income in other parts of the economy and thus the total effects may be far in excess of those accruing only to the natural gas sector. The restrictions placed on the natural gas sector in this study may be interpreted as government control over demands, designed to conserve natural gas supplies. Other types of conservation schemes could be considered, for example constraints placed on certain processing sectors use of natural gas. However, these types of constraints require a modification of the present analytical system which is beyond the scope of this study.

In assessing the output, employment and income impacts of restricting natural gas deliveries to final demand we employ several variants regarding demand restrictions. In the following discussion, sales by the natural gas sector to final demands are limited in all cases to an annual increase of 1.5 percent. Variant one employs an assumed annual increase in deliveries to final demand by the remaining processing sectors of 2.5 percent per year to satisfy household demand and 3.5 percent annual increase in government demand.

Variant two assumes that restrictions are also placed on sales to final demand by those sectors receiving input from the natural gas sector. The restrictions are the same in growth of sales to final demands for these sectors as for the natural gas sector--1.5 percent per year. The remaining few sectors are assumed to increase their sales to households at 2.5 percent per year and to governments at 3.5 percent annually.

The final variant differs from variant two only in one respect. In variant three, coal sector exports are allowed to increase at 8.0 percent per year.

In all cases the comparative analysis is performed by examining potential increase in output, employment and income under conditions of unrestricted growth and then examining the magnitude of these same variables as the constraints are imposed.

VARIANT ONE

Table V-8 presents the results of imposing a growth limit of 1.5 percent per year on deliveries of natural gas to final demands. Sales by all other sectors grow at 2.5 percent annually to households and 3.5 percent annually to governments. The results of imposing the restriction only on sales by the natural gas sector indicate that total output in the processing sectors might be expected to grow to $19,397,895 thousand. Comparing this with the projected potential output under no gas restriction (Table V-2) indicates that a potential loss of $12.9 million in total output by the processing sectors would occur as a result of this restriction. Similarly, a potential loss of 1,025 in the projected number of workers would be expected. Restricting the delivery of natural gas to final demands, as would be expected, also causes projected household income to be at a level less than would be achieved under unrestricted growth. The difference in the two is $1.968 million. This is the potential cost, in terms of lost income associated with the restricted final consumer purchases of natural gas.

VARIANT TWO

The second variant used to assess the impacts of restricted sales to final demand imposes restrictions on final demand sales by those sectors

TABLE V-8

Output, Employment, and Income, by Sector, Under Restricted

Natural Gas Sales to Final Demand, 1980: Variant One

Sector	($1,000) Total Output	(# Workers) Total Employment	($1,000) Total Income
1. Natural Gas	103,979	2,288	15,742
2. Livestock	1,080,937	33,509	171,977
3. Irrigated Agriculture	365,828	22,681	70,202
4. Dryland Agriculture	154,442	4,942	34,271
5. Food Processing	2,032,325	24,388	183,519
6. Metal Mining	222,092	6,219	52,747
7. Petroleum Production	135,584	4,474	50,830
8. Industrial Minerals Production	216,914	5,423	39,587
9. Coal Mining	44,399	1,199	13,662
10. Mining Services	61,151	2,385	23,898
11. Pipeline Transportation	283,722	284	3,064
12. Petroleum Refining	97,858	783	6,390
13. Primary Metals	244,655	7,829	69,580
14. Electric Power Generation	133,103	2,130	16,877
15. Fabricated Metals	1,101,482	20,928	168,857
16. Electronics	552,287	13,579	125,314
17. Transportation, Communication, and Public Utilities	1,273,921	53,505	452,752
18. Textiles	123,848	7,059	40,213
19. Paper	59,279	1,482	10,451
20. Printing	236,547	10,645	77,990
21. Chemicals	364,230	9,834	85,266
22. Wood Products	122,623	4,169	23,372
23. Other Manufacturing	108,486	6,401	43,796
24. Trade	6,850,846	191,824	1,057,086
25. Services	2,360,088	115,644	530,312
26. Elementary and Secondary Education	653,274	54,222	385,954
27. University Education	413,635	52,118	219,847
Totals	19,397,535	659,944	3,973,556

which require natural gas as an input in their own production processes. The impacts here are, again because of sectoral interdependence, more dramatic than those resulting from a restriction placed only on natural gas sales. Sectors purchasing directly from the natural gas sector are restricted to the same annual growth in sales to final demand as the natural gas sector. The few remaining sectors' deliveries to final demand were allowed to grow at a rate of 2.5 percent and 3.5 percent respectively in households and government. Table V-9 presents the total output, employment and income estimates for 1980 under this variant.

The material presented in Table V-9 represents the results of a deliberately harsh set of constraints imposed on the ability of existing sectors to make deliveries to final demands. It is quite unlikely that such severe measures would actually become a reality except in an extreme emergency. However, our purpose in this extension is mainly that of demonstrating the capability of the analytical system to handle questions concerning the impacts of energy cutbacks in the final demand sectors of the economy. Less drastic alternatives may be specified and readily incorporated into the analysis.

In demonstrating the impacts of variant two on potential output, employment, and income in the Colorado economy one might again contrast the results obtained with those from an unconstrained annual rate of growth in household final demand of 2.5 percent and government final demand of 3.5 percent. This unconstrained situation shows a potential 1980 output of $19,410,801 thousand, potential processing sector employment of 660,969 and income of $3,975,521 thousand. The imposition of restricted growth in final demand for the natural gas sector and those sectors purchasing from the natural gas sector results in a projected output of $18,174,632 thousand in the processing sectors or a potential cost of $1.24 billion in lost output.

TABLE V-9

Output, Employment, and Income, by Sector, Restricted

Natural Gas Sales to Final Demand, 1980: Variant Two

Sector	($1,000) Total Output	(# Workers) Total Employment	($1,000) Total Income
1. Natural Gas	101,114	2,225	15,309
2. Livestock	1,017,778	31,551	161,928
3. Irrigated Agriculture	343,745	21,312	65,965
4. Dryland Agriculture	144,076	4,610	31,970
5. Food Processing	1,911,963	22,944	172,650
6. Metal Mining	222,056	6,218	52,738
7. Petroleum Production	133,586	4,408	50,081
8. Industrial Minerals Production	204,923	5,123	37,398
9. Coal Mining	43,447	1,173	13,369
10. Mining Services	60,598	2,363	23,682
11. Pipeline Transportation	278,905	279	3,012
12. Petroleum Refining	94,279	754	6,156
13. Primary Metals	242,293	7,753	68,908
14. Electric Power Generation	123,828	1,981	15,701
15. Fabricated Metals	1,083,205	20,581	166,055
16. Electronics	541,247	14,072	122,809
17. Transportation, Communication, and Public Utilities	1,183,160	49,693	420,495
18. Textiles	117,215	6,681	38,060
19. Paper	56,442	1,411	9,951
20. Printing	223,172	10,043	73,580
21. Chemicals	347,013	9,369	81,236
22. Wood Products	120,308	4,090	22,931
23. Other Manufacturing	102,271	6,034	41,287
24. Trade	6,381,207	178,674	984,620
25. Services	2,188,351	107,229	491,722
26. Elementary and Secondary Education	548,085	45,491	323,809
27. University Education	360,365	45,406	191,534
Totals	18,174,632	611,468	3,686,956

Employment under restricted growth in final demand is 611,468 or a reduction of 49,501 workers when compared to the unconstrained growth projections. Total income, given the restricted growth in final demand, is $3,686,956 thousand, $289 million less than the potential unconstrained level. The impacts on each sector may easily be obtained from a comparison of sector-by-sector output, employment, and income for the respective tables (Table V-9 with tables V-1 through V-4, as desired).

VARIANT THREE

The final variant of this extension of the analytical system differs from variant two only in that exports from the coal mining sector have been increased at 8 percent annually. This variant demonstrates the capability of the model in handling different exogenous changes simultaneously.

Table V-10 presents the results of this extension. Comparison of the results presented in Table V-10 and those shown in Table V-9 yields the estimated impacts of allowing the final demand for coal mining to expand relative to that for the output of the other sectors. After all direct and secondary impacts have been accommodated, total output is $18,203,926 thousand (an increase of $29.3 million over that shown in Table V-9), total employment is 612,317 (an increase of 849) and total income is $3,695,754 thousand (an increase of $8,798 thousand).

Any number of alternative scenarios regarding changes in the size and composition of final demand may be considered within the analytical framework. Our purpose has been to demonstrate the capability of the model in addressing such changes. Our recommendation is that scenarios actually representative of proposed policies be examined within this framework in order to estimate their total economic consequences.

TABLE V-10

Output, Employment, and Income, by Sector, Restricted Natural Gas

Sales to Final Demand, 1980: Variant Three

Sector	($1,000) Total Output	(No. Workers) Total Employment	($1,000) Total Income
1. Natural Gas	101,136	2,225	15,312
2. Livestock	1,017,814	31,552	161,934
3. Irrigated Agriculture	343,758	21,313	65,967
4. Dryland Agriculture	144,079	4,611	31,971
5. Food Processing	1,912,029	22,944	172,656
6. Metal Mining	222,057	6,218	52,739
7. Petroleum Production	133,608	4,409	50,090
8. Industrial Minerals Production	205,786	5,145	37,556
9. Coal Mining	65,384	1,765	20,119
10. Mining Services	61,580	2,402	24,065
11. Pipeline Transportation	278,961	279	3,013
12. Petroleum Refining	94,288	754	6,157
13. Primary Metals	242,353	7,755	68,925
14. Electric Power Generation	124,127	1,986	15,739
15. Fabricated Metals	1,083,795	20,592	166,146
16. Electronics	541,337	14,075	122,829
17. Transportation, Communication, and Public Utilities	1,186,083	49,815	421,534
18. Textiles	117,226	6,682	38,063
19. Paper	56,460	1,412	9,954
20. Printing	223,208	10,044	73,592
21. Chemicals	347,252	9,376	81,292
22. Wood Products	120,459	4,096	22,960
23. Other Manufacturing	102,316	6,037	41,305
24. Trade	6,381,706	178,688	984,697
25. Services	2,188,672	107,245	491,795
26. Elementary and Secondary Education	548,085	45,491	323,809
27. University Education	360,367	45,406	191,535
Totals	18,203,926	612,317	3,695,754

A LINEAR PROGRAMMING APPLICATION

The final extension of the basic Leontief or input-output model consists of converting the positive model, which is a descriptive statement of the existing economy (or likely future economy) to a conditionally normative model describing what the organization of economic activity ought to be given specified objectives and resource constraints.

Standard input-output models do not account for resource limitations. Such models are assumed to reflect patterns of economic trade and technologies which are reasonably constant over time. Associated with the assumption of constant trade relationships is the tacit assumption that primary resources such as land, water, minerals and labor will be forthcoming at costs which change very little in response to demand. In reality, however, economic scarcity rather than abundance appears to be the rule. The simplest, most straightforward example of the problem of potential or actual economic scarcity is that in which a particular resource is fixed in supply for a particular region. For the particular extension considered here, water available for consumptive use in Colorado is the resource selected for examination. Incorporation of a resource restraint requires only the addition of a new row to the input-output model. Each sector of the economy has an entry in this row which represents that sector's use of the resource per dollar of output. In this particular case, the row elements are gallons of water used per one dollar ($1.00) of total gross output for each sector. These elements are taken directly from the second column of Table V-6.

As long as the economy is not using all of the resource, this restraint will not change the solution of the model. But when the resource is exhausted it becomes more valuable as various sectors compete for its use. If market forces are allowed freedom, the result will be a tendency for sectors which use the greatest amounts of this resource per dollar of net output, or profit, to restrict their use in deference to those which use less of the resource per dollar of profit.

To represent this phenomenon through the use of an input-output model, the final demands can be gradually expanded (it really doesn't matter in which proportions) until the resource becomes binding. However, given the assumptions of the input-output model, all that can be stated is that once the resource becomes binding the economy reaches a "bottleneck" which precludes further growth. Because of the nature of the input-output problem there is nothing to be maximized nor minimized. The model does not readily accommodate a change in the composition of output or economic activities which would logically follow increasing scarcity of resources. In order to introduce the capacity for accommodating economic growth in the face of resource restrictions it is necessary to introduce a set of criteria which give the model the capability of "choosing" which sectors to limit and which sectors to expand still further. In this extension, the objective is to simulate the working of the marketplace. Therefore, the criteria used are a set of weights ("prices"), one for each sector, which represent the value of that sector's output net of payments to other sectors. This reflects the sector's contribution to final demand, a rough estimate of gross state product.

Under this set of criteria, all final demands will expand as rapidly as they are allowed until the resource restraint becomes limiting. At that point the model selects those sectors which produce the least final demand output per unit of water and redistributes the resource used by those sectors to sectors which are more efficient in their use of water.

Consistent estimates of total water supply and water available for consumptive use in the future are difficult to obtain. We have selected a consumptive use availability figure of 6.6 million acre-feet for the entire state. Total consumptive use estimated for 1970 (see Chapter IV, page 55) is 5,030,604 acre-feet. Thus the question is one of estimating how much economic growth can be accommodated before this limit is reached and then determining which sectors will grow and which will contract.

The procedure used in this study was to allow final demands to expand at a rate which represented an annual 3 percent growth in households and an annual 3.5 percent growth in government components of final demand. At this rate, it took 18 years of growth, beginning in 1970, for the Colorado economy to exhuast annual consumptive water availability. This consumptive use restraint, however, represents total state availability and ignores the important issues of regional scarcity, institutional barriers to interbasin transfers and minimum flow requirements. Thus the figure of 18 years is quite optimistic. Despite this limitation the results obtained are of interest for two reasons. First, once the consumptive use restraint is reached, a reorganization in production will occur. Second, the resource may no longer be considered free in an economic sense; i.e., a value is imputed to the resource.

The first sector whose output was affected by the resource constraint was irrigated agriculture. Final demand for irrigated agriculture fell to its lower bound with total output $489,563,000 and the imputed value of an acre-foot of water consumptively used reached $75.34. As the outputs of other sectors continued to grow, the growth of the livestock sector was constrained to its lower bound because of the water use of irrigated agriculture for supplying productive factors. At this point the imputed value per acre-foot of consumptive use increased to $531.79. Eventually, growth in another sector, food processing, was also constrained to its lower bound at which point the imputed value per acre-foot of consumptively used water reached $2,536.51.

The effects of increased costs to irrigated agriculture on livestock and food processing is a good example of secondary and tertiary impacts in an input-output model. The food processing sector's consumptive water use per dollar of output is only .35 gallons. This modest requirement would not by itself make this industry a candidate for contraction. But the food processing industry has major inputs from irrigated agriculture and from livestock (which in turn uses large inputs from irrigated agriculture). This is reflected in the indirect consumptive water requirement for food processing which is 613.14 gallons per dollar of output delivered to final demand.

The values attached to water by the linear program seem excessive, but it must be remembered that this value is per acre-foot of consumptive use. If some mechanism were available for charging each sector according to consumptive use the price per acre-foot of withdrawals would be but a fraction of the price on consumptive use. For example, the fraction would be one-tenth or less for food processing, trade, services and education sectors.

The 18 years of growth which this model allowed the Colorado state economy prior to a consumptive water use limitation is obviously excessive. In fact, there is well-publicized evidence that water prices and inter-sectoral conflict over water rights are on the rise in parts of the state. Clearly, a regionalized model is called for in an area like Colorado with distinct geographical regions and uneven distribution of natural resources. Water is perhaps the best example of a resource which is both unevenly distributed and likely to play a determining role in economic development. Thus, the information furnished by a regionalized input-output model of

Colorado would surely justify the time and expense involved in building such a model which would likely also be nonlinear.

CHAPTER VI

SUMMARY AND CONCLUDING COMMENTS

The descriptive analysis contained in Chapter IV of this report culminates a four-year research effort on the part of the authors. The description of the Colorado economy for the base year 1970, contained in Table IV-1, represents the result of extensive interviews with Colorado businessmen who gave freely of their time and effort in providing information necessary to the descriptive analysis. This description of basic flows, or transactions, provides the empirical data base from which a variety of problems may be analyzed. Specific economic variables which are analyzed in the text of the report include sector-by-sector estimates of the total value of output in the economy, the contribution of specific economic sectors to personal income, estimates of consumptive water use on a sector-by-sector basis and estimates of employment, again on a sector-by-sector basis. In addition, the degree of economic interdependence among the processing sectors of the economy is analyzed and multiplier effects on business activity, income, employment and consumptive water use are estimated.

The estimation of these economic variables allows modification or extension of the basic model to examine other issues of concern to policy makers. It has been the intent of the authors to provide some insight into this analytical capability and to provide empirical examples of the types of questions which may be conveniently addressed. Thus, while the major purpose of the research is to relate levels of water use, employment and income to economic activity, an important by-product is the demonstration of the model's flexibility in the hope that many policy alternatives will subsequently be considered within the framework provided.

In this latter regard, the results of the extensions of the basic model must be interpreted in light of the intended purpose. These results are indicative of alternative futures if the assumptions employed are actually met. They should not be taken literally as predictions of the future economy. Although the authors have attempted to employ reasonable assumptions regarding growth in final demands, detailed analysis of final demand sectors other than households and government is needed.

SUMMARY OF FINDINGS

The major results of the descriptive analysis may be conveniently summarized in terms of the sector-by-sector contributions to several economic variables contained in the study. These include the total value of output, contribution to household income, employment and consumptive water use. In addition the major sectors in terms of the various multipliers effects are summarized.

Total gross output (the total value of goods and services delivered for intermediate and final consumption) provides a means for assessing the relative size of various sectors of the economy. For the base year 1970, the total value of all goods and services sold by sectors of the Colorado economy was estimated at $38.4 billion. The trade sector is by far the largest of the processing sectors in terms of total gross output which was estimated at $5.8 billion in 1970. Other relatively large processing sectors were services ($2.0 billion); food processing ($1.8 billion); transportation, communication and public utilities ($1.1 billion); fabricated metals ($1.1 billion); and livestock ($1.0 billion). These sectors combined accounted for 33.3 percent of the state total value of output as estimated for 1970. The final demands sectors, households, governments, exports and other final demands accounted for 56.3 percent of the total value of output with households valued at $8.1 billion, governments at $4.3 billion, exports at $4.4 billion and other final demands at $4.8 billion.

Payments to households or payments for labor services was estimated to be $8.1 billion in 1970. Again, the trade sector was the most important of the processing sectors in terms of contribution to household income with payments of nearly $900 million. This was followed by services ($444 million); transportation, communications and public utilities ($384 million); elementary and secondary education ($284 million); university education ($169 million); fabricated metals ($163 million); food processing ($161 million); livestock ($151 million); and electronics ($119 million). Other final demands and governments are quite important in terms of payments to households with a total of $4.7 billion between them.

Employment in the processing sectors of the economy follows a pattern reasonably consistent with payments to the household sector. The most important sectors with respect to numbers of workers employed are trade (163 thousand); services (97 thousand); transportation, communication, and public utilities (45 thousand); university education and primary and secondary education (each with approximately 40 thousand); livestock (29 thousand); food processing (21 thousand); fabricated metals (20 thousand); irrigated agriculture (20 thousand); and electronics (14 thousand).

The results of the descriptive water use analysis for the 1970 Colorado economy are hardly surprising given the semi-arid climate and well developed agricultural base. Irrigated agriculture emerges as the primary consumptive water user. Total consumptive use for 1970 exceeded five million acre-feet. Of this total, 83 percent or 4.3 million acre-feet was consumed in crop irrigation. Other important consumptive users include metal mining (36.6 thousand acre-feet); livestock (34.7 thousand acre-feet); and electric power generation (10.9 thousand acre-feet). Consumptive use by households amounted to an estimated 64.7 thousand acre-feet in 1970.

In addition to estimating the above economic variables, which are indicative of the relative importance of the processing sectors of the economy, the analytical technique employed in the study is useful in assessing the impact of exogenous changes in final demands for the outputs of specific sectors upon the economy in general. These impacts include not only the direct impacts on production, income, employment and consumptive water use but also indirect impacts which may be quite substantial. Since changes in final demand start the series of changes in processing sector activities, the direct and indirect effects on output, income, etc., are summarized in terms of changes in final demands.

The direct and indirect production generated in the economy in order to sustain the delivery of an additional dollar's worth of output to final demand in any sector is termed the business, or output, multiplier effect. The largest output multiplier was found to be that of the livestock sector. An increase of one dollar of output delivered to final demand by this sector generates a total of $3.18 worth of production throughout the Colorado economy. Thus the business multiplier is 3.18. Other important sectors are: other manufacturing (2.89); irrigated agriculture (2.72); trade (2.65); elementary and secondary education (2.62); food processing and also petroleum refining (2.57); university education (2.48); and services and also dryland agriculture (2.45). These are the sectors which exhibit the greatest interdependence with other sectors of the state economy and thus the sectors which generate the greatest dollar volume of business activity per each dollar's worth of output delivered to final demand.

Two other common multipliers are the Type I and Type II income multipliers. Both of these measure the total income change resulting from a change of one dollar paid directly to households. The Type I or simple income multiplier accounts for the direct and indirect income payments associated with an additional dollar of direct income while the Type II income multiplier also accommodates income payments induced by increased household spending. Thus the Type II multiplier will always exceed the Type I. These multipliers are presented in Table IV-5 of the report. Seven sectors of the 1970 Colorado economy had Type II income multipliers in excess of two. These sectors and the Type II multipliers are: petroleum refining (4.05); food processing (3.54); livestock (3.03); trade (2.49); irrigated agriculture (2.30); natural gas (2.26); and electric power generation (2.05).

Direct plus indirect employment changes associated with individual sector's deliveries of output to final demand also serve as an important input into the planning process. The magnitude of the direct plus indirect employment effects depends upon the direct employment in each sector and the degree of interdependence that exists between a sector and the rest of the economy. The leading sectors, in terms of direct plus indirect employment per $1,000 delivered to final demand, were: university education (.133); irrigated agriculture (.092); elementary and secondary education (.090); livestock (.087); other manufacturing (.083); and services (.072).[16/]

The water use analysis provides an excellent example of the importance of interdependence among economic sectors on natural resource requirements. Many sectors of the Colorado economy exert very little direct pressure on water supplies available for consumptive use. However, because of the direct and indirect ties to heavy water using industries, these same sectors

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[16/] For interpretation of these direct plus indirect employment coefficients, consider university education. The coefficient .133 states that an increase in this sector's deliveries to final demand of one million dollars would increase employment by 133 workers.

may generate significant direct plus indirect consumptive use requirements throughout the economy. An example of note is the food processing sector with a direct consumptive use requirement per dollar of output produced of only .35 gallons. However, the direct plus indirect consumptive use requirement generated throughout the economy for each new dollar's worth of output delivered to final demand by food processing is 613 gallons. This is quite justifiable given the large degree of interdependence between food processing, livestock and irrigated agriculture. The irrigated agriculture sector is far and away the most important sector in terms of water requirements, generating a consumptive use requirement of 4,331 gallons for every dollar of output delivered to final demand. This is followed by livestock (1,241 gallons); food processing (613 gallons); trade (128 gallons); metal mining (58 gallons);and dryland agriculture (44 gallons).[17/]

With regard to the extensions of the basic input-output model, several scenarios of future growth in the exogenous (final demand) sectors of the economy were analyzed. These scenarios, discussed in Chapter V of the report, result in a range of projected processing sector production, income paid to households by the processing sectors, employment and consumptive water use. All scenarios are for the period 1970-1980.

Projections of the total value of production for all processing sectors range from a low of $18.6 billion to a medium of $19.4 billion to a high of $21.3 billion. The corresponding income projections for the three categories are $3.8 billion, $4.0 billion and $4.3 billion. These estimates include only income payments made by the processing sectors and not payments to households by final demand sectors.

[17/] This does not infer that dryland agriculture uses 44 gallons of water consumptively for each dollar of output delivered to final demand. Rather, as dryland agriculture increases these deliveries by one dollar, other sectors of the economy which supply inputs to dryland agriculture require 44 gallons of water consumptively.

Projections of total state employment made under alternative assumptions as to growth in final demands resulted in a low estimate of 1.13 million workers, a medium estimate of 1.2 million and a high estimate of 1.5 million for the year 1980.

Projections of consumptive water use requirements indicate that the state will approach the estimated total water supply available for consumptive use by 1980. The low, medium and high estimates of consumptive water requirements for 1980 are respectively 5.44 million acre-feet, 5.7 million acre-feet and 6.1 million acre-feet. The high estimate is within 7 percent of the total estimated supply available for consumptive use.

Table VI-1 summarizes the impact of one future growth scenario on the key economic variables analyzed in the report and is indicative of the detailed analyses conducted on all alternative scenarios. This specific scenario assumes a 3 percent annual increase in households, a 3.5 percent growth in governments, and an 8 percent annual growth in coal sector exports. Under these assumed conditions the total value of all processing sector's deliveries to final consumption would increase to 119 percent of 1970 levels by 1980; the total value of output in these processing sectors would increase by 18.5 percent over 1970 levels; household income and employment would increase by 20.6 percent and 20.9 percent respectively, and consumptive use of water would increase by 16.3 percent in the processing sectors.

The sensitivity of the analytical framework to alternative scenarios for growth and to restrictions in the capability of certain sectors to satisfy final demands can be easily shown. For example, consider a scenario which differs from the one just described in that the coal sector is treated in exactly the same manner as the other sectors. Thus we drop the assumed 8 percent annual growth in coal exports. Under this scenario, aggregate final consumption reaches $11.8 billion by 1980. This is an increase of

TABLE VI-1 SUMMARY TABLE

IMPACT OF ECONOMIC GROWTH ON SELECTED ECONOMIC VARIABLES ASSUMING A 3% ANNUAL INCREASE IN HOUSEHOLD CONSUMPTION, 3½% ANNUAL GROWTH IN GOVERNMENT AND 8% ANNUAL GROWTH IN COAL EXPORTS.

Sector	($1,000) 1970 Final Demand	($1,000) 1970 Total Output	1970 Total Employment	($1,000) 1970 Total Income	(acre-feet) 1970 Consumptive Water Use	1980 % Change Final Demand	1980 % Change Total Output	1980 Change Total Employment	($1,000) 1980 Change Total Income	(acre-feet) 1980 Change Consumptive Water Use
1. Nat. Gas	58,713	89,623	1,972	13,570	30	31.8	28.3	555	3,820	9
2. Livestock	54,630	951,256	29,489	151,330	34,739	10.0	15.7	4,535	23,805	5,458
3. Irr. Ag.	24,532	320,982	19,901	61,586	4,177,514	12.8	16.0	3,187	9,876	668,790
4. Dry. Ag.	55,565	135,271	4,329	30,016	0	14.9	15.4	666	4,619	0
5. Food Proc.	1,025,575	1,787,260	21,447	161,333	1,920	11.7	15.7	3,376	25,460	302
6. Met. Min.	219,612	222,015	6,216	52,731	36,621	0.0	.04	3	19	15
7. Pet. Prod.	17,632	128,925	4,255	48,337	2,010	0.0	7.5	319	3,623	151
8. Ind. Min. Prod.	142,566	195,068	4,877	35,593	2,873	9.4	12.5	609	4,452	359
9. Coal. Min.	24,959	42,308	1,142	13,017	444	87.8	57.6	658	7,504	256
10. Min. Serv.	11,440	59,412	2,317	23,220	115	0.0	5.8	135	1,346	7
11. Pipe. Trans.	143,656	267,650	268	2,891	411	.8	8.7	23	252	36
12. Pet. Ref.	44,814	89,900	719	5,873	1,048	0.0	10.6	76	621	111
13. Prim. Met.	122,511	239,580	7,667	68,145	7,190	0.0	2.5	194	1,712	181
14. Elec. Pow. Gen.	2,302	112,802	1,805	14,300	10,939	26.8	21.3	384	3,046	2,326
15. Fab. Met.	817,788	1,062,756	20,192	162,957	5,218	.9	4.3	873	7,010	226
16. Electronics	380,641	528,697	13,746	119,980	438	.1	5.3	724	6,300	23
17. Trans., Com., Pub. Ut.	449,522	1,081,292	45,414	384,263	4,977	23.6	21.2	9,610	81,350	1,053
18. Textiles	43,627	108,940	6,210	35,373	107	8.2	16.5	1,025	5,834	18
19. Paper	14,905	53,240	1,331	9,385	41	0.0	13.4	178	1,255	5
20. Printing	101,519	208,600	9,387	68,777	51	7.7	15.6	1,465	10,732	8
21. Chem.	100,905	327,360	8,839	76,646	8,057	1.2	13.3	1,179	10,213	1,074
22. Wood Prod.	79,417	117,700	4,002	22,433	5,050	.1	5.0	202	1,130	254
23. Oth. Mfg.	29,224	94,615	5,582	38,195	581	16.0	17.7	986	6,749	103
24. Trade	4,042,490	5,807,247	162,603	895,859	4,099	21.6	21.6	35,055	193,376	883
25. Serv.	1,215,872	1,975,044	96,777	443,739	3,818	25.3	23.5	22,734	104,306	897
26. El., Sec. Ed.	476,097	480,580	39,888	283,913	870	35.9	35.9	14,334	102,041	313
27. Univ. Ed.	310,638	317,198	39,967	168,600	574	32.9	32.6	13,014	54,886	187

18 percent over 1970 levels compared to a 19 percent projected increase under the previous scenario. In dollar terms this translates into a difference of $100 million in growth in final consumption. Similar results are obtained for the remaining economic variables. The value of total output under this second scenario increases by 17.9 percent over 1970 levels compared to an 18.5 percent increase when coal exports are allowed to expand. The increase in consumptive use of water under the two scenarios is quite similar; 16.0 percent as compared to 16.3 percent. Employment increased by 20.6 percent in the second scenario as compared to 20.9 percent in the first. The increase in payments to labor (household income) in the second scenario amounted to 19.4 percent of 1970 income compared to an increase of 20.6 percent in the first scenario.

A third interesting scenario examines the question of assessing the impacts of restricting the ability of a sector or sectors to satisfy the final demands for their products. In this scenario, final demands for the output of the natural gas sector and of those sectors purchasing directly from the natural gas sector were restricted to an annual growth of 1.5 percent. Using the first scenario as a basis for comparison, the results of this restriction in terms of losses in potential value of output, employment, and income are fairly dramatic. Total output, when these restrictions are imposed, increases to $18.2 billion by 1980 as compared to $16.8 billion in 1970, an increase of 8 percent. This percentage increase is compared to an 18.5 percent increase under the assumptions of the first scenario. Employment increases from 560 thousand in 1970, to 611 thousand in 1980, an increase of 9.1 percent. This is compared with the potential increase of 20.9 percent under the first scenario and the difference between potential employment, in numbers of workers, is 66 thousand. Income paid to households under the assumption of the first scenario could reach $4.1 billion by 1980. However, the restrictions assumed in the third scenario allow household income to increase to $3.7 billion or an increase of 8.8 percent over 1970 levels. This compares with the 20.6 percent potential increase in the unrestrained growth of the first scenario. The difference between $4.1 billion and $3.7 billion or $400 million is the potential cost of the restrictions in terms of income foregone.

Other scenarios were analyzed and are contained in the body of the report. Certainly, many other alternatives can be considered. Using the analytical base provided, these additional alternatives can be addressed relatively rapidly and efficiently.

The final extension of the basic input-output model is the conversion to a highly simplified optimization model incorporating an objective function of maximizing dollar deliveries to final demands given a restraint placed on available water supplies for consumptive use. The final demand maximization function employs a set of weights (prices), one for each of the processing sectors, whose values are the respective contributions to the final bill of goods. The model employs a consumptive water use constraint of 6.6 million acre-feet for the entire state.

The procedure used in demonstrating the linear programming feature of the model was to allow final demands to expand at a rate representing 3 percent annual growth in household and a 3.5 percent annual growth in the government component of final demand. This represents a rather conservative growth for the Colorado economy and thus an optimistic view of how far the economy can expand given current technology and the suggested restraint on water supply.

The results of the linear programming application are interesting for two reasons. First, once the consumptive use restraint becomes effective, a change in the mix of production activities is realized. Second, the water resource begins to take on rather significant scarcity (imputed) values.

Given the growth rates imposed on the final demand sectors of the model and the total supply of water available for consumptive use, the economy can expand for approximately 18 years (beginning from the 1970 base) before water supplies available for consumptive use are exhausted. At this point, available water supplies can no longer sustain deliveries of outputs to satisfy all final demands and thus the output of certain sectors begin to fall. The first sector effected was irrigated agriculture whose final demand fell to its lower limit of $490 million. The imputed value of an acre-foot of water consumptively used reached $75.34. As the outputs of the other sectors continued to grow, growth of final demand in the livestock sector was also constrained and the imputed value per acre-foot of water consumptively used increased to $532. Eventually growth in yet another agriculturally related sector, food processing, was constrained to its lower bound and the imputed value of water reached $2,537 per acre-foot.

LIMITATIONS OF THE STUDY AND SUGGESTIONS FOR FURTHER RESEARCH

The general limitations of input-output models imposed by the assumptions of the model have long been recognized and need not be discussed in great detail here. Assumptions regarding the nature of input-output production functions, constant technology and lack of input substitution possibilities limit any projections use of the model to the relative short run. Thus, to be very useful from the planning perspective it is important for the model to be periodically updated.

The assumption of constant water use coefficients in irrigated agriculture appears to be more highly suspect than for other sectors. Expansion in irrigated agriculture implies that additional land (and other factors) must also be used. If additional land brought under irrigation, perhaps from dryland acreage or from previously uncultivated areas, is of significantly different soil type or quality than that currently irrigated, one would expect significant differences in water use coefficients. Because of the importance of irrigated agriculture as a water user, changes in the water use coefficients could have large impacts on projected water use.

Further, product mix in irrigated agriculture may change rather rapidly and, since different crops require different quantities of water, the average coefficients used for projecting water use may be expected to vary from year to year. Both of these limitations suggest the need for detailed research into the nature of irrigated agriculture in the state economy with particular emphasis being placed on changes in irrigation technology and various scenarios concerning the composition of irrigated agricultural output.

The projections of water use under both the static Leontief framework and the linear programming application may lead the reader to a false sense of security regarding the urgency of water problems within the state. The 18 year growth, allowed by the assumptions made with respect to annual increases in final demands and the water supply available for consumptive use, is quite optimistic for several reasons. First, the assumed growth rates do not accommodate rapid growth in energy; e.g., coal and potentially oil shale within the state. Thus, the potential for significant water use in these sectors has not been accounted for. Second, the consumptive use restraint employed in the study represents total state availability and thus ignores the very important issues of regional scarcity, institutional barriers to inter-basin transfers and minimum flow requirements. There is well-publicized evidence that water prices, as well as intersectoral conflicts over water rights, are on the increase in parts of the state. It is apparent that a regionalized model, perhaps consistent with the state planning regions, is called for in an area like Colorado with distinct geographical regions and uneven distribution of natural resources. Water is perhaps the leading example of a resource which is both unevenly distributed and likely to play a crucial role in continued economic development. Thus, additional information furnished by a regionalized model of the state economy would appear to justify the time and expense involved in its construction.[18/]

18/ Efforts at constructing smaller regional models may be cited. For examples, the authors have completed a regional input-output model of a three-county economy in northern Colorado and are currently constructing a nine-county model of northwestern Colorado. Additional work is underway at the University of Colorado under the direction of Drs. Charles Howe and Bernard Udis. However, no large scale, integrated effort at regionalizing the entire state economy presently exists.

Appendix A

SOURCES COLORADO TGO VALUES

All SIC definitions are based on the 1972 description as identified in Office of Management and Budget, Executive Office of the President, Standard Industrial Classification Manual 1972, U.S. Government Printing Office, Washington, D.C.

Sector Number

1 4924, 4931 (part) NATURAL GAS DISTRIBUTION.
Various Companies' Annual Reports to the Colorado Public Utilities Commission.

2 02 LIVESTOCK AND LIVESTOCK PRODUCTS.
Colorado Crop and Livestock Reporting Service, Colorado Agricultural Statistics. (various years)

Agricultural Stabilization and Conservation Service, U.S. Department of Agriculture, Colorado Annual Report. (various years)

Economic Research Service, U.S. Department of Agriculture, Supplement for 1972 to Wool Statistics and Related Data, 1930-1969.

3, 4 01 AGRICULTURE.
Op. cit., Colorado Agricultural Statistics.

U.S. Bureau of the Census, Census of Agriculture 1969, Volume 1. Area Reports. Part 41. Colorado Section 2. County Data. U.S. Government Printing Office, Washington, D.C., 1972.

Crop Reporting Board, Statistical Reporting Service, U.S. Department of Agriculture, Agricultural Prices. (various years)

Op. cit., ASCS, Colorado Annual Report.

5 20 FOOD AND KINDRED PRODUCTS.
U.S. Bureau of the Census, Census of Manufacturers, 1972, Area Series, Colorado, MC 72(3)-6. U.S. Government Printing Office, Washington, D.C., 1975. (also 1967)

6 1011, 1021, 1031, 1041, 1044, 1061, 1094, 1099 METAL MINING.
Colorado Bureau of Mines, A Summary of Mineral Industry Activities in Colorado. (various years)

Bureau of Mines, U.S. Department of the Interior, Minerals Yearbook, Vol. III, Area Reports: Domestic. U.S. Government Printing Office, Washington, D.C. (various years)

7 1311, 1321 PETROLEUM PRODUCTION.
Op. cit., A Summary of Mineral Industry Activities in Colorado.

Op. cit., Minerals Yearbook.

Sector Number

8 14 (except 148), 324, 325, 327 INDUSTRIAL MINERALS PRODUCTION.
Op. cit., A Summary of Mineral Industry Activities in Colorado.

Op. cit., Minerals Yearbook.

Op. cit., Census of Manufacturers, 1972. Area Series: Colorado.

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