WATER FOR THE SOUTH PLATTE BASIN

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The South Platte east of Longmont, looking NE

Water for the South Platte Basin

INTRODUCTION

The physical facilities to store and deliver water in the South Platte River basin and then return it for further use have been developed since 1858, when the first water right was established on Clear Creek, near Golden. Today these facilities represent an investment of millions of dollars. They include dams and reservoirs for storage, tunnels for transbasin water transfers, miles of pipelines and canals, distribution facilities as required by farms, cities, and industries and finally wastewater treatment facilities.

The management of these facilities is handled by a multitude of state and federal agencies, cities, irrigation districts, and other organizations. While both the management entities and the physical systems have been developed independently to serve separate units (i.e., cities, industries, agricultural areas) there is extensive interlinking between the two. The "linkages" may involve sharing storage or conveyance facilities, exchanges of water which increase its utility, or the hydrologic interdependence between wastewater production by a city and its downstream use by agriculture.

Physical Plus Institutional = A System

These many physical linkages and organizational arrangements collectively constitute a "system." Each linkage of each arrangement could be termed a "fit." Thus one can say that the South Platte River system is a collection of "fits."

A key point to remember is that the present South Platte system has evolved "spontaneously" over a considerable period of time, satisfying the multitude of individual fits between available water supplies and the water demands of the basin. Any deliberate comprehensive basin-wide planning would have had difficulty in achieving such well-serving fits.

Average and Stress Scenarios

However, there are demographic and development forces now evolving in Colorado which will give a new dimension to the water supply-demand picture. To examine what might be ahead for the basin, a study was made to project both the availability of future water supplies and future demands.

Several possible alternatives of supply-demand were developed during the study for the Years 1980, 2000, and 2020, for both "average" and "stress" scenarios. They are shown in Table 1 - pp. 2-5. Two water supply conditions were assumed: the long-term average annual streamflow and a "drought period" as experienced in 1953 to 1956.

A significant question examined during the study was: what projects can be used to furnish the water necessary to meet the scenario "demands"?

Although several combinations are possible, the scenario rule was: use existing facilities and imminent projects to the extent possible. Under this rule, the Windy Gap project was assumed to go on line by the Year 2000 since it already has considerable momentum. Also, it was assumed that the Joe Wright storage project of Fort Collins would be on line, that the City of Aurora would utilize its full entitlement of the Homestake Project, that the Narrows project would be completed, and that Denver would first perfect its conditional decrees on the Blue and Fraser Rivers.

"Several possible alternatives of supply-demand were developed for the Years 1980, 2000, and 2020"

Using these assumptions, it can be seen in Table 1 that some of the proposed projects are not utilized in the scenarios developed, i.e., 2020A and 2020B in particular. This is significant, because the 2020A scenario assumes an average streamflow and a high series population, along with the high per capita municipal use, while the 2020B scenario assumes drought level streamflows and a medium series population. These are both "stress" conditions for the basin. The first is with respect to demand and the second is with respect to supply — albeit they are not the most stressful scenario assumptions which could have been used.

The role of groundwater in the scenario can be also seen in Table 1. The use of groundwater in 1970 was

Continued on page 6

Table 1 Selected Information Taken
Model and Six Scenario Models*

Year	1970	1980	1980
Scenario Assumptions		A	B
Scenario Assumptions			
Native Runoff	1,826,510	1,354,000 (Avg)	672,060 (Drought)
Population	1,531,600	1,887,200 (Med Series)	1,887,200 (Med Series)
Per Capita Demand	220	214	150
Energy Dev		Self-Suff	Med Series
Industry		No Change	Stable
Agriculture		Free Market	Elastic
Irrigated Acreage			
Import Sources			
N Platte	-0-	1,360	1,350
Laramie	19,420	19,670	19,670
Colorado R	327,320	285,310	248,330
Fraser R	42,160	54,930	47,220
Williams Fork	2,110	5,550	5,510
Blue	31,410	42,460	68,080
Piney	-0-	-0-	-0-
Eagle	3,370	13,220	13,220
L Snake	8,230	7,130	7,130
Arkansas	-0-	-0-	-0-
Other Rivers	470	120	120
Total Exports	434,490	429,750	410,630
Project Water			
CBT (brought over)	204,640	226,960	226,980
Moffat (brought over)	43,960	59,870	52,120
Roberts (brought over)	10,620	30,160	59,670
Windy Gap	-0-	-0-	-0-
Eagle Piney	-0-	-0-	-0-
Eagle Colorado	-0-	-0-	-0-
East Gore	-0-	-0-	-0-
Other Projects	30	-0-	-0-

*See Figure 5 for example (1970 Base Year)

From 1970 Base Year (Input-Output)

2000 A	2000 B	2020 A	2020 B
_,350,650 (Avg)	1,350,650 (Avg)	1,350,650 (Avg)	672,060 (Drought)
2,617,100 (Med Series)	3,11?,070 (High Series)	3,980,300 (High Series)	3,118,180 (Med Series)
191	220	22-	167
Med Series	High	High Series	Med Series
Stable	Stable	Stable	Stable
Stable	Stable	Stable	Elastic
4,610	4,610	4,610	4,610
19,670	19,670	19,670	19,670
302,310	302,310	302,310	302,310
146,590	146,490	102,540	130,760
6,650	9,280	25,060	12,160
101,280	146,490	193,950	121,440
-0-	-0-	-0-	-0-
33,740	33,730	33,740	13,220
12,220	22,920	27,460	13,080
-0-	-0-	-0-	-0-
-0-	-0-	120	120
626,040	685,480	709,520	609,720
280,960	280,960	280,960	280,960
73,880	102,880	127,000	61,480
92,640	167,540	176,500	107,540
54,000	54,000	54,000	64,000
-0-	-0-	-0-	-0-
-0-	-0-	-0-	-0-
-0-	-0-	-0-	-0-
-0-	-0-	9 0	5,490

Table continued on pages 4-5

Table begins on pages 2-3

Table 1 (continued)

Year	1970	1980	1980
Scenario Assumptions		A	B
Native Runoff and Imports	2,261,000	1,783,750	1,082,690
Sector Water Demand			
Agriculture	3,997,840	3,781,690	3,651,350
Industry except thermal cooling	112,200	92,760	85,020
Thermal cooling	93,990	141,050	141,050
Municipal (water rights only)	383,270	458,210	316,980
Total Basin Demand	4,587,300	4,473,640	4,194,400
Reuse Factor for Basin (does not include groundwater or precipitation)	2.03	2 51	3.87
Sources of Water			
Stream Diversions	2,779,440	2,707,800	2,303,400
Imports	434,490	429,750	410,630
Transfers from Agriculture	-0-		
Water Conservation	-0-	-0-	
Direct Reuse	-0-	-0-	-0-
Groundwater	1,589,830	1,531,260	1,668,840
Water from Storage			
Basin Outflow	816,600	484,480	177,970
Sector Consumptive Uses			
Agriculture	2,606,220	2,582,310	2,284,490
Industry	17,360	20,250	20,250
From Reservoirs 1970	9,540	25,870	25,870
Consumptive Uses	105,140	132,960	90,590
Total Consumptive Use	2,738,260	2,761,390	2,421,200

	2000 A	2000 B	2020 A	2020 B
	1,976,690	2,036,130	2,060,170	1,281,760
	3,781,690	3,781,690	3,781,690	3,636,800
	106,470	113,600	113,600	108,100
	151,050	217,650	221,630	168,250
	559,490	766,510	983,020	593,010
	4,598,700	4,879,450	5,099,940	4,506,160
	2.33	2.40	2.48	3.52
	2,786,810	2,360,110	2,621,040	2,295,970
	626,040	685,480	709,520	528,770
			-0-	
			-0-	
	-0-	-0-	78,370	72,570
	1,550,100	1,587,900	1,627,900	1,726,750
	550,820	524,440	492,280	137,490
	2,582,310	2,582,310	2,582,310	2,408,180
	20,800	21,300	21,300	21,300
	37,580	98,620	102,500	50,520
	88,320	225,460	289,710	170,390
	2,729,010	2,927,590	2,995,820	2,650,390

about 1,589,830 acre-feet. Most is used by the agricultural sector. In the drought year scenarios, i.e., 1980B and 2020B, this usage could increase to about 1,700,000 acre-feet.

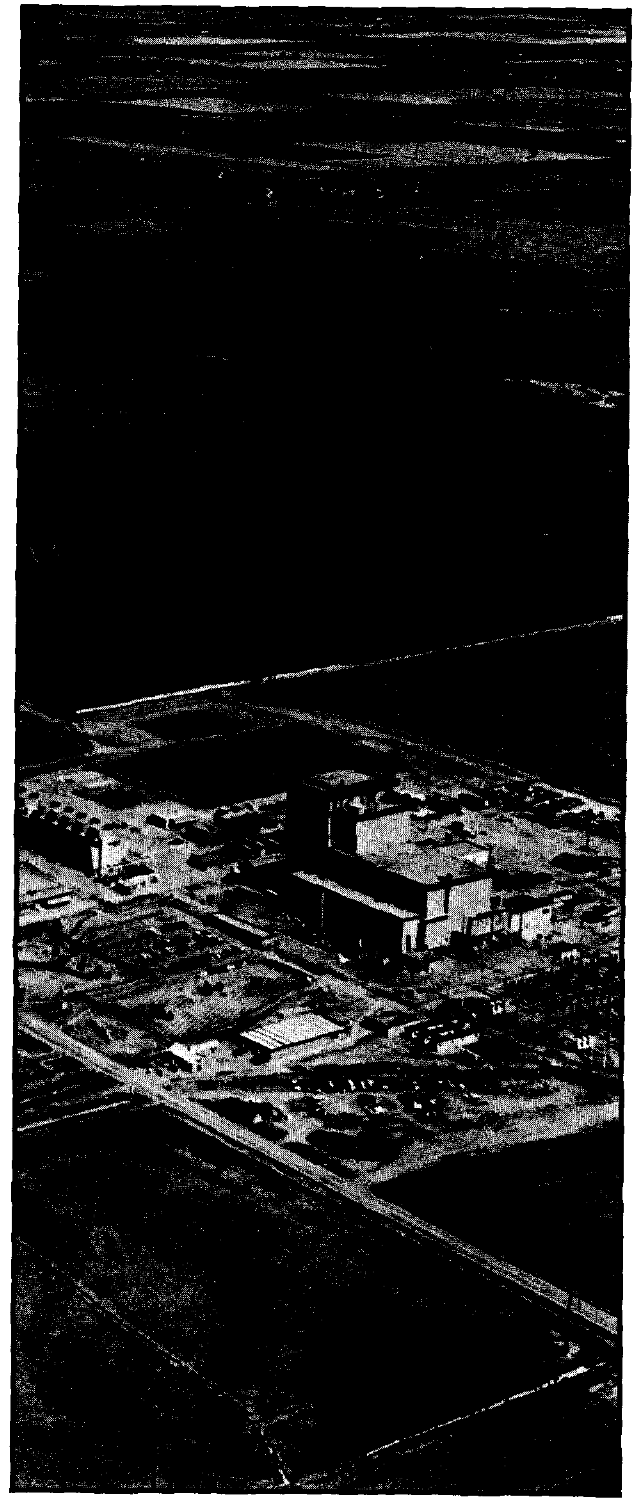
At the same time, it is postulated the municipalities will utilize fully their surface water rights, thus calling back all water being leased to agriculture. Thus the groundwater — under these scenarios — would act as a drought year buffer. For this scenario to be workable, the administration of water rights would have to be modified to permit heavier groundwater withdrawals during drought years and provide for its recovery during above-average years. (A conjunctive surface-groundwater management model has been developed for the lower South Platte basin which shows how this can be done.)*

"Thus the groundwater — under these scenarios — would act as a drought year buffer"

The water use by each sector can be seen in the lower portion of Table 1. Agricultural water use falls off from the 3,997,840 acre-feet used in 1970 to a low of about 3,600,000 for the various scenarios. The lower range is in response to the drought supply. The free market transfers of water were assumed to permit the municipal sector to meet its demand by renting agricultural water in times of stress.

Industrial water demand is assumed to remain fairly constant for all scenarios. However, the demand for thermal cooling could nearly double from the 1970 levels. Municipal water is postulated to go up from near 383,270 acre-feet in 1970 to 983,000 acre-feet — with a per capita daily demand of 220 gallons (gpcd). Using 167 gpcd demand for the 2020B scenario (instead of 220) results in a municipal demand of 593,000 acre-feet, a saving of some 390,000 acre-feet. Along with groundwater and the "water in the bank" with agriculture, this is another method for municipalities to maintain a resiliency for contending with droughts. From this point of view, it may not be wise to impose a low per capita use (i.e.,

*Colorado Water Resources Research Institute Technical Report No. 13, Dec. 1978.



by metering) except during time of drought. The cost in water treatment is, of course, another consideration.

The potential total basin water demands vary with the scenario assumptions. The total ranges from 4,194,400 acre-feet in the 1980B scenario (the 1970 basin demand was 4,587,300 acre-feet) to 5,099,940 acre-feet for the 2020A scenario. This range is not large relative to the total water demand.

Consumptive use by the various use sectors, which can also be seen in Table 1, ranges from 2,421,200 acre-feet to 2,995,820 acre-feet, with agricultural consumptive use accounting for over 80 percent of this amount. This exceeds the native flow plus imports to the basin. The difference is made up by precipitation and groundwater depletion. This large quantity of consumptive use is essentially unavoidable although it could be reduced by selective capital investments which would reduce evaporative loss of water to the atmosphere (i.e., phreatophtyte growths, seeps along canals, etc.).

An index of water use efficiency within the basin is "basin outflow." This varies from 816,000 acre-feet in 1970 to a low of 137,490 acre-feet for the 2020B drought scenario. Since only 47,116 acre-feet of flow across the Colorado-Nebraska border is required by compact, the difference could be captured for use in Colorado (this is true in a legal sense). The proposed Narrows Project would capture some of this, i.e., about 122,000 acre-feet net. Regardless of what is captured of this outflow, the amount is low relative to the native flows and imported water. However, the irrigation requirements of existing crops are not fully met in the basin (in fact about 60 percent are met) so the excess outflow could be used profitably.

"the demand for thermal cooling could nearly double . . . Municipal water demand is postulated to go up . . ."

Another index of basin water use efficiency is the amount of reuse. A "reuse index" is defined as the ratio of total volume of water diverted from surface sources (as permitted by water rights) to the sum of native water plus imports. The ratio varies from 2.03 to 3.87 for the different scenarios, indicating a substantial amount of reuse. Again the drought scenarios result in the highest reuse index.

The alternative scenarios are based on assumptions about future conditions and policies. While this is a limitation of the scenarios, it also illustrates the utility of the input-output methodology developed in this study for examining the impacts of proposed projects and policies, i.e., reduction in per capita demand, limiting further imports, building or not building certain projects, transferring water from agriculture, etc.

No One Solution Suits All

The results of this study indicate that there are water resource planning and management alternatives which can permit the appropriate fits between supplies and demands for both "expected" future scenarios and also those which would be the most stressful. Probably, however, there are no solutions which are mutually acceptable to all parties (i.e., West Slope interests, environmentalists, agricultural green belt advocates, those who want to maintain a viable agriculture, city water department officials, Trout Unlimited advocates, etc.). Thus the alternatives which may be chosen will be politically determined.

DETAILS OF THE STUDY

Information developed during the investigation was organized into five basic categories: 1) water supply sources, 2) municipal water demands, 3) industrial water demands, 4) agricultural water demands, and 5) energy water demands. Existing data were used to establish the base year, 1970, and a range of projections was made for supply and demand for 1980, 2000, and 2020.

Water Supply

The water demand can be met by: (1) increasing supply, (2) decreasing demand, or (3) reallocation. These alternatives are shown in Table 2. Proposed projects such as Narrows and Windy Gap are classified as "increasing supply" for the South Platte River Basin. Conservation programs that increase water use efficiency result in "decreased demand."

Continued on next page

Metering, pricing, and irrigation scheduling are examples. "Reallocation" includes water right transfers from agricultural uses to municipal and energy uses through the market system.

Water Demand

Water demand alternatives were developed for the municipal, agricultural, industrial, and energy sectors. A range of demands was used for each of these categories. This range makes it possible for decision-makers to select any specific combination of variables that is desired. The municipal demand category is described below as an example.

Development of the demand range for the municipal sector is dependent on per capita water demand and population variables. Per capita water demand is a function of indoor and outdoor residential use, as shown in Figure 1.

"the analytical tools are in hand to facilitate . . . examination of alternatives for . . . Colorado"

Daily per capita water demand can range between 123 and 220 gallons, depending on the conservation measures that are selected. The per capita water demand figures were given a time reference frame, as shown in Figure 2.

Population projections from the Colorado State Division of Planning were then combined with the per capita water demand. The combination establishes an envelope of municipal water demands for the South Platte River Basin, as shown in Figure 3.

The magnitude of demand by each of the water use sectors depend upon a wide variety of factors. Figure 4 identifies some of these factors and illustrates that many are mutually interdependent. However, their interactions are much more extensive and complex than indicated. A particular combination of these and other factors would comprise a "scenario assumption set."

Two scenario assumption sets were chosen for each of the Years 1980, 2000, 2020. Table 3 is a summary of the supply and demand factors used in each of the scenario assumption sets.

1970 Input-Output Model

The 1970 input-output model for the South Platte basin can be seen in Figure 5. The matrix was designed to display the water supplies and demands within the basin. The elements making up the rows are sources of supply and those in the columns are demand uses. The display shows all water transactions - both natural and manmade - from initial sources, to demand sectors, and finally to consumption or basin outflow.

Water Policy Formulation

From the point of view of state level planning, this methodology can show what policies ought to be used to better match supplies and demands of a whole basin or a whole state. Such policies might have several objectives, such as: (1) maintenance of sufficient water supplies to meet agricultural water demands while at the same time meeting the rising urban demands; (2) reducing basin outflow toward the minimum outflow required by interstate compact; (3) assessing the effects of water exports on the basin of origin; (4) determining what kinds of trades could be made to maintain minimum streamflows; and (5) assessing the basin-wide potential of water reuse. Combined with the model for conjunctive surface-groundwater management now available, the analytical tools are in hand to facilitate state or regional level examination of alternatives for improving water resource utilization in Colorado.

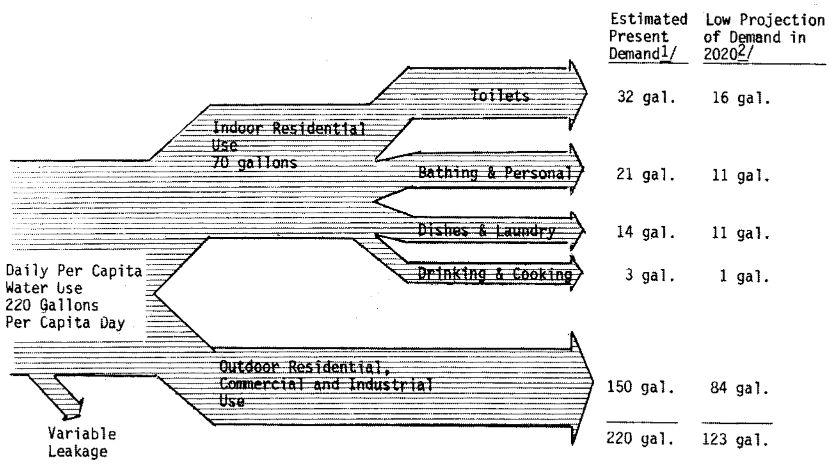
Table 2. Water Supply Alternatives, South Platte Basin

Category	Alternative	Examples
Increase Supply	● Develop new projects within South Platte basin	Narrows Two Forks
	● Develop new projects to import water from Colorado River basin	Windy Gap Eagle-Piney Eagle-Colorado
	● Cloud seeding	1977 Colorado Program
	● Water reuse	Denver's successive use program Exchanges between agriculture and urban uses
Decrease Demands	□ Domestic water conservation programs	Metering, pricing, water-saving plumbing
	□ Industrial water conservation	Process modifications Internal reuse
	□ Agricultural water conservation practices	Scientific irrigation Center pivot sprinkler technology Trickle irrigation technology Conversion of direct flow rights to volumetric rights
Reallocation	■ Transfers from agriculture to urban ■ Transfer from agriculture to energy ■ Symbiosis between agriculture and other use sectors	Continue free market purchases

Table 3. Scenario Factor Sets: 1980, 2000, 2020

SECTOR	DEMAND FACTOR	1980		2000		2020	
		A	B	A	B	A	B
Population	Low Series						
	Medium Series	x	x	x	x		x
	High Series				x	x	
Per Capita Use (gpcd)	220				x	x	
	214	x					
	191			x			
	167						x
	150		x				
Industrial Sector	1975 Activity Level (less 3 sugar factories)	x	x	x	x	x	x
Energy Sector	Pawnee No. 1	x	x	x	x	x	x
	Fort St. Vrain No. 1	x		x	x	x	x
	Hawhide			x	x	x	x
	Pawnee No. 2				x	x	
	Fort St. Vrain No. 2				x	x	
	Two Coal Strip Mines				x	x	x
	One Underground Mine				x	x	
	One Coal Gas Plant				x	x	x
	Fort St. Vrain No. 3						
	One Additional Nuclear						x
	Four Additional Coal Fired Plants						
Agriculture	Medium Level Urban Encroachment	x		x	x	x	x
	Medium System Efficiency	x		x	x	x	x
	Average Precipitation	x		x	x	x	
	Average Sub-Basin Transfers	x	x	x	x	x	x
	Drought Level Precipitation		x				x
	Transfers from Sector Permissible, as Necessary		x	x	x	x	x

SECTOR	SUPPLY FACTOR	1980		2000		2020	
		A	B	A	B	A	B
Exogenous Projects	Long Draw Expansion	x	x	x	x	x	x
	Aurora takes its 50% of Homestake Water		x	x	x	x	x
	Windy Gap			x	x	x	x
	Joe Wright			x	x	x	x
	Homestake Expansion			x	x	x	x
	Williams Fork Expansion			x	x	x	x
	Straight Creek					x	x
	East Gore					x	x
	Eagle-Piney					x	x
	Eagle-Colorado					x	x
Endogenous Projects	Two Forks			x	x	x	x
	Narrows			x	x	x	x
	Denver Reuse						x
	Other Minor Projects			x	x	x	x
	Other Cities Reuse Exchanges						
Native Flows	Average Precipitation and Runoff	x		x	x	x	
	Drought (1953-57 4-Year Average)		x				x



1/ Indoor Residential Uses are based upon commonly accepted values given by Milne, 1976 and Sharpe, 1976.

2/ Based upon the implementation of water conservation measures. Estimated reduction in demand is based on information given by Milne, 1976; Sharpe, 1976; California Department of Water Resources Bulletin No. 198.

FIGURE 1. DISTRIBUTION OF 1970 PER CAPITA DEMAND AMONG DOMESTIC USES, COMPARED WITH LOWER LIMIT ESTIMATE

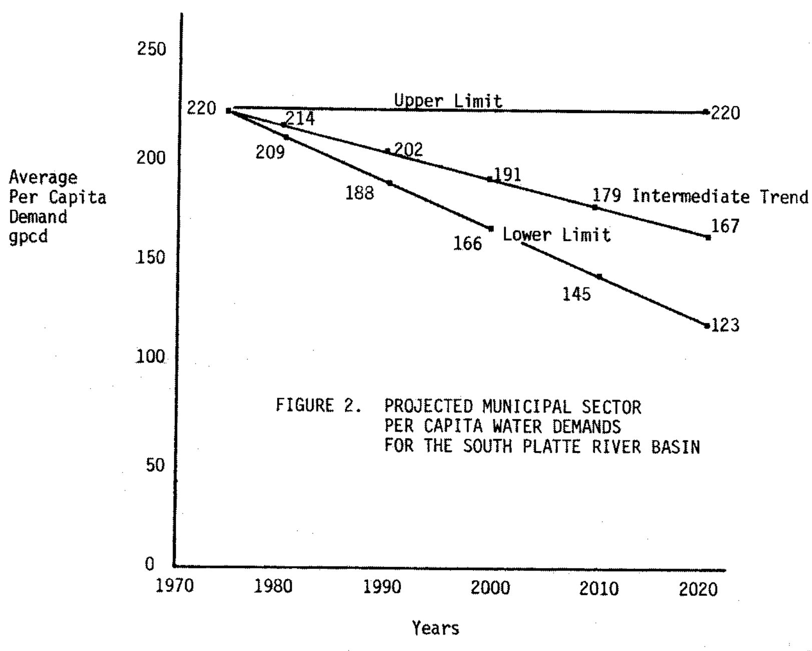


FIGURE 2. PROJECTED MUNICIPAL SECTOR PER CAPITA WATER DEMANDS FOR THE SOUTH PLATTE RIVER BASIN

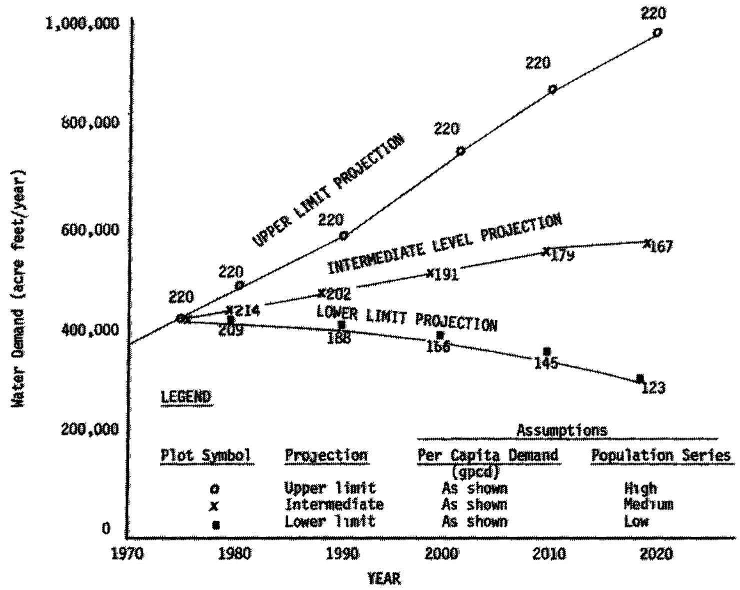


FIGURE 3 ENVELOPE OF PROJECTIONS OF MUNICIPAL WATER DEMANDS, 1970-2020, SOUTH PLATTE BASIN

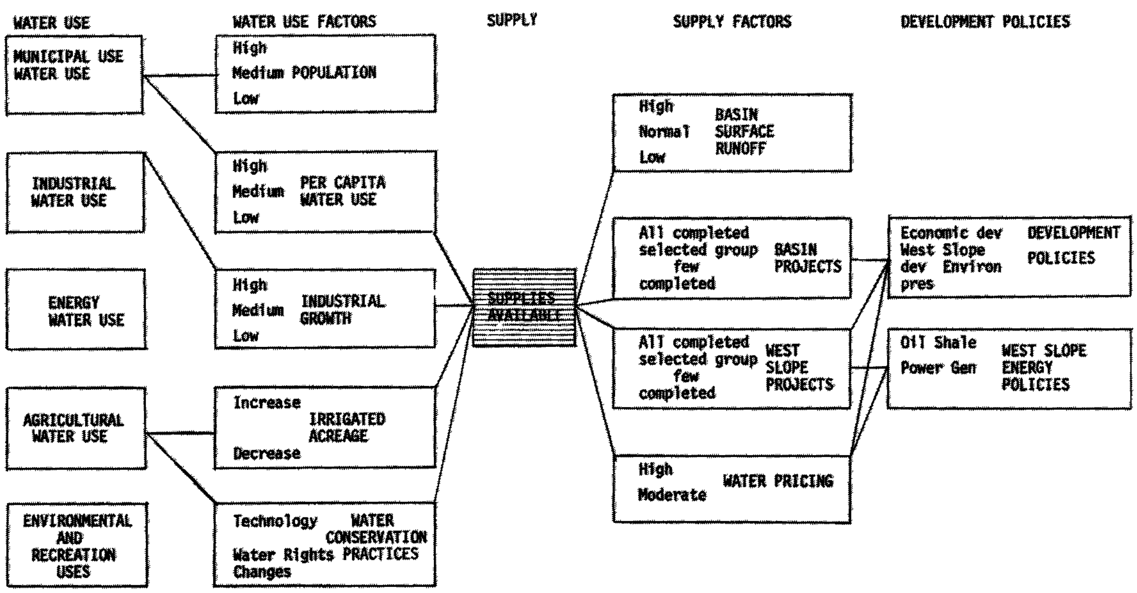


FIGURE 4 FACTORS RELATED TO SUPPLY AND DEMAND OF WATER IN SOUTH PLATTE BASIN AND CHOICES FOR A SCENARIO FACTOR SET

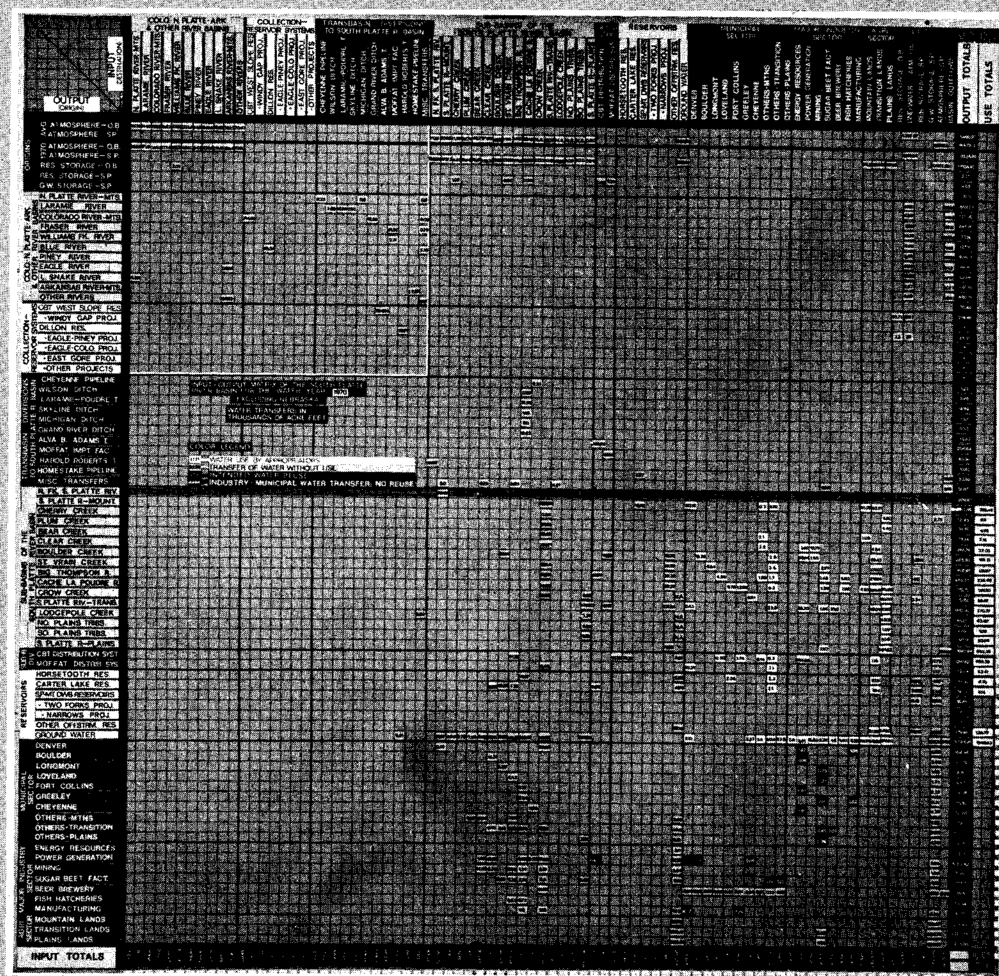


FIGURE 5. INPUT-OUTPUT PLANNING BOARD USED IN WATER SUPPLY AND DEMAND STUDIES OF SOUTH PLATTE RIVER BASIN

Through these publications and other means, the scientists of Colorado's universities hope to meet the challenge of providing information on how the natural water system works and how it can be reconciled to the complex demands placed on water by society today. This report was prepared by the Colorado Water Resources Research Institute to assist legislators, policy makers, and water resources planners and managers to better understand specific problems and issues.

The most predictable feature of water policy at the present time is change. Changes are occurring in the demands on water supplies, in the values people place on water resources and also in the institutional and legal foundations of public water administration.

This era of change emphasizes water resources administration and management rather than water resources project development. The focus is upon improving management of existing water supplies rather than on the development of new supplies.

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