THESIS

WATER SUPPLIES OF THE SOUTH PLATTE RIVER BASIN

Submitted by

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In partial fulfillment of the requirements
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ENTITLED Water Supplies of the South Platte River Basin

BE ACCEPTED AS FULFILLING IN PART REQUIREMENTS FOR THE DEGREE OF

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ABSTRACT OF THESIS

WATER SUPPLIES OF THE SOUTH

PLATTE RIVER BASIN

It has been told that early plains travelers declared the great arid region west of the Missouri River a desert which could never become the home of civilized man. While this may have been the prevailing sentiment of many, there were those who possessed the necessary insight to realize the vast potential of this land. John Wesly Powell, the great explorer, is credited with the observation that "all the great value of this territory has ultimately to be measured in acre-feet."

And so it was that water would become the life blood of the west, its availability determining and allowing for the very existance and prosperity of man in this region.

Today, one out of every five persons in the western states receives water imported from a source one hundred or more miles away. The water supply system developed by the city of Denver, for example, is a complex physical and institutional infrastructure; the cash value of all its transbasin tunnels, dams, pipelines, etc. is the greatest of any in the world.

The scarcity of water and its importance fostered a "get-your-gun" attitude concerning this resource which is manifested today by emotionally and politically controversial issues.

This report examines the water supplies of the South Platte River Basin, within which is contained one of the more important agro-metropolitan regions of the west and the center of Colorado's economy. The hydrologic and legal availability of water both within the basin and from sources without is addressed. The history of its water resources development is given to provide a context to view the present. Asserting that the basin is approaching apex development where substantial amounts of raw water are no longer available for development, the possible sources of supply for its future are discussed.

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Fall, 1977

ACKNOWLEDGEMENTS

A blanket acknowledgement is given here to all those who, through contributions both large and small and of many sorts, made this mammoth undertaking possible. They are to be thanked for providing the physical as well as the emotional means that were required. The resulting document, this mega-sized thesis, is dedicated to them.

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STUDY ORIENTATION

Context of Study

The continued development of agriculture and industry along with the growth of urban populations in the South Platte Basin, beginning with the Colorado gold rush, has meant extensive development of water supplies. This has resulted in nearly the full development of both surface and groundwater supplies within the South Platte Basin plus considerable importation of water from other basins. During this period of development each water demand has been met incrementally by an individual procurement of water, based upon the appropriation doctrine. As a result, the supply-demand configurations are a complex of water interdependencies between inputs and outputs for each of the numerous water using entities. There has been no overall look at the water supply-demand relationships for the entire basin. To meet future demands and plan for contingencies such an overall description is thought to be warranted at this time.

The Corps of Engineers was authorized to develop such a comprehensive water resources planning study for the South Platte Basin. This report is part of a much larger overall study performed for the Corps of Engineers by the Environmental Engineering Program, Department of Civil Engineering, Colorado State University. The subject of this particular volume is an analysis of the water supplies of the South Platte River basin.

In order to show the overall system linkages between the water supply sources, the water storage and transport facilities, and the water use entities within the basin, an input-output water balance model was used. The model relates supply and demand for any water use entity in the basin, for any hydrologic component, and for the basin as a whole.

Figure A is a photograph of the model developed for the South Platte Basin as a part of the larger study. The mechanics of use of the model are explained by Goldbach (1977) and its utilization in handling water supply demand questions for the South Platte Basin is explained by Hendricks et al., (1977).

The purpose of this report is to qualitatively and quantitatively describe the South Platte River basin's present and potential sources of water. The demands for water in the South Platte River Basin, 1970-2020, relative to the input-output model developed for the overall study, were also addressed. Individual reports investigated the present and potential future water demands by Agriculture, (Janonis and Gerlek, 1977), by Municipalities, (Janonis, 1977), by Industries, (Patterson, 1977a) and by the Energy Resources and Production Sectors (Patterson, 1977b).

Study Area

The study area included in this report is the South Platte River Basin in Colorado and Wyoming. The portion of the basin in Nebraska is excluded by contract provisions. Figure B shows the study area boundaries with the respect to state lines.

A significant portion of the water supplies presently used by, and potentially available to, the study area are from other river basins. Therefore, the area of interest encompassed by this report includes the South Plattes adjacent river basins. These can be seen in Figure B also.

Organization of Study

This report is comprised of three parts and four appendices. Part I provides a physiographic and hydrologic description of the South Platte

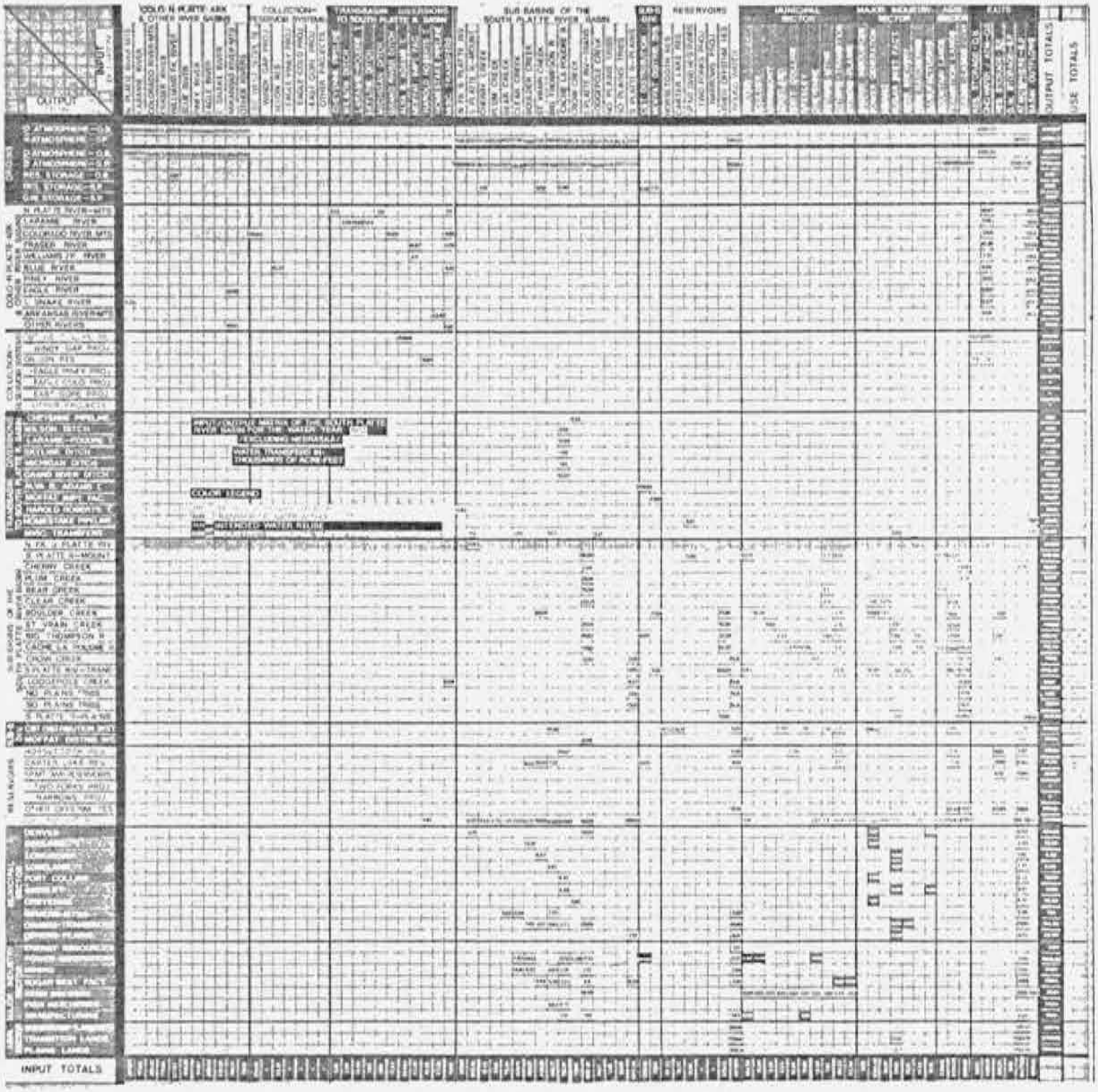


Figure A Input/Output Matrix of the South Platte River Basin (excluding Nebraska) for the Water Year 1970.

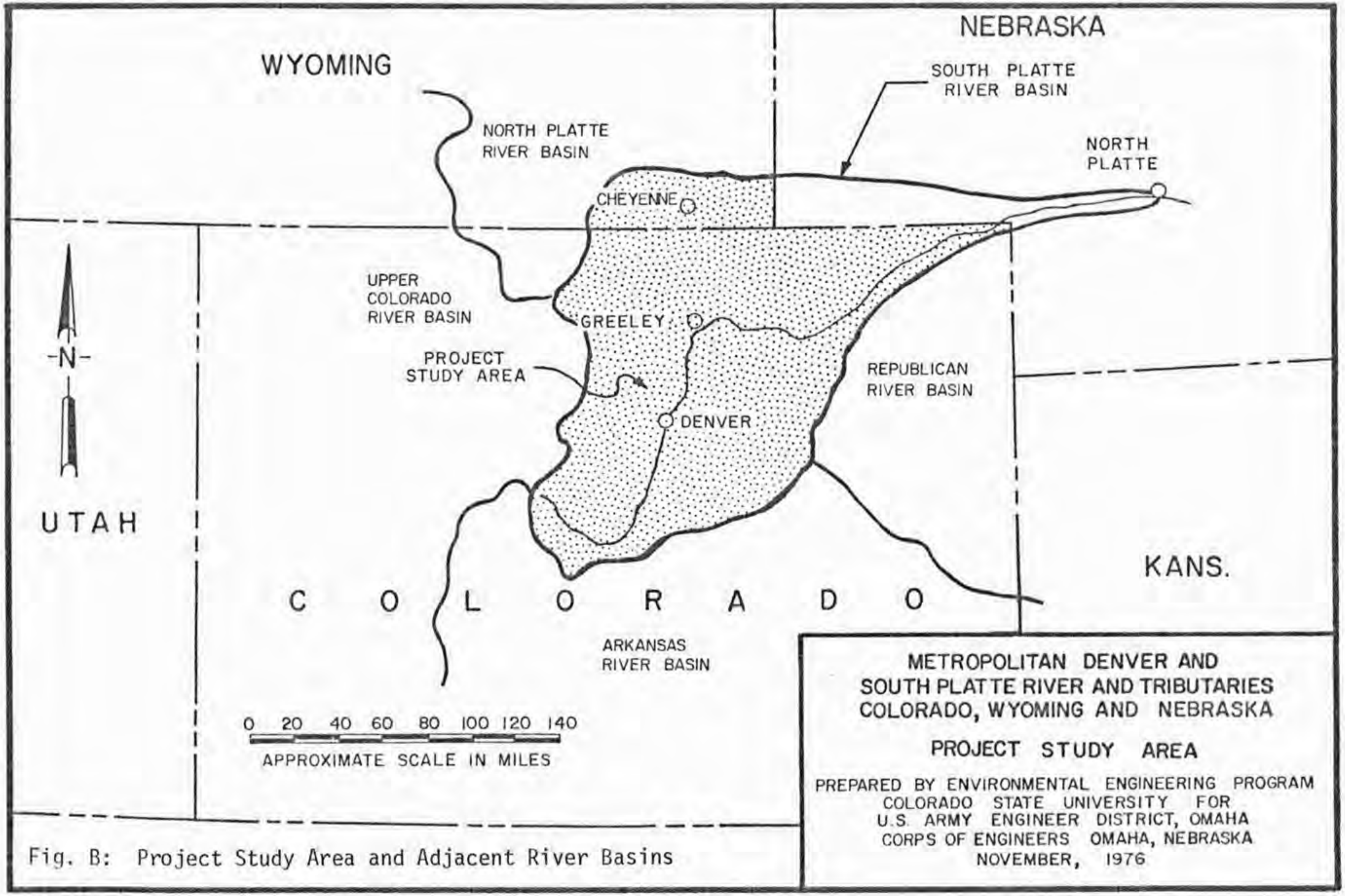


Fig. B: Project Study Area and Adjacent River Basins

River basin. It gives a historical perspective on the physical and administrative nature of the water resources system that has developed in the basin. Finally, and most importantly, it summarizes Parts II and III and sets forth the conclusions generated by the water supply study. The conclusions are the final culmination of the extensive amount of information necessary for documentation.

Parts II and III contain the detailed analysis of the South Platte native water supplies and foreign water supplies, respectively.

Part II deals with the native water supplies of the South Platte River basin. The study area has been broken into 16 sub-basins which are shown in Figure C. The water supply characteristics, existing water resources development, and projects proposed to develop additional supplies, as available, are delineated for each sub-basin.

Part III examines present and potential sources of foreign water. Figure D shows the river basins adjacent to the South Platte River basin, and their designated sub-basins. The water supply characteristics, the existing water resources development and projects proposed to develop additional supplies for export are delineated for each of the sub-basins which have or may have a water export relationship to the South Platte River basin.

The four appendices of the report contain much of the hydrological support data and legal documentation required for the study.

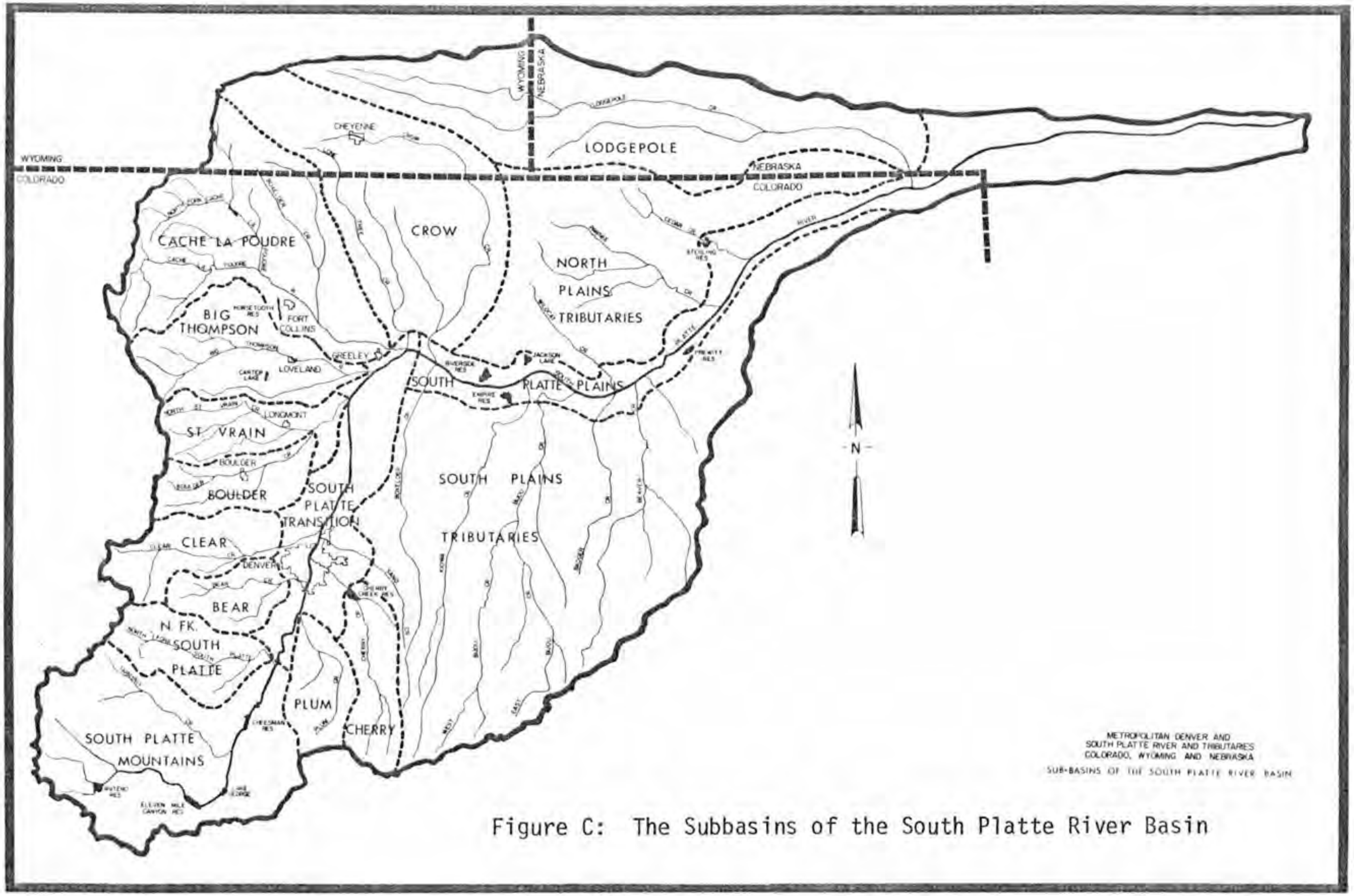
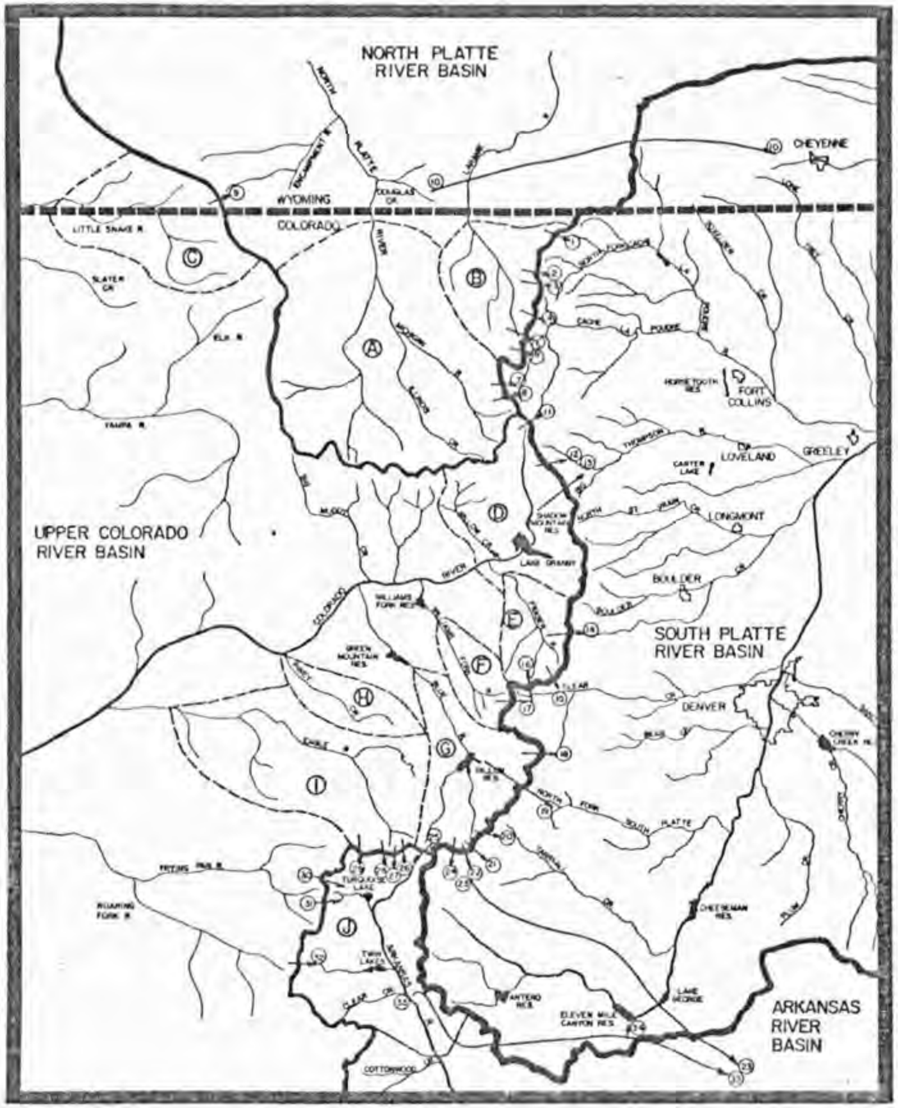


Figure C: The Subbasins of the South Platte River Basin



THE NORTH PLATTE RIVER BASIN

Subbasins:

A - North Platte River-Mountains
B - Laramie River

Transbasin Diversion Structures:

1 - Wilson Supply Ditch
2 - Columbine Ditch (closed)
3 - Bob Creek Ditch (closed)
4 - Laramie-Poudre Tunnel
5 - Skyline Ditch
6 - Lost Lake Outlet (closed)
7 - Cameron Pass Ditch
8 - Michigan Ditch

THE COLORADO RIVER BASIN

Subbasins:

C - Little Snake River
D - Colorado River-Mountains
E - Fraser River
F - Williams Fork River
G - Blue River
H - Piney River
I - Eagle River

Transbasin Diversion Structures:

9 - Cheyenne Tunnel (Provides replacement water for diversions by the Cheyenne Pipeline)
10 - Cheyenne Pipeline
11 - Grand River Ditch
12 - Eureka Ditch
13 - Alva B. Adams Tunnel
14 - Moffat Water Tunnel
15 - Berthoud Pass Ditch
16 - Vasquez Tunnel (Part of the collection system for the Moffat Water Tunnel)
17 - Jones Pass Tunnel (Part of the Collection system for the Moffat Water Tunnel)
18 - Vidler Tunnel
19 - Harold D. Roberts Tunnel
20 - Boreas Pass Ditch
21 - East Hoosier Pass Ditch (closed)
22 - Hoosier Pass Tunnel
23 - Montgomery Pipeline (All imports through the Hoosier Pass Tunnel are subsequently exported by this pipeline)
24 - West Hoosier Pass Ditch (closed)
25 - Freemont Pass Ditch (closed)
26 - Columbine Ditch
27 - Ewing Ditch
28 - Wurtz Ditch
29 - Homestake Tunnel
30 - Busk-Ivanhoe Tunnel
31 - Charles H. Bonstead Tunnel
32 - Twin Lakes Tunnel

THE ARKANSAS RIVER BASIN

Subbasins:

J - Arkansas River-Mountains

Transbasin Diversion Structures:

33 - Homestake Pipeline (All imports through the homestake tunnel are subsequently exported by this pipeline. Occassionally, native Arkansas River water is exported also)
34 - Aurora -Homestake Pipeline (Turn-out from the Homestake Pipeline

Figure D: The Subbasins of the South Plattes Adjacent River Basins

PART I

BASIN GEOGRAPHY AND WATER SUPPLIES

CHAPTER I

WATER GEOGRAPHY AND HISTORY OF WATER RESOURCES DEVELOPMENT

1.1 Physical Description of the South Platte River Basin

1.1.1 *Location and Area* - The Mississippi River Basin drains the lower middle portion of the North American Continent. It drains approximately 1,250,000 square miles of the midwestern one third of the United States and extreme southern Canada. One of its major tributaries is the Missouri River which drains about 530,000 square miles of all or part of nine states and a small part of Canada. One of the major tributaries of the Missouri River is the Platte River, whose tributary the South Platte River is the topic of this study. Figure 1-1 shows the location of the South Platte River basin with respect to the Missouri River basin.

The western boundary of the South Platte River basin lies on the Continental Divide which separates the surface water runoff that reaches the Pacific Ocean from that which reaches the Atlantic. To the north, south and east lie tributary drainage areas of the Mississippi River Basin, specifically the North Platte, Arkansas, and Republican Rivers. Figure 1-2 shows the location of the South Platte River basin with respect to its neighboring river basins.

The South Platte River basin drains approximately 24,300 square miles which comprises about 4.6% of the total drainage area of the Missouri River Basin and 1.9% of the Mississippi River Basin. The approximate maximum dimensions of the basin are 240 miles in the east-west direction, 175 miles north-south, and 270 miles diagonally.

The basin lies between the 101st and the 107th Meridans and the 38th and 42nd parallels in the states of Colorado, Wyoming and Nebraska. Table 1-1 shows the basin area within each state.

Figure 1-1: South Platte River Basin Location Map

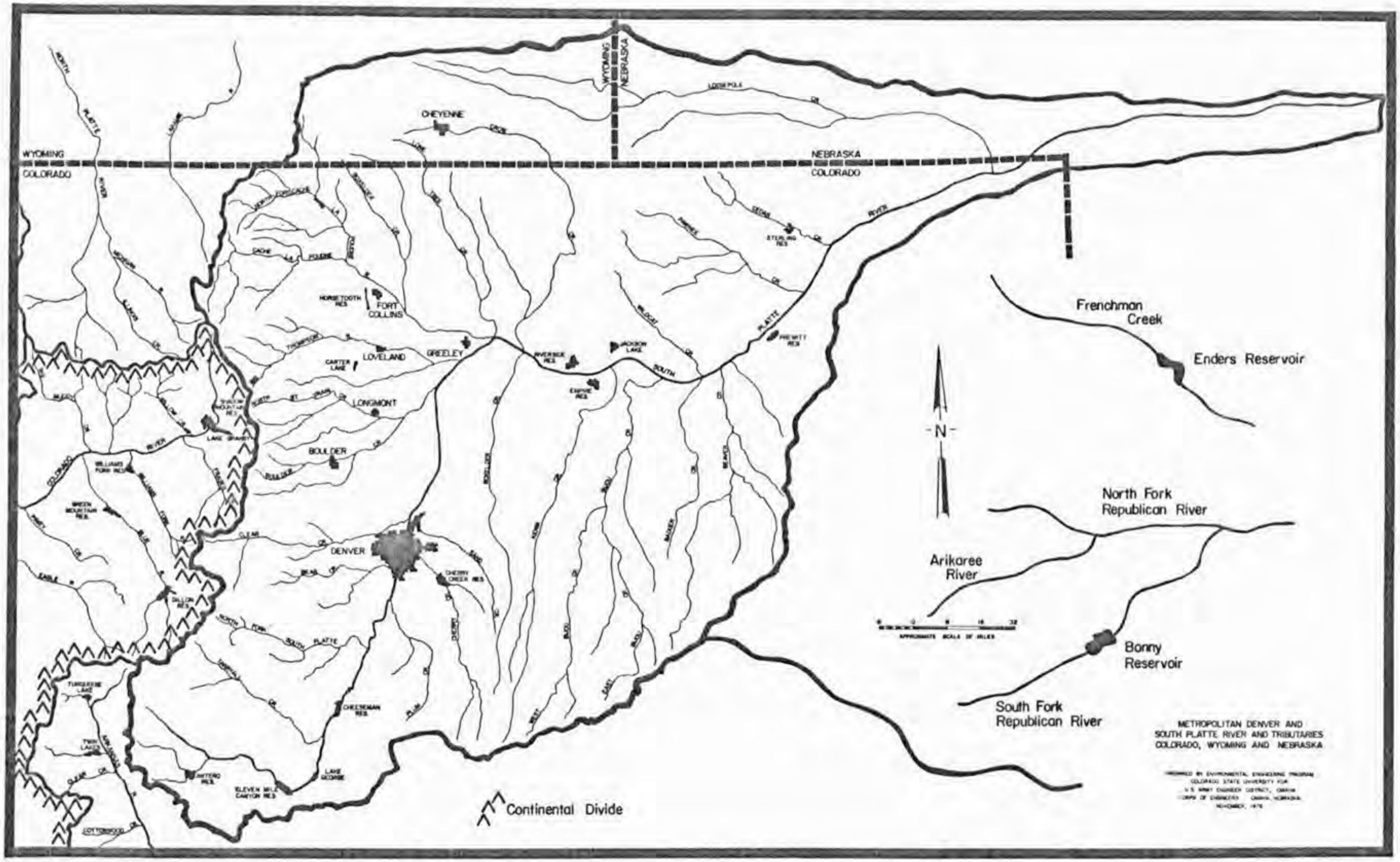


Figure 1-2: The South Platte and Adjacent River Basins

Table 1-1 Drainage Area of the South Platte River Basin (USBR, 1959).

State	South Platte River Basin		Percent of Total Land Area of States
	Drainage Area (square miles)	Percent of Total Land Area of Basin	
Colorado	19,450	80.1	18.7
Wyoming	2,050	8.4	2.1
Nebraska	2,800	11.5	3.6
Total	24,300	100.0	-

As shown in Figure 1-3 all or part of 26 counties are contained within the basin. Eighteen of these are in Colorado, two are in Wyoming, and six are in Nebraska.

1.1.2 *Physical Characteristics* - The South Platte River basin lies in two major physiolographic divisions - approximately 25 percent is contained within the Southern Rocky Mountain Province of the Rocky Mountain system and the remainder is within the Great Plains Province of the Interior plains. The western section, in the Rocky Mountain Province, is characterized by prominent mountain ranges, including the Colorado Front Range and Rampart Range in Colorado, and the southern end of the Laramie Range in Wyoming. Elevations vary from about 5,700 feet to over 14,000 feet along the eastern edge of the province. Longs Peak and Mount Evans are well known mountains in the basin which are over 14,000 feet in height. The highest point is Mount Lincoln which has an elevation of 14,284 feet.

Open parks and wider valleys intersperse the mountain region. The most notable of these areas is South Park which is a broad plateau covering nearly 800 square miles at an elevation of 10,000 feet in the southwestern portion of the basin. Several glaciers occupy the mountain region of the basin, just below the Continental Divide. The type of vegetative cover within the basin is related to the available water supply and climate which is influenced by the topography. The higher mountain peaks and ranges are generally treeless above 11,000 feet. Only a few hardy shrubs and grasses survive the rigors of the high altitude and climate. Below timberline the mountain slopes are covered with Spruce, Lodgepole, and Yellow Pine, Fir, Juniper, and Aspen. The mountain valleys generally have a good covering of grass and shrubs; the streams are bordered by willows and other shrubs.

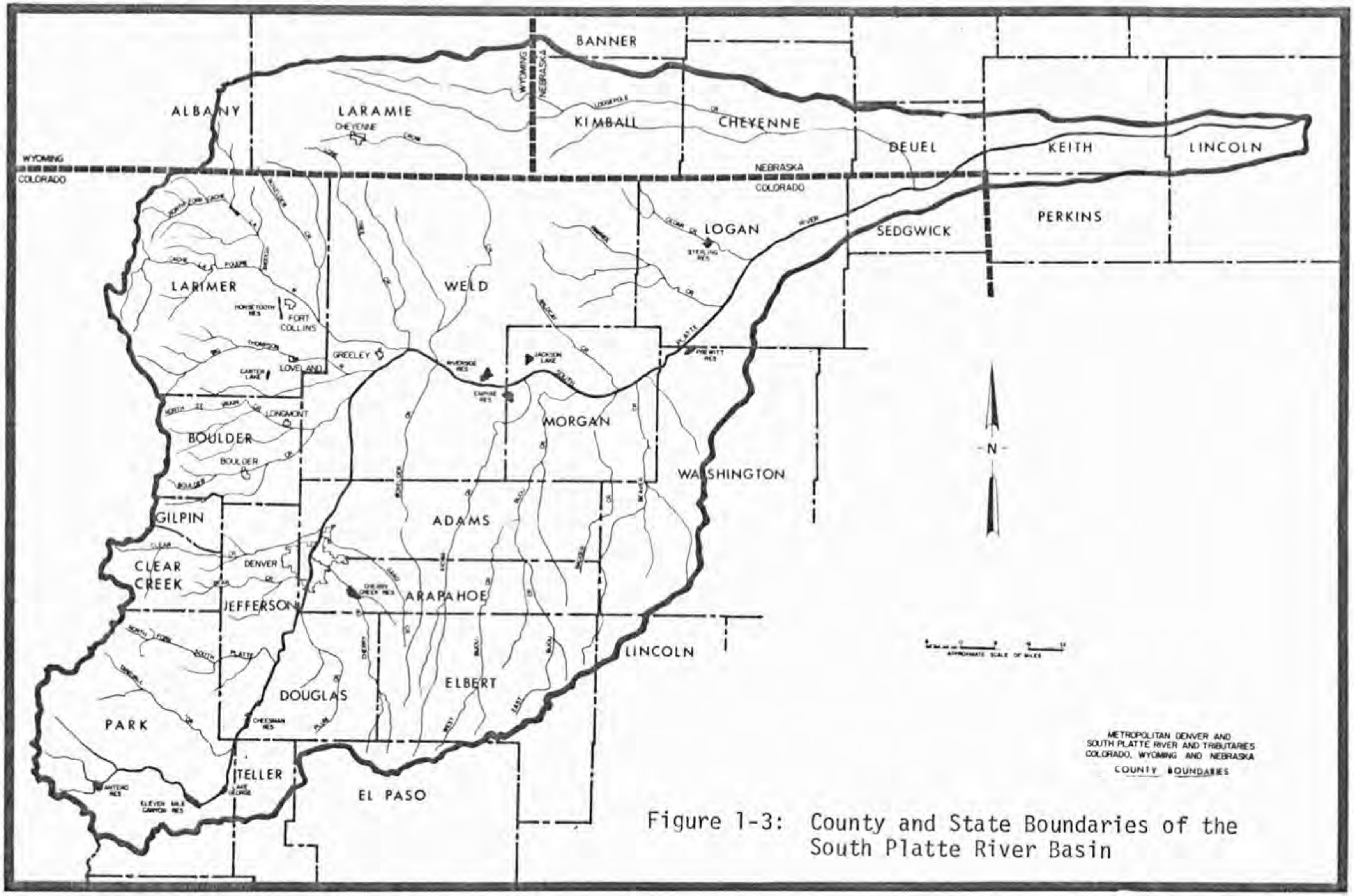


Figure 1-3: County and State Boundaries of the South Platte River Basin

Between the mountains and plains is a long, narrow series of hogbacks or foothills that attain altitudes of 5,700 to 6,600 feet. These features rise 300 to 500 feet above the adjacent valleys.

The plains, which slope away from the foothills, are located in the Colorado Piedmont and High Plains sections of the Great Plains Province. The Colorado Piedmont includes most of the plains region of the basin in Colorado. The Lodgepole Creek drainage and the South Platte River drainage downstream from Lodgepole Creek are in the high plains section. The watershed through the Piedmont section is a broadly rolling plain. The flood plain of the South Platte River in this portion varies from one to three miles in width. The bench lands are from 20 to 200 feet above the flood plain; they rise gently toward the mountains to the west and the escarpment to the east. The western part of the Colorado Piedmont contains low rounded hills and irregular basins. Many of these basins are shallow, undrained depressions and some are occupied by lakes and ponds. Figure 1-4 shows the elevation contours above sea level within the South Platte River Basin.

As the High Plains in the eastern and northern part of the basin are approached from the west, altitudes descend abruptly in some places and gradually in others but level off to an average of 3,000 feet. The High Plains slope gently eastward to an elevation of 2,795 feet at the mouth of the South Platte River.

The foothills and plains areas that still remain in native vegetation are covered with native grasses and occasional clumps of deciduous trees. Cottonwood and Willow Brush are found along the streams.

<u>The South Platte River and Its Major Tributaries</u> - The basin is drained by the South Platte River and its tributaries which can be seen

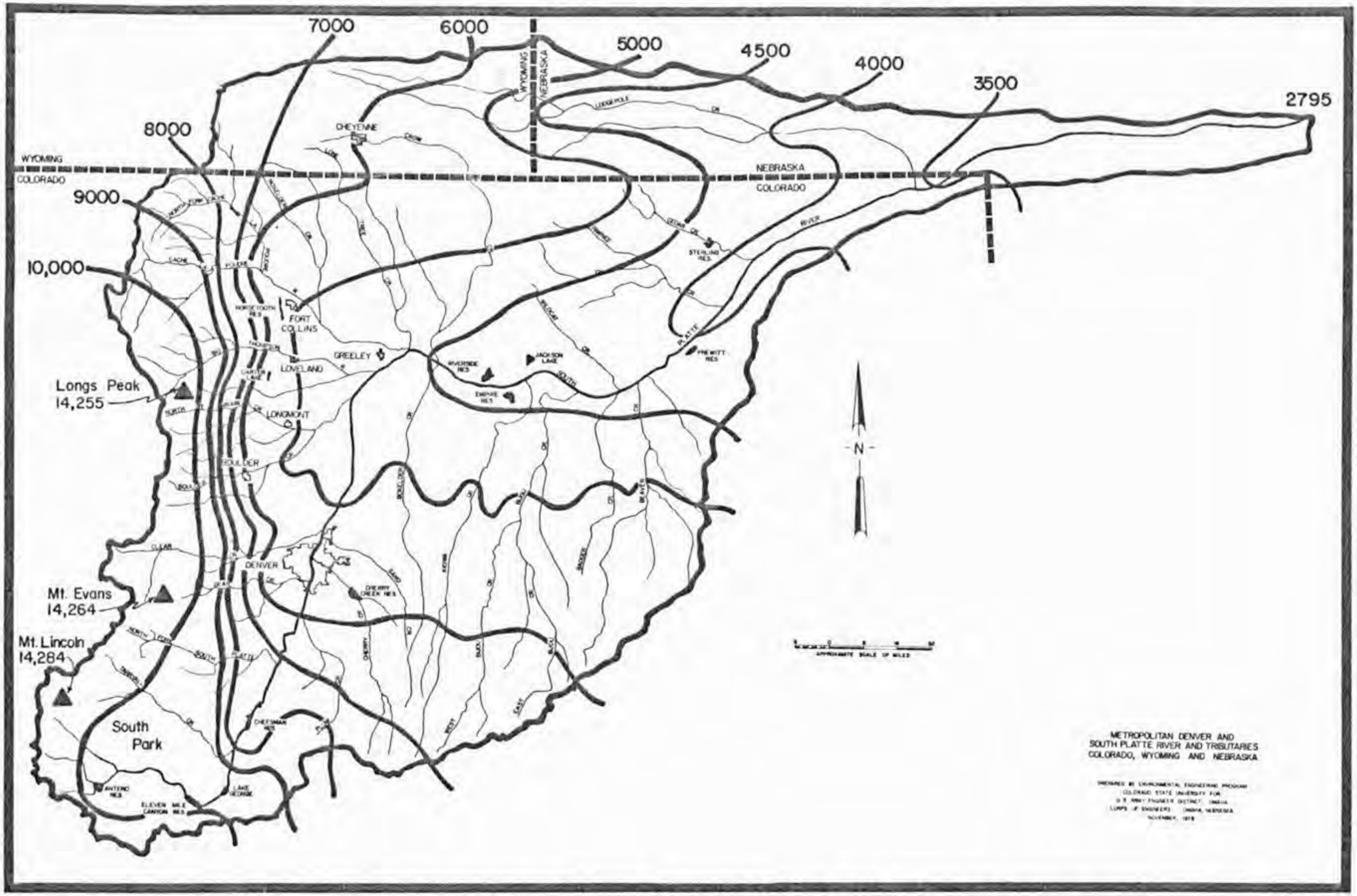


Figure 1-4: Elevations Above Sea Level within the South Platte River Basin

in preceding Figure 1-2. The South Platte rises along the eastern slope of the Continental Divide in the southwest portion of the basin. This reach of the Continental Divide, which skirts around Mount Lincoln the highest point in the basin, forms a 4,000 foot wall to the west of the broad South Park Valley. The river flows from the high mountains down slopes of more than 1,000 feet per mile and into South Park. Here, the Middle Fork joins the South Fork and the river then flows southeast for approximately 45 miles through slopes of about 20 feet per mile. From South Park the river passes through Eleven Mile Canyon; it then strikes northward through 40 miles of mountainous terrain while dropping an average of 68 feet per mile.

Tarryall Creek and the North Fork of the South Platte flow in from the north and west and meet the mainstem of this, its final mountainous reach. On the plains the flows of Plum and Cherry Creeks are added. These streams drain a corridor of foothills and high plains to the south. Turning more northward and paralleling the Front Range, the South Platte enters a strategic 100 mile reach where the maximum slope is 15 feet per mile. Here it receives the inflows from six major tributary streams which drain the Front Range to the north. These streams start on the Continental Divide among extended and precipitious mountain ranges. They generally flow east to the foothills and out through narrow canyons where, among broadly terraced plains, they meet the South Platte River. In downstream order they are, Bear and Clear Creeks, Saint Vrain Creek (and its major tributary Boulder Creek), and the Big Thompson and Cache La Poudre Rivers.

Having collected these inflows the South Platte turns due east and straight onto the plains. The 9,000 square mile watershed upstream from this point yields most of the surface water runoff of the basin. Ahead lies approximately 15,300 square miles of high plains and about 230 river miles with an average slope of eight feet per mile. Here the land is relatively flat. Infiltration and evaporation are substantial here. The South Platte tributaries in this reach are intermittent and they contribute little or nothing to its flows. The streams draining this area are the Lonetree, Crow, Wildcat, Pawnee, Cedar and Lodgepole Creeks, which enter from the north, and the Boxelder, Kiowa, Bijou, Badger, and Beaver Creeks, which enter from the south. The length of the South Platte River from its source in the mountains on the Continental Divide, to its confluence with North Platte River in the plains, is about 442 miles.

1.1.3 *Climate and Hydrology* - The major sources of atmospheric moisture for the South Platte River basin are from the Pacific Ocean and the Gulf of Mexico. Prevailing air currents which reach the basin from the west bring the most of the atmospheric water that will end up as stream flows. However, because of the distance from the Pacific Ocean, the eastward moving storms lose much of their moisture in passage over mountain ranges to the west. Most of the precipitation in the basin occurs during the winter as snow in the mountains from these Pacific storms. Warm moist air from the Gulf of Mexico moves into the basin most frequently in the spring. It is carried northward and westward from the coast to higher elevations; the heaviest rainfall occurs on the plains during the April-July period. Figures 1-5 and 1-6 show the normal May-September and October-April precipitation of the basin over the 1930-61 period.

Analysis of runoff records and of tree ring growths indicate a drought cycle of about 20 years (i.e., 1930's, 1950's and 1970's) The important point is that large annual variations in runoff do occur.

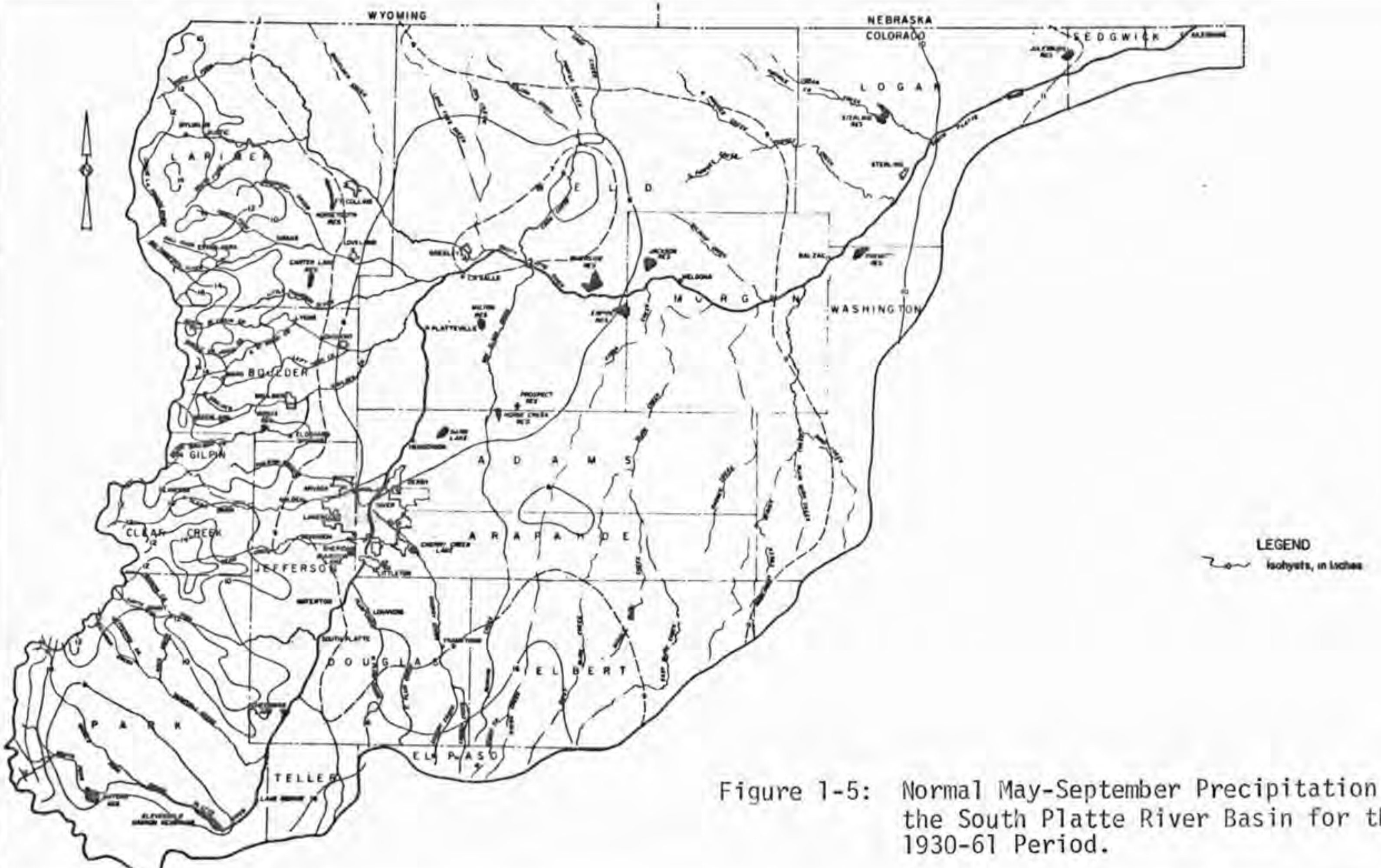


Figure 1-5: Normal May-September Precipitation over the South Platte River Basin for the 1930-61 Period.

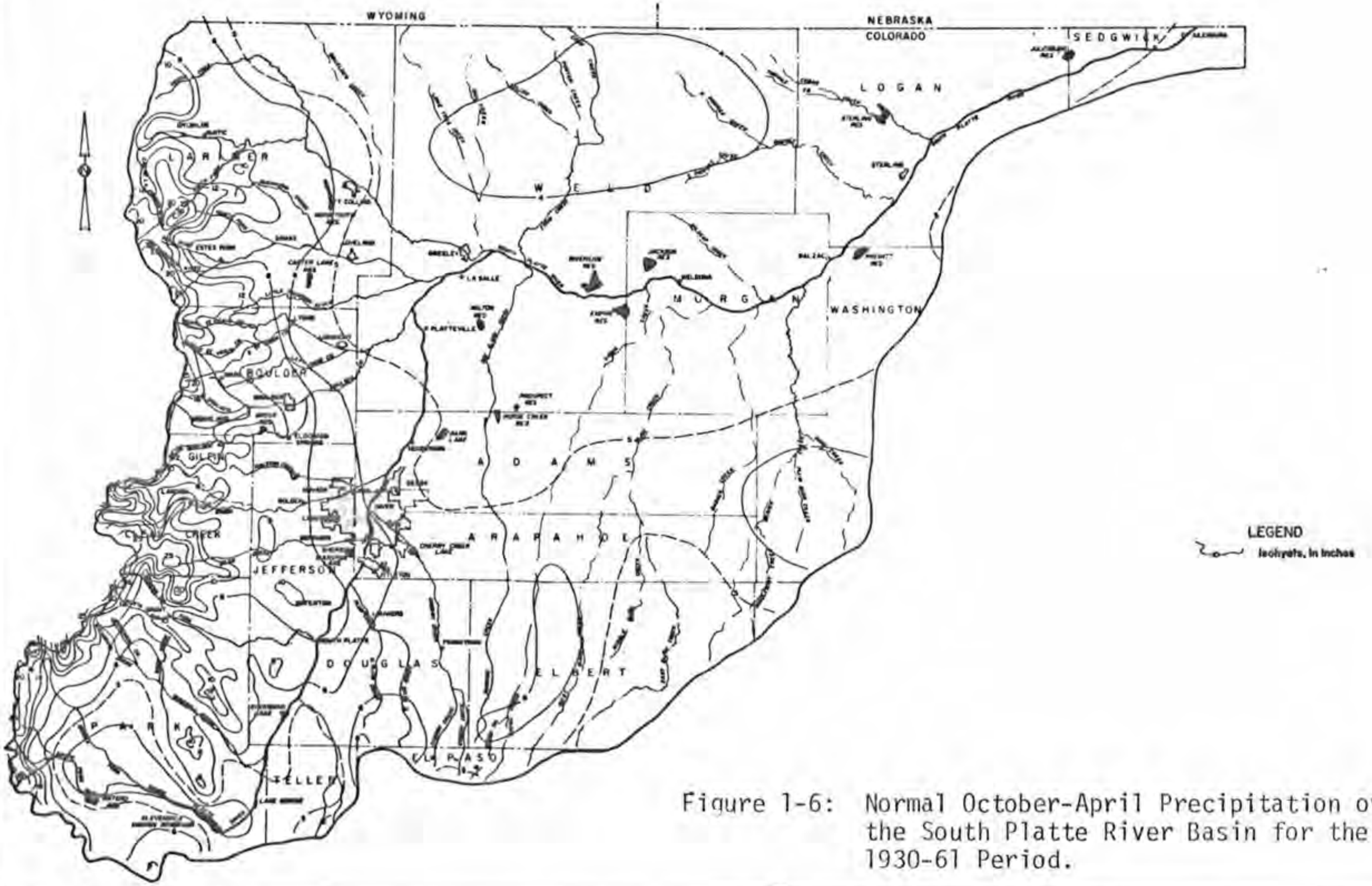


Figure 1-6: Normal October-April Precipitation over the South Platte River Basin for the 1930-61 Period.

The climate of the South Platte River basin is influenced strongly by topography. Weather conditions vary widely as influenced by elevation. However, many of the same storms cover mountains, foothills and plains.

The Mountains - The mountains region has an alpine climate of heavy snows. Because of this the mountains are the most important water production area of the basin. Snow covered mountain peaks and valleys often have very cold night temperatures in the winter, occasionally dropping to 50°F below zero. Summer temperatures in the mountains seldom exceed 90°F, and killing frosts are apt to occur at any time. At the summits on the Continental Divide, temperatures average less than 32°F over the entire year. Precipitation varies with the altitude and exposure and generally increases towards the higher elevations. A look at isoheyetal maps reveal "islands" of heavy precipitation surrounding the major peaks and mountain ranges. The greatest precipitation - in excess of 50 inches annually - falls on the mountains of the Continental Divide that separate the watersheds of the Cache La Poudre River, the Big Thompson River and the Saint Vrain Creek from the Colorado River Basin. The majority of this precipitation occurs in the winter as snow. The amount is upward of 200 inches annually. Several glaciers can be found here on the headwaters of the Saint Vrain and Boulder Creeks. Also, the least precipitation in the basin occurs in the mountain region; South Park, shielded by surrounding high ranges, receives approximately 11 inches annually.

The very existence of the mountains causes "islands" of heavy winter precipitation, as seen on the isohyetal maps. During the spring as air temperatures rise the spring runoff begins. This continues during the period May-July. The residual remains behind in glaciers and large drifts and melts throughout the summer. Because the watersheds in this region are covered with rock, they are relatively impermeable and the melting snow quickly runs off the land. However, some will infiltrate, and emerge later as interflow.

Figure 1-7 is a typical hydrograph showing the characteristic period of snowmelt and runoff. This melting snow is the source of water for the Front Range tributaries which supply the basin with the bulk of its surface waters.

A flood potential results from this melting snow in the spring. In a year of normal snow accumulations in the mountains and normal spring temperatures, river stages become high, but there is no general flooding. In years when snow cover is heavy, or when there is a sudden warming in the spring at high elevations, there may be extensive flooding.

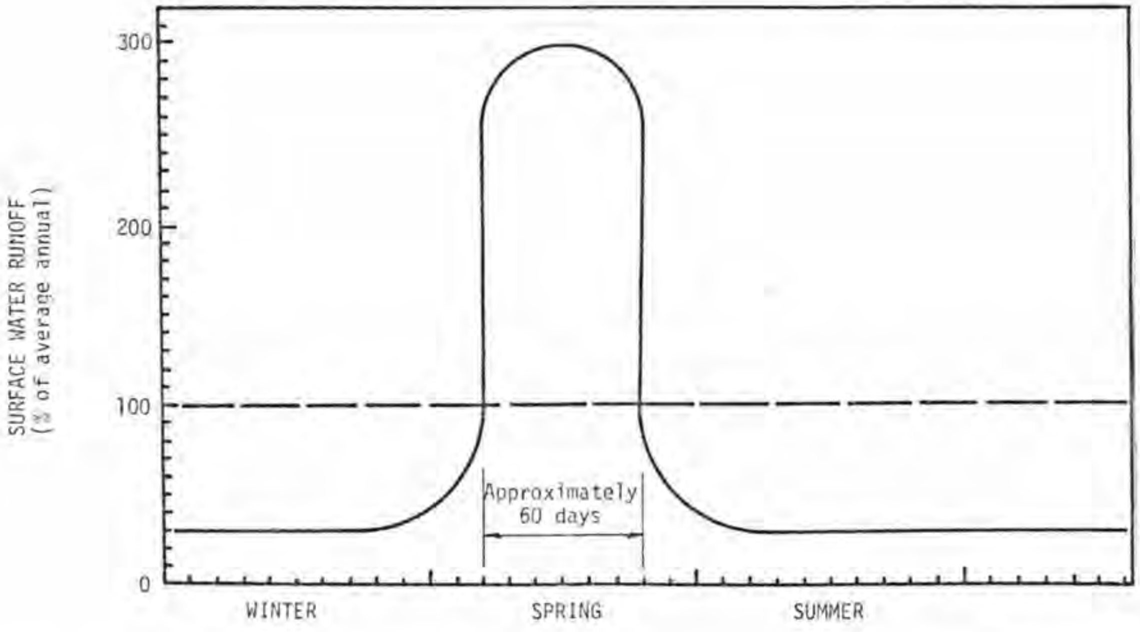


Figure 1-7 Characteristic Hydrograph of the Front Range Tributaries Draining the Mountainous Region of the South Platte River Basin.

The Foothills - The climate of the foothills region is a transition between the climates of the plains and the mountains. Both summer and winter temperatures are more moderate than in either the plains or mountainous regions, and day-to-day weather is comparatively uniform. Precipitation averages between 15 and 20 inches annually. There is less snow fall than in the mountains.

The Plains - The climate of the plains is uniform from place to place. Characteristic features are low humidity, abundant sunshine, warm summers, cold winters, and considerable wind. Seasonal variations in temperature and wind movement increase on the plains in relation to the distance from the protective mountains. Toward the east, summer temperatures are greater and winter temperatures are lower. Summer temperatures in this region are often 95°F or above. The highest official temperature on record in Colorado occurred in the basin at Bennett where 118°F was recorded on July 11, 1888 (National Oceanic and Atmospheric Administration, United States Department of Commerce, 1974). The usual winter extremes in the plains are from zero to 10-15°F below zero. Because of the comparatively level and treeless character of the plains terrain, high wind velocities often occur here. The precipitation in this region varies from year to year. Near the foothills, it averages about 15 inches annually. Precipitation decreases to a low of about 12 inches annually near the center of the plains region then it increases to nearly 19 inches at the mouth of the basin. Seventy to eighty percent of the precipitation falls during April through September in the form of rain, whose source is northward moving air masses from the Gulf of Mexico. However, its monthly distribution is often erratic and prolonged dry spells occur during the summer. The summer rainfall is largely from thunderstorm activity and usually it is very intense and of short duration. Often these storms cause low volume flash floods of a local nature. The watershed of this region is relatively flat and permeable and as a result, most of the precipitation and surface water occurring here infiltrate into the ground to raise soil moisture levels. In addition, since there is no winter snow pack the streams are empheral. It is here, in the plains region of the basin, that the most abundant groundwater supplies are found. The river valleys of the plains South Platte and its tributaries are underlain by valley-fill alluvium containing an aquifer in hydraulic connection with the surface flows. In the Ogallala and Dakota sandstones which underlie and flank the riparian aquifers, groundwater is also present, but in smaller quantities. The recharge of these confined aquifers is primarily by direct precipitation. On the average, 30-40 thunderstroms occur at any point in the plains region each year; quite frequently these are accompanied by hail (Geraghty et al., 1973). The highest incidence of hail in the nation occurs in an area centered about at the Colorado, Wyoming and Nebraska tri-state corner, extending north to South Dakota and south to Kansas.

The Effect on Irrigation on the Natural Hydrology of the South Platte River-Plains Reach - When the Front Range tributaries were still in their natural state, spring runoff flashed unchecked down the stream channels, out through the foothills, and onto the plains. During the summer, after the melting of the mountain snowpack, the flow in these streams became very low. These low flows continued until the next spring runoff.

The South Platte River runs a northerly course, intercepting these streams, and then turns due east heading into the flat, relatively permeable plains. In the plains the South Platte was a disappearing river; during the low flood periods the flows infiltrated into the stream bed. Surface water left the basin only during the spring runoff. It has been told that the early pioneers following the South Platte Trail sometimes had to dig holes in the sandy river bottom to get water.

Today, after more than 100 years of irrigation and water resource development in the basin, the hydrologic nature of the plains reach of the South Platte has changed from an ephemeral stream to a perennial one. By the intervention of man the spring flood from the mountains is now diverted to off-stream reservoirs and held back by on-stream reservoirs, to be used later in the year as needed. Through irrigation this water is spread over immense tracts of land. The basin water balances are changed further by imported water from adjacent river basins which amount to almost one third of the average annual native runoff.

Historically, irrigation practices in the basin have not been efficient. Through custom, lack of capital to invest in scientific irrigation methods, and water laws which do not encourage the most efficient water use, much excess water is applied relative to the most efficient practices which are attainable today. In addition, there are miles of unlined canals, ditches, feeders and laterals in the basin. As a result of these irrigation practices, water tables have risen over the years, making the plains South Platte River an effluent stream, i.e., it gains flow from the irrigation return flows. These return flows are in turn diverted from the plains South Platte, sometimes leaving a dry stream below the point of diversion. Thus the stream has an erratic flow-distance profile. This pattern of use and reuse extends from the tributary streams all the way along the mainstem into Nebraska.

This balance between return flows and diversions has been affected very strongly in recent years by extensive pumping from the riparian aquifer. The pumping activity really got underway during the 1930's drought period. Presently there are an estimated 7,000 wells which pump over one million acre-feet annually from the riparian aquifer in the plains. This has had a serious effect on surface water diverters who are dependent on these groundwater seeps; the equilibrium and effectiveness of the return flow mechanism has been upset. Occasionally, only a minor fraction of upstream reservoir releases reach diverters in the plains as the flows are not sustained in the river chanel. Rather they infiltrate into the ground to replace the depletions of pumpage from the aquifer. Therefore, the practice of irrigation has severely affected and completely overridden the natural factors influencing the hydrology of the South Platte in its plains reach.

1.2 Evolution of the South Platte Water Resources System

The water resources development and history of the South Platte River basin is characteristic, of that of much fo the entire arid west. The natural environment which the early settlers and pioneers inherited, along with the needs and demands they placed upon it, has shaped the physical and institutional characteristics of the present water resources systems of the South Platte River basin.

1.2.1 *The Influencing Factor of the Native Surface Water Supply Characteristics* - About 73 percent of the average annual precipitation over the Continental United States occurs east of the Kansas-Missouri state line. Of the remaining 27 percent, about one half falls in the Columbia River Basin; this leaves about 14 percent of the nations average annual precipitation to be divided by 14 of the western states. They comprise over half of the land mass of the Continental United States.

The relatively small amount of water available caused early plains travelers to declare the great arid region west of the Missouri River a desert which could never become the home of civilized man (Watrous, 1911). However, this water is not distributed evenly over the land. While it is true that some parts receive very little, a look at isohyetal maps reveal "Islands" of heavy precipitation that have allowed for the very existence and prosperity of man in the western United States. These are caused by mountain ranges intercepting atmospheric moisture as it moves east from the Pacific Ocean. The combination of the great height of the mountains and the major occurrence of this moisture during the cold months cause much of this water to fall as snow. As their very existence causes these "islands" the mountain ranges also determine when, and the way, this water runs off the land. In the spring, the majority of the mountain snow pack rapidly melts. Over a 60 day period, roughly May through July, the bulk of the surface water runoff occurs. The remaining snow pack sustains the streams throughout the summer but at flows which are much lower. John Wesley Powell, the great explorer, told the Mountain Constitutional Conventions in 1889, that "all the great value of this territory has ultimately to be measured in acre-feet." The key observation will be that the majority of the surface water supplies do not occur coincidental with the majority of the water demands.

1.2.2 *The Influence Factor of Water Demand* - After the first settlers arrived in the South Platte River basin, it was soon apparent that irrigation would play a major role in water demands. Today agriculture diverts seven times more and consumptively uses 25 times more than all other water users in the basin combined. Generally, the need for irrigation water extends throughout the summer and for several weeks on either side. It is greatest when the natural availability of water is the least. The evolution of the demand for water in the South Platte River basin, and some of the resulting physical, administrative, and institutional developments, is presented below in a historical context.

1.2.3 *Evolution of the Water Resources Physical Infrastructure*

The Early Pioneers and the Gold Rush - The United States acquired the South Platte River basin in 1803 from France as a part of the Louisiana Purchase. The early explorers included the party of Major Stephen H. Long, who traversed the basin in 1819-1820. Following these initial explorations, trappers and fur traders began settling the area and establishing trading posts. The native inhabitants on the basin included the Arapahoe, Cheyenne and Ute Indian tribes. The first white settlers in the South Platte River basin had access to all the water they needed for their limited requirements.

By 1930, the Oregon trail was well-known and, with the discovery of gold in California, travel through the basin intensified. Many trails became established routes of travel. It has been told that emigrants and freighters following the South Platte Trail sometimes had to dig holes in the sandy bed of the river to get water for themselves and their livestock. The natural state of the South Platte River is that of an exfiltrating stream. Towards the mountains the river is perennial, but once on the plains it disappears rapidly into the groundwater reservoir.

In 1858 William Green Russell discovered gold at the confluence of Cherry Creek and the South Platte River. With this discovery, the mining towns of Montana City and Placer Camp were founded; they later became the City of Denver. In the very next year gold was discovered on Chicago Creek, a tributary of Clear Creek, by George Jackson. Gold was the talisman that drew thousands of pioneers across the plains to the Rocky Mountains and the South Platte River basin. Much has been written and told about how the mining camps in the Colorado Mountains developed into boom towns. Gold was found within the basin along the stream courses in the mountains and foothills and water was generally available for the requirements of mining. However, as the search progressed, mines were opened further and further up into the mountains towards the Continental Divide. In 1860 water from the Colorado River Basin was diverted eastward to provide for mining in the area around Fairplay at the headwaters of the South Platte (Radosevich, et al., 1976).

The Beginnings of Irrigation - While these pioneers delved among the rocks for gold, the fertile soil along the water courses was left untouched. Instead, great caravans of wagon trains transported the necessary amount of flour, bacon, and produce to the miners. The difficulty and uncertainty in obtaining supplies of fruit and vegetables by this method, and their high prices, led to experiments to produce them locally. According to available records, the first person to irrigate land in the South Platte River basin was David K. Wall, a disillusioned "fifty-niner" seeking gold. In the spring and summer of 1859 he diverted water from Clear Creek and directed his energies to the irrigation of about two acres of land near Golden (Radosevich et al., 1976). Later in the fall of that year, irrigation ditches were being built on Bear and Boulder Creeks; when Colorado water laws were enacted, they became the one through four water right priorties in the basin. The following year ditches were built on the Cache La Poudre River and on Saint Vrain Creek. In 1861, diversions were made from the Big Thompson River. Thus, within three years after the start of the Gold Rush, one or more irrigation ditches were diverting water out of nearly all of the principal front range tributaries of the South Platte River. Table 1-2 shows the ten most senior water rights in the South Platte River basin.

The construction of the first transcontinental railroad in 1867 brought more settlers to the basin. It was established that the soil was fertile and would produce abundant crops. However, the pioneer farmer had much to content against. The semi-arid climate of the basin was strange to the pioneers from the east. Irrigation was the only sure way to produce a harvest and they were not familiar with this practice. However, among the settlers were some who knew of irrigation in New Mexico, where it had been practiced by Spaniards for over 200 years; and in California, where it had been adopted from Mexico; and in Utah, where it was being implemented successfully by the Mormons.

Without exception, the early irrigation ditches in the South Platte River basin were privately owned by single farmers. They were short inexpensive ditches with sufficient grade to irrigate only a few acres of land. The prevailing sentiment at this time was that the uplands could not be farmed. As a consequence, the agriculture in the basin was confined to the proper valleys; specifically these were the bottom lands, or first bench. This represented the first of several rather well defined stages in the development of irrigation in the South Platte River basin.

Table 1-2 The Ten Most Senior Water Rights in the South Platte River Basin (Wilkinson, 1974)

Name of Structure	Type of Structure	Name of Source	Type of Use	Amount	Adjudication Date	Appropriation Date	Basin Rank
Lower Boulder Ditch	Ditch	Boulder Creek	Irrigation	25.0000 cfs	06/02/1882	10/01/1859	1
McBroom Ditch	Ditch	Bear Creek	Irrigation, Municipal	11.5800 cfs	02/04/1884	11/01/1859	2
Smith Goss Ditch	Ditch	Boulder Creek	Irrigation	5.0000 cfs	06/02/1882	11/15/1859	3
Howell Ditch	Ditch	Boulder Creek	Irrigation	47.5500 cfs	06/02/1882	12/01/1859	4
Howell Ditch	Ditch	Boulder Creek	Irrigation	42.5500 cfs	06/02/1882	12/01/1859	4
Black Hawk	Ditch	North Clear Creek	Industrial*	35.0000 cfs	10/09/1914	12/31/1859	5
Kimber Flume and Ditch	Ditch	North Clear Creek	Industrial*	111.51 cfs	10/09/1914	12/31/1859	5
Mead and Polar Star	Ditch	North Clear Creek	Industrial*	34.6000 cfs	10/09/1914	12/31/1859	5
Mead and Polar Star Ext	Ditch	North Clear Creek	Industrial*	34.6000 cfs	10/09/1914	12/31/1859	5
Sensenderfer	Ditch	North Clear Creek	Industrial*	45.0000 cfs	10/09/1914	12/31/1859	5

*i.e., mining.

Community Cooperation in Irrigation Development - As mining continued to develop, Denver and other towns grew into cities. When these cities were linked to the east by railroads, the markets supported a demand for a more diversified and larger agricultural supply.

In time, it was discovered that the soils of the bluffs and of the second and third bench lands were as productive as that of the lower lands, and so farming began to push out from the immediate vicinity of the streams. This new departure involved a change in the manner and methods of building ditches; and at this point large irrigation canals came into existence.

In 1869 Horace Greeley, Editor of the New York Tribune, followed the very advice he had been offering to others, i.e., "Go West Young Man and grow up with the Country." He established the Union Colony in 1870 which settled near the confluence of the Cache La Poudre River with the South Platte River.

The Union Colony, which was later to become the City of Greeley, was founded on the principal of cooperative diversion and use of water, as well as cooperative construction of irrigation canals. This settlement initiated an irrigation system for some 30,000 acres, which consisted of farms ranging in size from 80 to 160 acres (Radosevich, et al., 1976). The Greeley Canal Company No. 2 Canal was the first large canal in the basin and in Colorado to be built by community cooperation. It was also the first to irrigate extensive areas along the higher bench lands. The Union Colony was a success from the start, due in large measure to the fact that they were people of considerable means and were able to finance themselves over the period required to bring raw prairie land into profitable cultivation.

Soon afterwards, similar irrigation communities were settled along the Cache La Poudre River at Fort Collins, on the Big Thompson River at Loveland, and on the Saint Vrain Creek near Longmont.

The Corporate Era in Canal Construction - The success of the community efforts set the stage for the next development, which was corporate investment. Seven years after the establishment of the Union Colony, with the organization of the Larimer and Weld Irrigation Company in 1879, the corporation era of canal building was launched (Boyd, 1897). The ability of corporate form of organization to marshal greater economic forces resulted in the enlargement of existing canal systems and the construction of new systems diverting direct flows for larger areas of higher bench lands. Many of these irrigation companies were land development companies as well; they brought the land in large tracts, constructed the canal, and then sold the land with water attached.

Reservoirs and Transbasin Diversion Structures - It was soon apparent that the increasing direct flow irrigation requirements were out of phase with the spring runoff. When it appeared that the later summer demand would soon outstrip the later summer supply, several of the most important developments took place; the construction of reservoirs and transbasin diversion structures to physically make available more water. In addition two other significant developments occurred at this time. They were: (1) the creation of a system of water law, and (2) the initiation of streamflow gaging stations to assess the availability of the natural supplies. These events are discussed in more detail in Section 1.2.4.

During the spring large flows wasted down the streams of the basin. The stroage of these surplus flows became a necessity for continued growth in the agricultural sector, which soon became the mainstay of the basins economy. The first 774 South Platte Basin water rights are for direct flows and occupy basin ranks 1 through 216. In the spring of 1869 the Churches Reservoir began storing the flows of Ralston Creek, a tributary of Clear Creek, for irrigation water supplies. Adjudicated in 1884 this reservoir holds the most senior storage right in the basin (Wilkinson, 1974). However, it was from roughly 1880 to 1920 that the era of reservoir construction flourished. There are numerous depressions scattered throughout the plains drainage of the basin that are a result of natural phenomena. These depressions are from 5 to 50 feet deep and were formed by wind scour.

Some collected rain water and formed watering holes and "buffalo wallows." These same basins now provide facilities for storing water at a relatively low expense. The discovery was made at an early date that these natural depressions could have their holding capacity increased greatly by building an embankment across the lower rim.

The final result of the extensive reservoir construction is a patchwork of off stream storage facilities ranging in capacity from a few acre-feet to over 50,000 acre-feet. Their general location is between the foothills on the west and the mainstem of the South Platte as it courses north flowing parallel to the Front Range. However, several of the largest offstream reservoirs are located further out in the plains, along either side of the South Platte as it flows east from Greeley to the state line.

During this time also, mountain reservoirs were being planned and built. While these were generally more expensive to construct and maintain their evaporation and seepage losses were much less than those in the plains. Most of these storage facilities were on-stream and consisted of a dam to impound water in a high mountain canyon or valley. The most notable of these reservoirs is Lake Cheesman, the first reservoir to be built on the mainstem of the South Platte River. It is located about 40 miles upstream from Denver, in a rugged canyon, at an elevation of about 6,800 feet. Lake Cheesman is owned by the City of Denver. Construction began at the turn of the century, but a torrential flood on May 3, 1900 washed away the first partically completed dam. Undaunted, construction was started again, and when completed in 1905 Cheesman Dam was the highest dam structure in the world.

Even as the first reservoirs began holding back a portion of the high spring flows, promising greater and more reliable supplies, many realized that the need for water in the basin would continue, and that the native runoff was not sufficient. This led to importation of water from foreign drainage basins.

The first transbasin diversion structure importing water to the South Platte River basin was constructed in 1860 near Fairplay. The water was used for mining and it was a short lived need. About thirty years later in 1889 then State Engineer, K. P. Maxwell, made surveys investigating the possibilities of diverting water from the headwaters of the Colorado River through a tunnel to Saint Vrain Creek. The State legislature appropriated $20,000 for this survey and $3,000 for an investigation of the feasibility of diversions from the North Platte and Laramie Rivers (United States Bureau of Reclamation, 1968). Although no conclusions resulted from these studies, they signaled the start of the formal period of development of foreign water supplies for the South Platte River basin. One year later in 1890, the Water Supply and Storage

Company (an Irrigation Water Supplier) began construction of the Grand River Ditch, which is the oldest operating diversion structure in the basin today. The Grand River Ditch intercepts the very high altitude runoff just under and along the west side of the Continental Divide. The water collected is transported across the Continental Divide via La Poudre Pass, at an elevation of 10,190 feet, and put to storage until needed in Long Draw Reservoir at the head of the Cache La Poudre River. The ditch was generally cut by hand into steep rocky mountain sides. The excavated material was used to form the lower outer bank. The first water was diverted in 1892. Expansion of the collection system continued intermittently through the 1930's. In fact, as recently as 1975 portions of the Grand River Ditch were upgraded and lined and Long Draw Reservoir was also enlarged.

Thirty years after the Grand River Ditch began importing water, ten other transbasin diversion structures were in operation also. One of these structures, the Laramie-Poudre Tunnel, was the first to bring water into the basin through the mountains, vis a vis through the passes by ditch.

With the overappropriation of the native surface water supplies close at hand, it was apparent that in addition to groundwater supplies, the importation of water from other river drainages would be the final source of large amounts of new water.

In the 1935 water year, 13 transbasin diversion structures imported 55,020 acre-feet of water to the South Platte Basin from the North Platte and Colorado River Basins. Also in 1935 the USBR began studies on what was to become the Colorado Big Thompson Project. This signaled the era of the Mega structures, i.e., hugh importation facilities that would bring into the basin tens of thousands of acre-feet of water each year. The CBT project was planned and constructed to import almost six times as much water as all of the previous transbasin diversion structures combined. With its population rapidly increasing, Denver contributed to this era with the Moffat Water Tunnel Project (first diversions in 1936) and the Harold D. Roberts Tunnel Project (first diversions in 1963).

The era of Mega-structures contiues as it is the only means to obtain major supplies of new raw water. However, the remaining unappropriated waters of those basins which are potential sources of new water for the South Platte River basin are now all under conditional decrees. Once these rights have been perfected, additional imports will be available only through purchases.

Groundwater - Because streamflow was not always a dependable source of supply, especially for junior diverters, in the 1890's farmers began drilling wells to obtain water for irrigation. The first major well in the South Platte River basin was put down in the Beaver Creek Valley (an intermittent plains tributary) in 1910 (USBR, 1959). The water withdrawn from the ground by this well was used for irrigation as the surface water supplies in this part of the basin were notoriously unreliable. The drilling of new irrigation wells continued slowly; there were about 550 pumping plants throughout the entire basin by 1930. The drought years, beginning in 1931, along with the introduction of high speed diesel engines, stimulated the growth of irrigation wells to a great extent. Reduced electric power rates were initiated about 1930 (USBR, 1959). By 1940, 1900 pumps were withdrawing water from the groundwater sources in the basin. By 1950, there were 5,000 wells (USBR, 1959).

The next drought, in the mid 1950's, caused another sharp increase in the number of wells drilled; this was a direct result of the deficient surface water supply during those years. For the next several years the number in new wells drilled decreased as the surface water supply was back to normal; this, combined with production from existing wells, reduced the need for supplemental water.

An increase in the number of well installations in the basin can be seen again during the years 1963-1965. This can be attributed in part to a decrease in surface water supply but according to Hurr (1975) the main reason was an anticipated change in Colorado's groundwater law, which would regulate the drilling and use of wells. The small number of wells drilled after 1965 is a result of the implementation of the law. Figure 1-8 shows the annual installation and cumulative number of irrigation wells in the South Platte valley proper between Henderson (just below Denver) and the Colorado State Line.

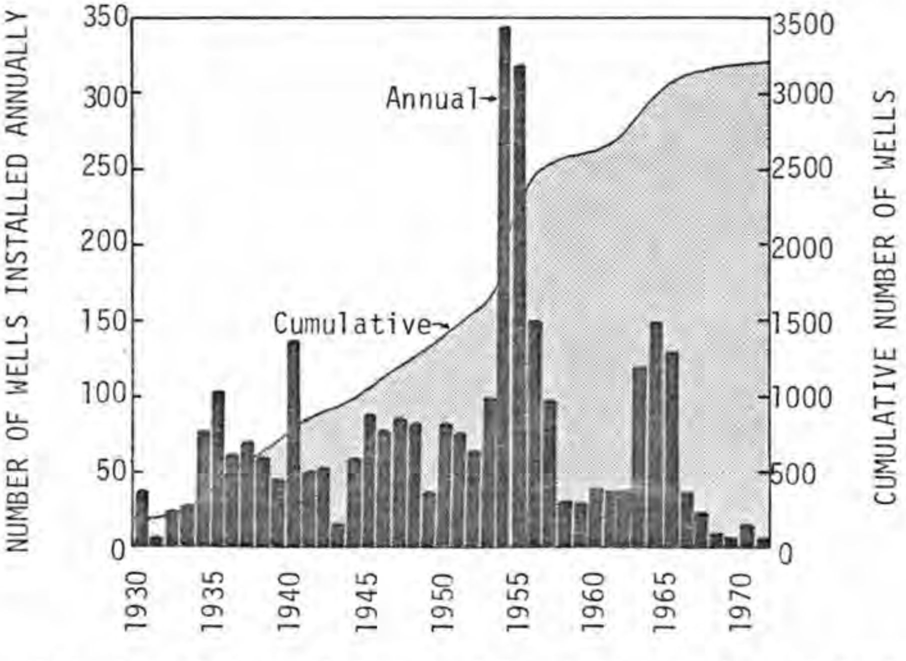


Figure 1-8 Annual Installation and Cumulative Number of Irrigation Wells in the South Platte River Valley Between Henderson and the Colorado State Line (Hurr, 1975).

Today, an estimated 7,000 wells through out the entire South Platte River Basin pump each year an amount of water approximately equivalent to the Basins average annual native surface water runoff.

Apex Development - The South Platte River basin has passed through several well defined stages in developing its raw water supplies. The result is that in just over 100 years it has physically developed practically all of its native sources as well as a substantial amount of the water supplies of other river basins. It has also organized an institutional framework for the distribution of this water in an civilized manner. But it is an accomplished fact that the dominant economic activities in Colorado are located in the South Platte River Basin, i.e., along the Front Range. The basins thirsty population is increasing and its industrial demands (especially by the energy sector) are following suit. Irrigated agriculture in the basin remains fairly constant, the trend has been generally to displace it to the east, allowing for municipal development near the foothills. To meet these future demands, the question is: where will the water come from? Since the native sources of water in the basin are overappropriated (and if one were to discount cloud seeding), the most obvious answer is that the new water supplies needed will come from other river basins.

However, as it will be shown, except for the Colorado River, virtually all of the native surface water runoff in every basin surrounding the South Platte basin, has been absolutely decreed. What remains in the Colorado River basin that is not now used has been conditionally decreed several times over to potential development both within the Colorado River basin and outside. Barring the purchase of water from existing users in other river basins it appears that an upper limit of transbasin diversions to the South Platte River basin will soon be reached. Imports of water through such grand schemes as the NAWAPA Plan (which would bring water from Alaska and Canada to the arid western United States and Mexico) appear politically unrealistic at this time. The "bargain basement" days of water resources development are at an end. Not only is there no more large amounts of water available for development; but the political obstacles of various sorts are becoming increasingly formidable.

Thus the South Platte River basin is in the midst of its last stage of raw water resources development which will terminate upon the perfection of its existing conditional decrees. It is approaching an apex, so to say, where those supplies presently developed, along with some additional potential supplies will constitute the upper limit of available raw water supplies; i.e., no longer will there be the hope of developing large amounts of new water supplies. But this does not have to mean that the unavailability of new raw water supplies will hamper the future growth in the basin (or that it will not allow for the prosperity of its present populace and their endeavors during drought situations). Much can be done in anticipation of this inevitable upper limit. Considerable latitude is still possible to meet new demands using present and potential supplies of water. This apex stage may involve new capital investments (i.e., for drip irrigation technology), some modifications to the water rights system (i.e., for the courts to define the duty of water), and an overall management scheme to guide these activities and perhaps to develop more efficient conjunctive use progarams within the basin.

Since agriculture is the single largest user category, the bulk of the new water demands under apex development will be satisfied through purchases from agriculture. Such transfers can be accomplished without the demise of irrigated agriculture. A system of purchases tied to giving agriculture compensation or incentives to devise greater efficiencies (i.e., consolidation of ditches, use of scientific irrigation, use of new irrigation technology, etc.) could provide some water and yet maintain agriculture for both its economic and social values. Presently the irrigators have the least available capital and the fewest incentives (mainly through water right laws) to increase efficiency. While the municipalities may have some opportunities for water conservation (e.g., by metering) the net effects on the basin water balance would be small.

Another facet of Apex development (which was seen for the first time in the basin just last winter) is the inducement of additional water supplies through cloud seeding. However, the only realistic approach in providing for the future is to plan for water self sufficiency. This includes utilization of the native surface water supplies with perhaps some strategic improvements, allowing for an upper limit of foreign water, and subjecting the whole to an overall management review. Any changes will be induced by the market system, combined with strategic modifications to the water rights system.

1.2.4 *Evolution of the Water Resources Administrative Institutions*

Water Rights and the Concept of the Appropriation Doctrine of Water Law - Early in the history of Colorado's Government, the territorial legislature acknowledged the riparian right to divert water for agricultural purposes. The predominant characteristic of the riparian doctrine of water law is that it gives the owners of land adjacent to a body of water equal rights to the use of the water. The act of 1861 states:

> All persons who claim, own or hold a possessory right or title to any land or parcel of land within the boundary of Colorado Territory... when those claims are on the bank, margin or neighborhood of any stream of water, creek or river, shall be entitled to the use of the water of said stream, creek or river, for the purposes of irrigation, and making said claims availalbe, to the full extent of the soil, for agricultural purposes (Colorado Territorial Legislature Session Laws of 1861, Act of November 5, 1861).

The tradition and philosophical basis of the Riparian Doctrine is just one example of so much excess luggage that the early settlers brought with them from the east. They were soon to find that many of the old ways did not meet the circumstances of their new situation. So in the true pioneering spirit they adjusted and adapted.

In 1864 the Territorial Legislature recognized the doctrine of appropriation water rights in Colorado. This concept in water law had its beginnings in California about 15 years earlier during the 1849 gold rush. The following is from Radosevich et al., 1976;

> In diverting water from nearby streams to their diggins, gold miners intially applied their rules of mining claims to the use of water. Over time, it became customary for the first diverter of water to have a prior right to the use of water, during periods of scarcity, over latter diverters. Thus, a system of priorities was established. This practice was then accepted by the agricultural settlers. As agricultural municipal, and industrial requirements grew throughout the western states, along with the need for some civilized way to resolve emerging conflicts, the application of appropriation doctrine came into accepted and widespread use.
>
> The present prior appropriation doctrine is basically the same as that first developed through custom in California. That is a water diversion first in time is first in right, thereby establishing a list of priorities. Generally, to validly appropriate water under this doctrine, it must be diverted from the stream and put to beneficial use. Since its creation, a few other principles have been added to the doctrine. For example, land ownership is not required to appropriate water, and water may be transferred out of the watershed of origin. Also, an appropriation is for a specific quantity of water and is a property right that is recognized as being salable like any other commodity.

In 1872 the first court decision in Colorado dealing with the Appropriation Doctrine was handed down. This case, Yunker vs. Nichols, 1 Colorado 551 (1872), gave preference to the Appropriation Doctrine and also established the procedure of obtaining an easement to convey water across anothers land in order that the water might be applied to a beneficial use.

In 1876 Colorado was accepted into the union and in its constitution it was stated that:

> The water of every natural stream, not heretofore appropriated, within the State of Colorado, is hereby declared to be the property of the public, and the same is dedicated to the use of the people of the state, subject to appropriation as hereinafter provided. (Colorado Constitution, Article XVI, Section 5).

In 1879 the Colorado State Legislature passed an act, (which was supplemented two years later by an act of 1881) to provide (1) for the acquisition of titles to water rights and (2) for the administration of water so that each appropriator might receive his authorized amount. These two laws were historic in irrigation legislation; they were the first to provide for public administration of water used for agricultural purposes. The case in Colorado confirming the Appropriation Doctrine was Coffin vs. Left Hand Ditch Company [6 Colorado 443, (1882)], which involved water users in the South Platte River Basin. In its decision, the Colorado Supreme Court held that:

> ...the common law doctrine giving the riparian owner a right to the flow of water in its natural channel upon and over his lands even though he makes no beneficial use thereof, is inapplicable to Colorado...and we hold that, in the absence of express statutes to the contrary, the first appropriator of water from a natural stream for a beneficial purpose has with the qualifications contained in the Constitution, a prior right thereto to the extent of such appropriation.

The concept of prior appropriation has been carried throughout the entire body of law and legislation concerning water. As water use in the state grew, the foundations of its water law were built through legislative statues and case law. In order to resolve water conflicts the courts have been called upon to define what constitutes a water course; waste, return, salvaged, developed, foreign and spring waters; abandonment; beneficial use; etc. The impact of the developing water law on the early agriculture in the State was summed up by Hafen in 1897.

> The development of irrigation is not merely the result of a succession of victories over physical or material obstacles. In our contry, these form but a part—and, unfortunately, often a relative small part—of the difficulties encountered by the irrigator. By far the most vexatious and expensive impediments to be removed have been those arising from the inapplicability of our laws and customs to the conditions prevailing within the arid region. Every instinct acquired through generations of life in a humid country seems to rebel against the methods of the irrigator, and every tradition of law is in direct opposition to the proper employment of the natural waters. These instincts and traditions have had to be laboriously demolished, usually after severe struggle, and the series of contests appears a never-ending one.

The Office of the State Engineer - As a result of the 1881 act, the Office of the State Hydraulic Engineer was created, water divisions, and districts were formed, and the vehicle for the administration of water in Colorado was set in motion. The South Platte River basin is contained within Colorado Water Division 1. Figure 1-9 shows the current configuration of water districts (which are subservient to water Division 1) in the basin. The first steps taken in Colorado to obtain definite information concerning its natural water supplies were also initiated at this time. The State Engineer was given general supervisory control over the public water supplies of the State. The office was also charged with the collection of data and information regarding snowfall for the

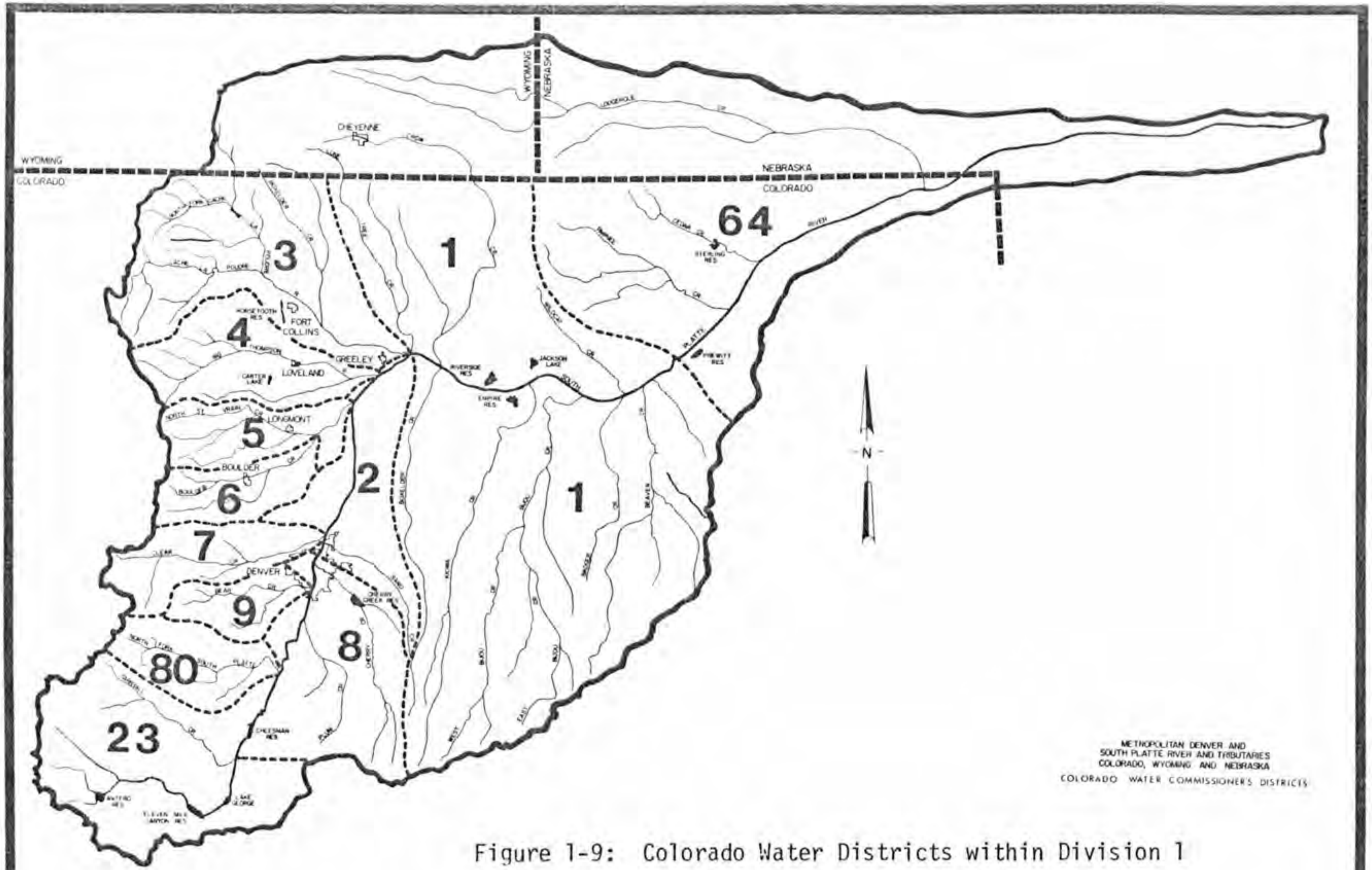


Figure 1-9: Colorado Water Districts within Division 1

purpose of predicting probable runoff and with the duty of making measurements of the flow of public streams of the state.

Pursuant to these requirements the first stream gaging station in Colorado was established on the Cache La Poudre River at the mouth of its canyon on June 20, 1881, (Colorado State Planning Commission et al., 1939). The second station was established on the Big Thompson River in August of the same year. In 1883, E. S. Nettleton, the State Engineer, extended the work of stream flow gaging stations to include the Saint Vrain Creek and other tributaries of the South Platte.

During his time as State Engineer, E. S. Nettleton developed the first practical current meter to meet the conditions of stream flow in the state. Known as the "Colorado Meter" it is quite similar in principal to, and was a forerunner of, modern current meters. He also devised and installed at the Cache La Poudre River Station, in 1884, what was probably the first automatic river-stage recording instrument ever used in the United States. It is believed that this record is the oldest continuous record in the United States (Colorado State Planning Commission et al., 1939). The recorder for a time was connected by a 12-mile wire with a recroding instrument in the office of Professor L. G. Carpenter in Fort Collins and this also constituted the first attempt at long distance recording.

CHAPTER II

SUMMARY AND CONCLUSIONS

2.1 Native Water Supplies

2.1.1 *Hydrologic Availability* - An endogenous or native source of water of a river basin includes both surface water runoff and groundwater supplies. Native water supplies come from precipitation falling on the basin.

Precipitation over the entire South Platte River basin averages 14.81 inches per year, (United States Department of Commerce, Environmental Data Service, 1970). Local precipitation within the basin ranges from an average of about 12 inches per year on the plains to about 40 inches per year in the high mountains. Most of the precipitation which falls on the plains, i.e., 70 to 80 percent, occurs in the summer as torrential rains from scattered thunderstorms. Precipitation in the mountains occurs mostly in the winter as snowfall; snow depth may reach up to 200 inches in places.

Table 2-1 summarizes the work of De Haan (1975) who concluded from the isoheyetal maps shown in the Figures 1-5 and 1-6 that the South Platte River basin within Colorado receives 15,229,000 acre-feet of water in an average year in the form of precipitation. In an analysis by Janonis and Gerlek, (1977) it was determined that the portion of the South Platte River basin in Wyoming receives 1,749,300 acre-feet of water as precipitation in an average year. Therefore, on the average the entire South Platte River basin study area receives 16,978,300 acre-feet of water, as precipitation each year.

According to precipitation data gathered at various weather stations throughout the basin, the average annual precipitation during

Table 2-1 The Normal Precipitation for the South Platte River Basin in Colorado, Between 1931 and 1960[1/] (De Haan, 1975).

Season	Precipitation (inches)[2/]	Precipitation (sq. miles)[3/]	Precipitation (10^3 acre)[4/]	Total Water Received (10^3 acre ft)[5/]
October through April	3.5	1,468.	939.	274.
	4.5	8,201.	5,249.	1,968.
	5.5	4,552.	2,913.	1,335.
	7.0	1,721.	1,101.	642.
	9.0	1,342.	859.	644.
	15.0	1,187.	760.	950.
	22.5	144.	92.	172.
	Sub total	18,615.	11,913.	5,985.
May through September	6.5	376.	241.	130.
	7.5	2,569.	1,644.	1,027.
	8.5	6,087.	3,896.	2,760.
	9.5	5,935.	3,798.	3,007.
	11.0	2,413.	1,544.	1,415.
	13.0	780.	499.	541.
	15.0	455.	291.	364.
	Sub total	18,615.	11,913.	9,244.
	GRAND TOTAL	18,615.	11,913.	15,229.

1/All data was obtained from Figures 2-5 and 2-6.

2/Average precipitation between isohyets was assumed to be one half of the sum of the two isohyets.

3/Area of precipitation was measured from an isohyetal map as the area between isohyets. Areas less than 100 sq. miles were assumed to be part of their surrounding areas.

4/Area of precipitation in thousands of acres is equal to 0.64 times the area in square miles.

5/Total water received is equal to the area of precipitation times the average precipitation. The South Platte basin within Colorado receives approximately 15.2×10^6 acre ft. per year of precipitation.

the four drought years 1953-1956 was 85 percent of normal (Smith and Shultz, 1962).

The disposition of this precipitation is: as surface water runoff, seepage directly into the ground, and retention in the winter snowpack and glaciers. However, the largest part returns back to the atmosphere through evaporation from soil and water surfaces, through transpiration from plants, and through sublimation from the snow cover.

Surface Water - About 50 to 70 percent of the surface water runoff in the South Platte River basin occurs during the period April-July as snowmelt from the mountain tributaries. During the four summer months July to October the residual snow pack and interflow from the groundwater sustains these streams at lower flows. The flows may drop substantially during the fall and winter.

Minor additional water accrues to the basin from intermittent discharges of the plains area tributaries. This surface water runoff is derived principally from summer thunder storms characterized by short intense rainfall and generally appears as short duration flash floods of a local nature. Because the plains are relatively flat and permeable, a good deal of this rainfall and subsequent runoff ends up seeping into the groundwater reservoir.

According to the United States Bureau of Reclamation who studied that basin in 1959, the native surface water runoff between 1930 and 1949 averaged 1,243,500 acre-feet per year (USBR, 1959). This figure does not represent the total virgin flow, however, because some man made depletions above the points of measurement were ignored and only the residual historical flows were considered (specifically they were the consumptive use of some mountain municipalities and of approximately 50,000 acres of irrigated hay lands in South Park).

In 1973 the Colorado Westwide Study Team estimated the native virgin runoff in the South Platte River basin to average 1,441,000 acre-feet annually. This study considered a 21 year base period, water years 1950-1970.

Table 2-2 shows the annual surface water runoff for the study area of the basin, and for each sub-basin, in terms of (1) long term average, (2) the 1970 water year, and (3) the average for the 1953-1956 drought period. The computations involved in developing this table can be found in Appendix A, Section A4. The average annual suface water outflow from the study area has averaged 351,752 acre-feet per year, as seen in Appendix C, Table C4-42. The outflow consists of return flows mostly. During high runoff years some native flows may leave the basin also.

According to the 1926 South Platte River Compact, Colorado cannot consumptively use all of the surface water runoff arising in the South Platte River Basin. In this agreement with Nebraska, Colorado must let flow across the state line 47,116 acre-feet per year, if available, in a specified manner (i.e., 120 cfs between October 1 and April 15). This compact can be found in Appendix D, Section D4; a more detailed interpretation is provided in Section 6.5.2. An additional constraint regarding the basins surface water outflow is the salinity question. The basin must maintain its salt balance which requires certain minimum flows to flush out excessive buildups.

Groundwater - To adequately address the question of groundwater supplies of the South Platte River basin a more extensive study would be

Table 2-2 Native Surface Water Runoff of the South Platte River Basin in Wyoming and Colorado.

Sub-basin	Drainage Area (Square miles)	Surface Water Runoff (Acre-feet/Year)1/				
		Long Term Average	1970 Water Year		1953-56 Drought Period Average	
			Annual Flow	% of Long Term Average	Annual Flow	% of Long Term Average
South Platte River-Mountains	2,142	201,211	402,235	199.9	105,354	52.4
North Fork South Platte River	479	112,604	198,680	176.4	64,286	57.1
Plum Creek	302	22,789	31,440	138.0	7,142	31.3
Cherry Creek	385	11,075	6,119	55.3	4,606	41.6
Bear Creek	214	44,927	76,244	169.7	4,411	
Clear Creek	448	173,994	225,362	129.5	114,784	66.0
Boulder Creek	439	122,832	162,914	132.6	83,824	68.2
Saint Vrain Creek	537	117,600	131,549	111.9	74,820	63.6
Big Thompson River	828	147,600	177,006	119.9	93,903	63.6
Cache La Poudre River	1877	234,833	321,220	136.8	158,066	67.3
South Platte River Transition	1447	12,341	9,074	73.5	5,133	41.6
Crow Creek	1824	60,000	60,000	100.0	36,540	60.9
North Plains Tributaries	2400	1,090	1,090	100.0	664	60.9
Lodge Pole Creek	1946	43,023	43,023	100.0	26,201	60.9
South Plains Tributaries	4276	50,000	50,000	100.0	30,450	60.9
South Platte River-Plains	1956	0	0	-	0	-
Basin Total	21,500 2/	1,355,919	1,895,956	139.8	825,590	60.9

1/Appendix A. The figures above do not include "return flows" from municipalities and industries; groundwater which exfiltrates to these streams sustaining flows in their plains reaches is not included either. This phenomena is the result of the basins history of irrigation. Return flows from agriculture are the residual of applied irrigation water which seep through the ground, accrue back to the streams, and allows for their use once again. Because of this, total surface water diversions may be much greater than total surface water runoff, however, total consumptive use is never greater (discounting imports and ground water use).

2/The drainage area of the entire South Platte River Basin is 24,300 square miles, (USGS, 1970). However, the 2,800 square miles in Nebraska are not included in the study area.

required than is possible here. Only a brief overview is provided in this study in the following paragraphs.

The principal supplies of groundwater in the South Platte River basin are in the plains. Specifically these supplies are contained in the alluvial deposits underlying the valleys of the mainstem South Platte River and its tributaries. A typical valley fill aquifer consists of an ancient stream channel eroded in the bed rock and partly filled with unconsolidated sand, gravel, and clay. These aquifers are hydrologically connected to the surface flows of the streams which have fostered their very existence. During high flows much of the adjacent meadow land is inundated resulting in groundwater recharge to the valley alluvium. As the floods subside and during periods of low stream flow, much of the water stored in the alluvium slowly seeps back into the stream.

It has been estimated that the alluvium of the South Platte River and all its tributaries contain 25 million acre-feet of groundwater, of which 11 million are in the South Platte River alluvium below Hardin, Colorado, which is approximately 15 miles downstream from Greeley, (USBR, 1959).

In addition to the alluvium groundwater, older and deeper water bearing formations are presented in the study area. These include the Ogallala and Dakota sandstones which underlie and flank the alluvium deposits in the plains. The recharge to these aquifers is principally from the scant precipitation which occurs overhead. No quantitative information could be found on the amounts of water stored in these formations; however, according to Bjorklund (1957) "groundwater is present in small or moderate quantities."

2.1.2 *Existing Development of the Surface Water Runoff* - In the late summer of 1859, the Lower Boulder Ditch diverted 25 cfs from Boulder Creek for the purpose of irrigation. In the summer of 1882 when the water runoff for the Lower Boulder Ditch was adjudicated, it was assigned priority number one in the South Platte River basin (Wilkinson, 1974). The ten most senior water rights in the South Platte River basin (all of which are direct flow rights) have been shown in Table 1-2. The most senior storage right in the basin belongs to the Churches Reservoir which, as already mentioned, began storage in the spring of 1868.

In just over 100 years since that time over 5,000 major direct flow and storage rights have been decreed. These water rights total more than 30,000,000 acre-feet, based upon appropriations to the fullest extent, i.e., continous diversions for the direct flow rights. Of course, these rights are not exercised continuously. However, the amount noted is an index of the demand for water in the basin. Compared to the 1,355,919 acre-feet of average annual runoff, it is clear that the surface waters are over appropriated.

In 1969 the water rights Determination and Administration Act required tabulation of water rights in Colorado by the State Engineer. It was found that in 1970 there were a total of 3,274 individual water rights, both conditionally and absolutely decreed, held in the South Platte River basin. These included 2,092 direct diversion rights and 1,182 storage rights (Wilkinson, 1973).

The annual water commissioners report for 1970 showed 174 applications for direct flow rights and 90 applications for storage rights. In addition, there were 45 parties showing due diligence that year on conditional decrees held in the basin, (Colorado Water Division No. 1 Water Commissioners, 1970).

In 1973 the Colorado tabulation of water rights was revised to reflect water rights that had been abandoned and those conditionally and absoluately decreed since 1970. In addition, this most recent tabulation included omissions from the first listing and correctional modifications. It was found that the total number of individual absolutely and conditionally decreed water rights held in the South Platte River basin within Colorado amounted to 5,724 (Wilkinson, 1974).

The surface water in the Wyoming portion of the South Platte River basin is appropriated by 393 direct flow water rights and 32 storage rights (USBR, 1959). In Nebraska, 116 direct flow rights and five storage rights are held by South Platte River basin water users (USBR, 1959).

Table 2-3 shows the approximated distribution of these decreed water rights by sub-basin. It also tallies the amounts decreed to the major water rights in each sub-basin and the approximate number of well rights. It can be seen that the 1,560 major direct flow and storage rights have been decreed a total equivalent at 31,623 million acre-feet of surface water each year. This sum represents about 23 times the average annual native surface water runoff of the basin.

It is obvious that even in an extremely wet year, a great deal of these water rights are not satisfied. However, the decreed amount includes conditional decrees some of which will never come to fruition. In addition, water users in the basin do not consumptively use 100 percent of their diversions. Agriculture, which places the greatest demand on water in the basin, consumptively uses only about 4.1 acre-feet for every ten acre-feet of water diverted. The unused portion of the diversion is return flow, and it generally seeps through the ground and accrues

Table 2-3 Absolutely and Conditionally Decreed Water Rights Held in the South Platte River Basin.

Sub-basin[1]	Approximate Total Number of Decreed Water Rights[2]: Well	Direct Flow (Ditch)	Storage	Major Decreed Water Rights[3]: Direct Flow: Number	Total CFS	Equivilant (Acre-Feet/year)	Storage: Number of Reservoirs	Total Acre-Feet
North Fork of the South Platte River	41	240 (175)	45					
South Platte River-Mountains	0	625 (385)	40	93	6,850	4,959,400	44	393,000
South Platte River-Transition[4]	2	245 (190)	65					
Plum Creek	119	190 (180)	55	77	403	291,772	13	16,800[13]
Cherry Creek[5]								
Bear Creek[5]	2	810[8] (250)	60	21	1,167	844,908	16	31,000
Clear Creek[5]	0	335 (285)	200	72	4,950	3,583,800	47	113,000
Boulder Creek	1	320 (220)	155	90	5,500	3,982,000	31	49,300
Saint Vrain Creek	6	310 (205)	190	90	3,040	2,200,960	55	42,200
Big Thompson River	8	265 (210)	80	75	2,730	1,976,520	14	101,000
Cache La Poudre River	224	490[9] (450)	210[12]	188	6,440	4,662,560	76	200,000
Lodgepole Creek[6]	NA	189[10] (NA)	14[13]	189	367	265,708	14	23,900
Crow Creek[6]								
North Plains Tributaries								
South Plains Tributaries	411[7]	455[11] (450)	156[14]	436	10,668	7,723,632	48	335,411
South Platte River-Plains								
Basin Total	814	4,464 (3,000)	1,270	1,213	41,875	30,317,500	347	1,305,591

Table 2-3 Continued.

1/The sub-basin heading designates the source of water for these rights. For direct flow and storage rights these may be rivers, streams, creeks, gulches, draws, springs, seeps, sloughs, underflows, or wastes; for wells it is underground water. These terms have all been legally defined by the courts.
2/Wilkinson, 1974, for data pertaining to Colorado water rights and SUBR, 1959, for data pertaining to water rights in Nebraska and Wyoming. Direct flow rights as a category includes ditches as well as surface water pumps and pipelines.
3/USBR, 1959. Does not include CBT east slope project facilities water rights to the native surface water runoff of the Basin.
4/Does not include the drainage area of the lower portions of Cherry, Bear, and Clear Creeks which are encompassed by this sub-basin.
5/Includes the entire drainage area, not just the designated sub-basin drainage area.
6/Includes the drainage area of these Creeks in Wyoming and Nebraska, not just the designated sub-basin drainage area.
7/Does not include wells in the drainage area of Crow Creek in Wyoming.
8/Includes some 480 spring rights.
9/118 of these direct flow rights are located in Wyoming. They are worth 241 cfs from Boxelder and Dale Creeks, tributaries of the Cache La Poudre River.
10/106 of these rights (worth 157 cfs) are located in Nebraska and the remainder are for the waters of Lodgepole Creek in Wyoming. There are no direct flow rights decreed for water from Lodgepole Creek in Colorado.
11/119 of these rights (worth 953 cfs) are for surface water from the Crow Creek sub-basin in Wyoming.
12/One of these rights (worth 41 acre-feet) is for water from the Cache La Poudre River drainage in Wyoming.
13/5 of these rights (worth 21,500 acre-feet) are located in Nebraska and the remainder are for the waters of Lodgepole Creek in Wyoming. There are no storage rights decreed for water from Lodgepole Creek in Colorado.
14/22 of these rights (worth 15,870 acre-feet) are for surface water from the Crow Creek sub-basin in Wyoming.
15/Includes Cherry Creek Lake whose storage rights (two; worth 15,580 acre-feet) were not included in the USBR 1959 compilation.

back to the surface flows where it is used again and again—or, in the Plains sub-basin, it may be pumped. In this manner, water users with decrees for several times the actual volume of water available are all satisfied as each passes on a residual for further consumptive by a junior appropriator. However, even accounting for this fortuitious reuse, the system is overappropriated.

Leonard Rice Consulting Water Engineers, Inc. made a study of the operation of the South Platte River for the 1952-1972 period with particular emphasis on the relation of calls affecting water District 23 to monthly runoff at key gaging stations (Beck, 1974). The effect of priority administration of water rights in South Park was evaluated by reviewing the call records maintained by the Office of the State Engineer. These records show the date and priority of ditches that place a call for water on the South Platte and its tributaries within Division I. The records also show which water districts are subject to the call and the period of time the call is in effect. The call records for 1952-1972 were used to determine the number of days various priorities were called out for each month of the year. From these data equations were developed to compute the average percent of time a right will be called out in terms of the priority date of the right. The analysis showed that a right appropriated in 1861 would virtually never be called out, whereas a right with an appropriation date of 1875 would be called out 34 percent of the time in May and 25.5 percent of the time in June.

The more recent priority date of a right, the more it depends on above average runoff. A brand new water right might have to wait several years at a time for a wet enough year for it to be exercised.

Of course, this would depend on when the right was to be used. During the low flows in the summer which is also the period of peak irrigation demands, there would be no chance for a new right to have any water, since calls by the senior rights would deplete the stream. During the low flows of winter a recent water right would also yield nothing. It would again be at the bottom of the peaking order since reservoirs would be filling, based upon their storage rights. In addition, prior municipal direct flow rights would also be operating at this time as they are continuous over the year. Therefore, only during the high spring flows would there be any chance for a new appropriator to have water. If the new right was a storage appropriation, then diversions could be made. As we shall see, the only potential development left of the basins raw water supplies is in fact through new reservoirs, and several have been proposed.

One of the results of the extensive reservoir and canal construction has been to expose the basins surface water runoff (and foreign water imports) to an increased surface area. As shown in Table 2-4, this has resulted in the annual evaporation of 229,052 acre-feet, which is equivalent to 16.9 percent of the average annual native surface water runoff in the basin.

Direct Diversion Structures - The existing canals, ditches, laterals, feeders, and pipelines in the South Platte River basin form a complex system of water transport and distribution, with a total length of thousands of miles. Those structures which connect with a stream are termed here, direct diversion structures. The majority and the most important direct diversion structures in the basin are located in the plains, along the Front Range tributaries, and along the South Platte River mainstem to the Colorado-Nebraska state line.

Table 2-4 Surface Water Areas and Evaporation from Reservoirs, Lakes, Streams, and Canals in the South Platte River Basin (Meyers, 1962).

		Principal reservoirs and regulated lakes		Other lakes over 500 acres		Principal streams and canals		Small ponds and reservoirs		Small streams		Total for all classes	
River Basin	State	Effective area (acres)	Annual evaporation (acre-ft)	Effective area (acres)	Annual evaporation (acre-ft)	Effective area (acres)	Annual evaporation (acre-ft)	Effective area (acres)	Annual evaporation (acre-ft)	Effective area (acres)	Annual evaporation (acre-ft)	Effective area (acres)	Annual evaporation (acre-ft)
South Platte River	Wyoming	63	194	0	0	0	0	637	2,086	759	2,564	1,459	4,844
	Colorado	29,649	97,524	227	720	4,302	15,588	13,664	44,365	4,396	15,106	52,238	173,303
	Nebraska	0	0	0	0	4,741	18,750	7,935	31,100	274	1,055	12,950	50,905
	Total	29,712	97,718	227	720	9,043	34,338	22,236	77,551	5,429	18,725	66,647	229,052

There are approximately a total of 4,165 absolutely and conditionally decreed direct diversion rights held in the South Platte River basin. The previous Table 2-3 shows their approximate distribution by sub-basin. This table also shows that the 1,312 major direct flow rights in the basin have been decreed a total of 41,875 cfs which is equivalent to an annual volume of about 30.32 million acre-feet.

Direct flow rights are granted to ditches, pipelines, and surface pumps which, in addition to surface flows may also divert water from seeps, springs, etc. Table 2-3 shows that there are approximately 3,000 ditch rights absolutely and conditionally decreed in the South Platte River Basin which are supported by the surface waters of its rivers, streams, creeks, gulches, and draws and springs, seepages, sloughs, underflows, and wastes.

Table 2-5 shows the 48 major diversion structures with points of diversion on the mainstem of the South Platte in downstream order by county. This table also shows that their total 1973 diversions amounted to 1,005,600 acre-feet.

Table 2-6 shows the total 1970 diversions in the South Platte River basin by sub-basin and by use sector. This table shows that 542 ditches diverted a total of 3,982,653 acre-feet of surface water in 1970. This total includes 237,376 acre-feet of imported water and 126,785 acre-feet of reservoir releases. The reservoir releases were comprised of water stored in the spring of 1970 water year and some which had been stored from a previous water year. Therefore the remainder 3,618,492 acre-feet, represent the direct use of the basins native surface water runoff plus return flows. Not included in the total diversions are 244,878 acre-feet that was diverted by offstream reservoirs and held in storage or which subsequently evaporated or seeped into the ground.

Table 2-5 The Major Diversion Structures with Points of Diversion on the Main Stem of the South Platte (Toups, 1975).

Name	Location of Point of Diversion (county)	1973 Diversion (acre-feet)	Associated Reservoir Storage
Beery Ditch	Park	N.A.	N.A.
Harrington & Richards Ditch	Park	N.A.	N.A.
Aurora Ramparts Tunnel	Douglas		Aurora Ramparts Reservoir
Denver Municipal Aqueduct	Douglas		Martson Lake
Kastler Treatment Plant Pipeline	Douglas	183,000	None
Platte Canyon Ditch	Douglas		Platte Canyon Reservoir
Highline Ditch	Douglas		None
Brantner Ditch	Adams	11,900	None
Brighton Ditch	Adams	7,400	None
Fulton Ditch	Adams	23,000	Mose Davis Lake
Highland (Plumb) Ditch	Weld	N.A.	None
Lower Latham Ditch	Weld	32,000	None
Union Ditch	Weld	18,700	Lower Latham Res. (5,755 A.F)
Farmers Independent Ditch	Weld	12,600	None
Evans #2 Ditch	Weld	25,600	Milton Lake (43,147 A.F)
Lupton Bottom Ditch	Weld	15,500	None
Meadow Island Ditch #2	Weld	8,300	None
Platteville Ditch	Weld	17,300	None
Western Ditch	Weld	14,900	None
Jackson Lake Inlet	Weld	18,800	Jackson Lake (35,629 A.F)
Bijou Canal	Weld	24,800	Bijou Res. (9,183 A.F)
Bijou #2 Inlet	Weld	11,700	Bijou Res. (9,183 A.F)
Riverside Direct	Weld	20,900	Riverside Res. (57,507 A.F)
Riverside Inlet	Weld	58,600	Riverside Res. (57,507 A.F)
Empire Inlet	Weld	48,900	Empire Res. (37,710 A.F)
Empire Direct	Weld	21,300	Empire Res. (37,710 A.F)
Prewitt Inlet	Morgan	45,600	Prewitt Res. (32,300 A.F)

Table 2-5 Continued

Name	Location of Point of Diversion (county)	1973 Diversion (acre-feet)	Associated Reservoir Storage
North Sterling Inlet (Canal Union)	Morgan	99,100	North Sterling Res. (73,920 A.F)
Snyder Canal	Morgan	N.A.	None
Tremont Canal	Morgan	N.A.	None
Lower Platte & Beaver Canal	Morgan	21,800	None
Duel and Snyder Ditch	Morgan	N.A.	None
Upper Platte & Beaver Canal	Morgan	27,800	None
Fort Morgan Canal	Morgan	32,100	None
Weldona Valley Ditch	Morgan	27,300	None
North Sterling Inlet Canal	Morgan	76,000	North Sterling Res. (73,920 A.F)
Bravo Ditch	Logan	N.A.	None
Farmers Pawnee Canal	Logan	20,500	None
Harmony Seep #2	Logan	N.A.	None
Harmony #1 Ditch (Julesburg Reservoir Inlet)	Logan	21,000	Julesburg Res. (28,178 A.F)
Iliff & Platte Valley Ditch	Logan	13,500	None
Lowline Ditch	Logan	5,100	None
Schneider Ditch	Logan	6,100	None
South Platte Ditch	Logan	8,100	None
Springdale	Logan	N.A.	None
Sterling #1 Ditch	Logan	19,100	None
Peterson Ditch	Sedgwick	7,300	None
South Reservation	Sedgwick	N.A.	None
Total	—	1,005,600	—

Note: Some of these diversions were put to storage and not used in the 1973 water year. Some were of foreign origin, i.e., CBT project allotments. In addition, some of these diversions included return flows from water usage pustream. The Aurora Ramparts Tunnel, the Denver Municipal Aqueduct, and the Kastler Treatment Plant Pipeline are the only municipal diverters on this list. The rest of the diversions were used for irrigation. A map of the counties in the South Platte River basin can be seen in the prior Figure 1-3.

Table 2-6 Total Surface Water Diversions in the South Platte River Basin During the 1970 Water Year.

Sub-basin	Number of Ditches Reporting Diversions[1/]	Surface Water Diversions by Use Sector (acre-feet)[2/]			
		Agricultural	Municipal	Industrial	Total
North Fork South Platte	0	0	0	0	0
South Platte River-Mountains	226 (South Platte River-Mountains, Plum Creek, Cherry Creek)	134,304	132,176	0	266,480
Plum Creek		4,949	0	0	4,949
Cherry Creek		8,795	0	0	8,795
South Platte River-Transition	86 (South Platte River-Transition, Clear Creek, Bear Creek)	511,931	86,578	63,057	661,566
Clear Creek		4,644	2,200	15,191	22,035
Bear Creek		1,054	2,100	0	3,154
Boulder Creek	62	108,493	17,894	51,876	178,263
Saint Vrain Creek	45	125,610	11,241	2,613	139,464
Big Thompson River	37	229,054	9,792	1,007,715	1,246,561
Cache La Poudre River	28	493,526	29,048	8,854	531,428
Crow Creek	58[3/] (Crow Creek through South Platte River-Plains)	60,005	8,811	0	68,816
Lodgepole Creek		43,023	0	0	43,023
North Plains Tributaries		1,090	0	0	1,090
South Plains Tributaries		50,000	0	0	50,000
South Platte River-Plains		749,414	0	7,615	757,029
Basin Total	542	2,525,892	299,840	1,156,921	3,982,653

1/Division No. 1 Water Commissioners, 1970. These ditches were responsible for the bulk of the surface water diversions shown in the following three columns.

2/Authors personal files and project notes developed for the study. These figures include diversions of imported foreign water (237,376 acre-feet), native surface water runoff, and return flows. In addition, they include 126,785 acre-feet of diversions from reservoirs which had been stored in the spring of the 1970 water year and in subsequent water years. Not included are 244,878 acre-feet that was diverted by off stream reservoirs and held in storage or which subsequently evaporated or seeped into the ground. Agricultural and Municipal diversions include some diversions made in the sub-basin but applied elsewhere. Municipal diversions include some industrial diversions when the municipality is the contracted supply entity. Industrial diversions include diversions by hydroelectric power plants.

3/The number of ditches reporting diversions in 1970 for these sub-basins only pertains to their drainage area in Colorado.

Most of the ditches in the South Platte River basin were constructed with limited funds during periods of rapid growth. Those carrying water to the most productive areas and for the lowest cost were constructed first, with no plan for comprehensive or overall development. With additional growth, more ditches were added to serve lands at a slightly higher elevation. Frequently, lands in the same elevation as those already developed but further from the point of diversion required increased canal capacities or new canals. Some ditches are separated at the point of diversion by only a concrete wall. The result is that three or four canals exist where only one would suffice.

This piece meal development has required several times as much main canal and rights-of-way as needed, which results in more operation and maintenance costs, and more seepage and water logged lands than would occur if the development were more unified. A multiplicity of water rights and complicated exchanges makes administration difficult. Some canals are larger than their decreed capacity as storage rights are also exercised through them; they were built larger to reduce the time required to fill reservoirs. Some other ditches are smaller than their decreed capacity as they were not enlarged for later decrees.

Most of the systems were built by cooperative or community effort with interested individuals contributing much of the necessary labor. The present form of ownership is usually a stock company with users as shareholders. Funds for the necessary maintenance or upkeep of the system are provided by assessments or a per-share basis. To keep these assessments low, maintenance has been kept to an absolute minimum in most cases. Usually only enough maintenance is performed to enable the distribution of water during the coming season.

As a result, the condition of the systems is not good; many structures are inadequate and some have been left isolated in the middle of a channel by widening canals; serious bank sloughing, deepening and general erosion are evident; numerous large trees use water and interfere with operations; also leaky structures of ditches are ignored, resulting in seepage and water logging of adjacent lands.

In contrast to these piecemeal systems, the more modern projects in the basin were planned comprehensively in advance of construction. Main channels and laterals were placed where needed and structures were carefully designed. Future surface and sub-surface drainage needs were considered. Canals were lined where necessary to prevent excessive seepage and they were designed with grades that would prevent excessive velocities and erosion.

Storage Facilities - According to Toups (1975) there are presently 370 reservoirs in the South Platte River basin with capacities in excess of 500 acre-feet. There are about 1,256 absolutely and conditionally decreed storage rights held in the basin. Table 2-3 shows their approximate distribution by sub-basin. The total absolutely decreed storage capacity in the basin is in excess of the total available physical capacity by approximately ten percent (Clark, 1976). This is due primarily to sedimentation.

Table 2-7 lists the largest reservoirs in the South Platte River basin within Colorado. In aggregate these 150 reservoirs provide 2,129,742 acre-feet of storage which represents more than 90 percent of the total storage capacity available in the basin (Toups, 1975).

Table 2-7 Major Reservoirs in the South Platte River Basin (within Colorado) with Capacities Greater Than 500 Acre-feet (Toups, 1975).

County[1/]	Name of Reservoir	Capacity (af)	County	Name of Reservoir	Capacity (af)
Adams	Barr Lake (Oasis)	32,150	Boulder (Cont.)	Left Hand Valley	10,575
	Bootleg	6,190		Leggett (Harlow)	971
	Hidden Lake	3,242		Marshall Lake	10,462
	Prospect	7,660		Mesa	946
	Terminal	3,411		Panama	616
				Pleasant Valley	2,532
Arapahoe	Cherry Creek (Flood Control)	246,084		Reservoir No. 22	41,920
				Silver Lake	3,987
	Clark County No. 2	1,150		Six Mile	10,850
	Englewood	6,000		Twin Lakes	17,080
	Kenwood	10,000		Valmont	13,931
	Noonan No. 2	2,662			
	Quincy	2,800	Boulder/ Larimer	Boulder	7,344
Boulder	Albion Lake	1,072			
	Allen Lake	569	Clear Creek	Altura (Duck Lake)	4,393
	Barker Meadow	12,125		Cabin Creek	1,827
	Base Line	5,300		Fall River	890
	Billings, Arbuckle	966		Georgetown	760
	Boulder	17,400		Loch Lomand	8,746
	Button Rock	15,458		Upper Urad	700
	Clover Basin	596			
	Foothills	4,238	Douglas	Castlewood	3,434
	Gold Lake Dam	1,343		Franktown Parker	678
	Gross	43,065		Lake Cheesman	79,064
	Hayden	502		Platte Canyon	941
	Highland No. 2	3,757			
	Hillcrest	1,811	Elbert	Agate	10,446
	Left Hand Park	1,528			

Table 2-7 Continued.

County[1/]	Name of Reservoir	Capacity (af)	County	Name of Reservoir	Capacity (af)
El Paso	West Cherry Creek	567	Larimer	Curtis Lake	3,206
	Det. No. 7		(Cont.)	Donath Lake	1,148
				Douglas	8,947
Jefferson	Bergen	907		Dowdy Lake	5,490
	Bowles Reservoir No. 1	1,910		Dry Lake	1,450
	Evergreen	669		Flatiron	760
	Francis Smart			Fossil Creek	11,508
	(Rocky Flats)	617		Halligan	6,428
	Great Western	6,917		Handy (Welch)	4,640
	Leydon	1,500		Horseshoe (7 Lakes)	
	Long Lakes	1,346		No. 2	8,315
	Marston Lake	17,213		Horsetooth	151,800
	Pollay A. Dean	512		Hourglass (Big Beaver)	1,694
	Ralston	11,272		Lake Estes	3,100
	Soda Lakes	660		Lake Loveland	41,320
	Standley Lake	42,380		Long Draw	12,200
	Ward No. 1	533		Long Draw (Grand)	4,270
	Wellington	4,399		Lon Hagler Det. & Irr.	5,032
				Loveland	630
Larimer	Barnes Meadow	2,349		Mariano	41,320
	Berthoud	516		Mary's Lake	900
	Black Hollow	8,585		Mattingly	570
	Boyd Lake	58,524		Milton Seaman	5,008
	Buckhorn	12,443		Mirror Lake	823
	Cameron Pass	814		North Poudre No. 2	3,910
	Carter Lake	112,200		North Poudre No. 3	3,441
	Chambers Lake	8,824		North Poudre No. 4	1,674
	Clarks Lake	1,720		North Poudre No. 5	8,413
	Cobb Lake	34,226		North Poudre No. 6	9,986
	Comanche	2,629		North Poudre No. 15	5,526

Table 2-7 Continued.

County[1/]	Name of Reservoir	Capacity (af)	County	Name of Reservoir	Capacity (af)
Larimer Cont.)	Panhandle	1,043	Park (Cont.)	Lost Park	45,900
	Park Creek Dam	7,343		Montgomery	5,080
	Peterson Lake	1,183		Tarryall	13,135
	Peterson Lake	892			
	Rattlesnake	2,180	Sedgewick	Julesburg (Jumbo)	28,178
	Reservoir No. 4	1,311			
	Reservoir No. 8	10,524	Washington	Prewitt	32,300
	Sheep Creek	1,815		Williams McCreery	17,593
	South Gray	1,142			
	Terry Lake	8,145	Weld	Coalbank Watershed	2,101
	Timnath (Cache La Poudre)	10,119		D.A. Lord No. 4	3,449
				Horse Creek	29,356
	Warren Lake	2,295		Hudson	11,878
	Wasson	789		Klug No. 3	715
	Water Supply No. 3	4,750		Klug No. 3	55,935
	Water Supply No. 4	996		Lovella/Wilkinson Lake	6,764
	Worster (Eaton)	2,040		Lower Latham	5,755
Logan	Jumbo	2,511		Milton Lake	43,147
	North Sterling	73,920		Riverside	57,507
	Point of Rock	80,588		Union	12,739
				Windsor	15,620
Morgan	Badger	9,879		Wild Horse	810
	Jackson Lake	35,692			
	McIntyre No. 1	879	Weld, Morgan	Empire	37,710
	Kiowa	8,314	TOTAL ACRE-FEET		2,129,742
Park	Antero	15,878			
	Elevenmile Canyon	97,779			
	Lidderdale Lake	735			

1/The counties located in the South Platte River Basin are shown in Figure 1-3.

Table 2-8 shows the amounts in storage during the 1970 water year in 338 of the basin reservoirs. Some of the water in storage was imported from other river basins.

The existing storage facilities in the basin can be grouped in three broad categories; offstream, onstream, and project reservoirs.

Offstream reservoirs were the first to be constructed; the majority were built during the period 1880-1930. Most are used for the storage of agricultural water supplies. Presently, very few good sites for offstream reservoirs remain in the basin. The general location of these reservoirs is in the plains where they form a patchwork between the canyon mouths of the Front Range tributaries and their confluence with the South Platte. In addition, a number of others divert water from the mainstem South Platte and are located on both sides from its canyon mouth to the Colorado-Nebraska state line. These reservoirs occupy shallow offstream depressions, with depths ranging from five to 50 feet and capacities ranging from a few acre-feet to more than 50,000 acre-feet. Because of their large areas and their locations in the plains evaporation and seepage losses are high.

Table 2-9 shows the assumed operation of the major offstream reservoirs in the basin during the 1970 water year. Figure 2-1 displays this information graphically.

The period of onstream reservoir construction in the South Platte River basin began in the early 1900's and continues to the present. The majority are located in the mountains; they impound water by damming a stream canyon or valley. Most of these reservoirs are used for municipal water supply. Because of their mountain location, evaporation and

Table 2-8 Amounts in Storage During the 1970 Water Year in the Major Reservoirs of the South Platte River Basin

Sub-basin[1/]	Number of Reservoirs Reporting Contents[2/]	Total Acre-feet in Storage[2/]		
		November 1, 1969	May 1, 1970	October 31, 1970
North Fork South Platte	2	N.A.	N.A.	4,400
South Platte River-Mountains	7	216,716	223,651	214,467
Plum Creek	1	N.A.	N.A.	N.A.
Cherry Creek[3/]	1	15,491	15,936	14,242
South Platte River-Transition[4/]	57	53,526	78,821	64,286
Clear Creek[3/]	69	75,649	96,502	83,252
Bear Creek[3/]	17	6,685	9,576	7,504
Boulder Creek	45	87,674	88,296	83,591
Saint Vrain Creek	63	51,703	55,820	54,701
Big Thompson River	20	125,937	204,817	168,352
Cache La Poudre River	47	165,469	266,984	203,307
Crow Creek[5/]	1	492	445	140
Lodgepole Creek[5/]	0	0	0	0
North Plains Tributaries	0	0	0	0
South Plains Tributaries	1	0	0	0
South Platte River-Plains	7	135,307	253,929	121,560
Basin Total	338	934,649	1,294,777	1,019,802

1/For reservoirs storing native surface water runoff, the sub-basin heading identifies their source. For reservoirs storing imported foreign water, the sub-basin heading identifies their location.
2/Division No. 1 Water Commissioners, 1970.
3/Includes the entire drainage area, not the designated sub-basin drainage area.
4/Does not include the lower portion of Clear, Bear, and Cherry Creeks drainage areas located in this sub-basin.
5/The data is only for the portion of the drainage areas of these sub-basins within Colorado.

Table 2-9 Assumed Operation of the Major Offstream Reservoirs in the South Platte River Basin during the 1970 Water Year.1/

Sub-basin	Inflows (acre-feet)	Outflows (Acre-feet)			Net Storage Change (acre-feet)
		To Use	Evaporation	Seepage	
North Fork South Platte	0	0	0	0	0
South Platte River-Mountains	0	0	0	0	0
Plum Creek	0	0	0	0	0
Cherry Creek	0	0	0	0	0
South Platte River-Transition	102,239	27,918	25,715	29,649	+ 18,957
Clear Creek	0	0	0	0	0
Bear Creek	0	0	0	0	0
Boulder Creek	13,378	9,068	3,685	2,676	- 2,051
Saint Vrain Creek	10,377	591	4,632	2,075	+ 3,079
Big Thompson River	32,284	2,715	12,203	6,457	+ 10,909
Cache La Poudre River	82,200	21,697	17,800	16,400	+ 26,303
Crow Creek	0	0	0	0	0
Lodgepole Creek	0	0	0	0	0
North Plains Tributaries	0	0	0	0	0
South Plains Tributaries	0	0	0	0	0
South Platte River-Plains	139,000	64,796	48,058	39,893	- 13,747
Basin Total	379,478	126,785	112,093	97,150	+ 43,450

1/Because of the lack of data, much personal judgement was involved in determining the data presented in this table. It was known that the average yield of the storage rights of the offstream reservoirs in the Cache La Poudre River Sub-basin is 60,000 acre-feet/year (USBR, 1966). These reservoirs are generally at their highest levels by the end of June. Calls on these reservoirs while they were filling were assumed negligible. The 1970 surface water runoff of the Cahce La Poudre River Sub-basin was 57% above normal and it was assumed that the yield of these storage rights (called inflows) would be likewise affected. The offstream reservoirs in this sub-basin are representative of those throughout the basin. Their estimated 1970 inflows (yield of rights) compared to their partial 1970 inflows given by the State Engineer (May 1, 1970 contents minus November 1, 1969 contents), gave an index to apply to each sub-basin with major offstream reservoirs in estimating how much more water was yielded by their rights after May 1. Total outflows from the offstream reservoirs was then the contents after the 1970 yield minus the end of year contents (October 31, 1970) given by the State Engineer. This outflow was then apportioned to evaporation, seepage, and reservoir releases. The following was also known about the offstream reservoirs in the Cache La Poudre Sub-basin (USBR, 1966):

1. Average annual evaporation depletes total storage by roughly 11%.
2. 20% of the diversions from the stream to storage seep into the ground.

Assuming again that the Cache La Poudre reservoirs were representative in geometrical configuration (which affects the evaporation relationship with storage amounts) and have representative feeder canals (which affects seepage losses), the above percentages were applied to each sub-basin. The following were exceptions; Bittinger, 1968 gives a seepage loss of 29% for diversions to storage in the South Platte River-transition reach and Hurr, et al., 1975, 28.7% for the South Platte Plains. Subtracting the evaporation and seepage losses from the outflows gave what was assumed to be reservoir releases to agriculture. The net storage change was computed by subtracting the 1st of year contents from the end of year contents.

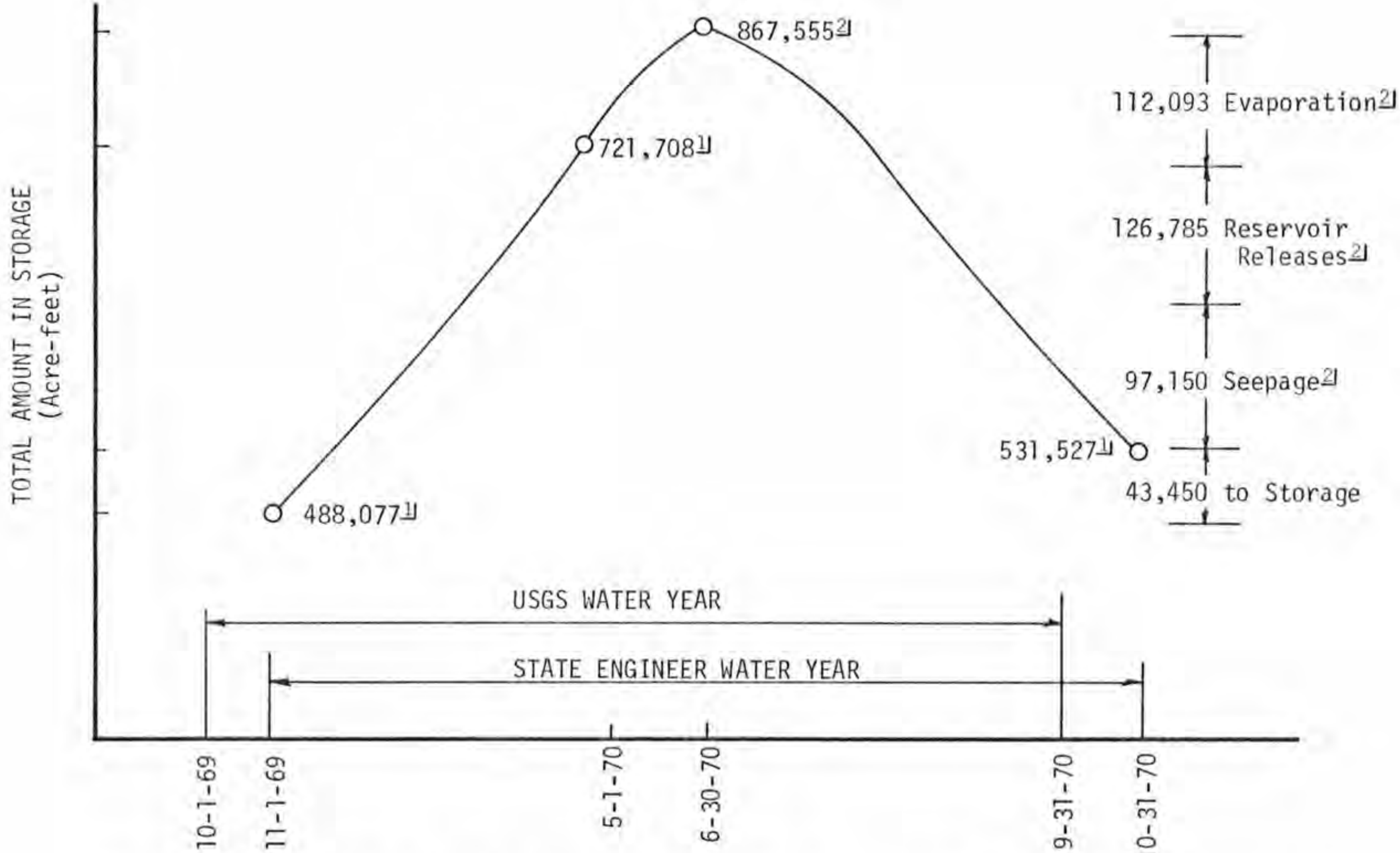


Figure 2-1: Aggregate storage history of the major offstream reservoirs of the South Platte River Basins during the 1970 water year (from data in Table 2-9)

[1]Division I Water Commissioners, 1970

[2]Determined by the assumptions presented in footnote [1] Table 2-9

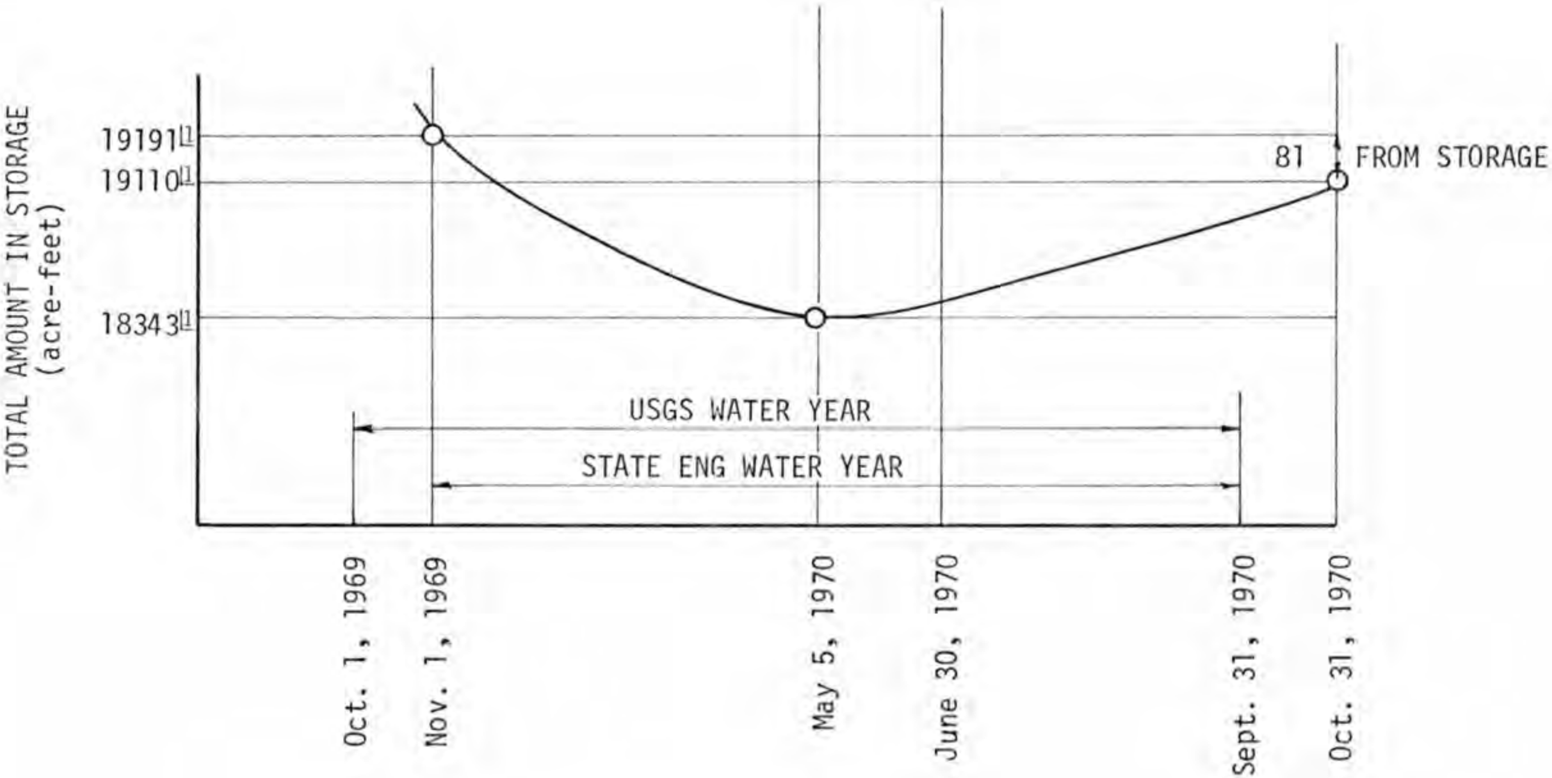


Figure 2-2: Storage History of eleven on-stream mountain reservoirs in the Saint Vrain Creek Sub-basin during the 1970 water year.

[1]Division 1 Water Commissioners, 1970.

seepage losses are much less than for an equal volume stored on the plains.

From the records of the State Engineer, the storage history of these reservoirs was found to be quite different from that of the off-stream reservoirs. Figure 2-2 is a graphical depiction of the total contents in 11 mountain reservoirs in the Saint Vrain Creek sub-basin during the 1970 water year. The largest of these 11 reservoirs was Button Rock Reservoir, which is owned by the City of Longmont. Throughout the 1970 water year it consistently accounted for 70 to 75 percent of the total storage of the 11 reservoirs. From this graph it can be seen that the onstream mountain municipal reservoirs do not follow the distinct seasonal fill-draw pattern of the offstream irrigation reservoirs. One of the principal reasons is that the municipalities which are the most dominant owners of these reservoirs, have continuous demands throughout the year.

Some of these mountain reservoirs also store imports from trans-basin diversion structures. For all of the onstream reservoirs in the basin whose records were available, a total of 12,341 acre-feet was put in storage during the 1970 water year. It was estimated that 10,657 acre-feet was lost to evaporation from these reservoirs in that water year. Seepage losses were assumed negligible.

The final category of reservoirs in the South Platte River basin are project reservoirs. These are linked with one or more of the mega-sized transbasin diversion structures. Their main functions are to regulate and store imports but on occasion they also store some of the native surface water runoff. There are two sets of these reservoirs in the basin; those associated with the Colorado Big Thompson project and those associated with the Moffat project. The CBT project reservoirs store irrigation water mostly while those of the Moffat project store municipal water. These projects also have associated reservoirs on the west flopw ehich serve mainly to collect water from import and to provide a replacement water. The project reservoirs on the east slope serve as distribution nodes, in addition to their role in providing storage. The adjunct services these reservoirs provide for the transbasin diversion structures can be seen more clearly in Figures 3-3 and 3-4.

2.1.3 *Existing Development of the Groundwater Supplies* - Most of the present groundwater pumping in the South Platte River basin is from the river alluvium and uprising terrace deposits along the mainstem of the South Platte River and its tributaries below Denver. Above Denver there is very little groundwater development except in the Cherry Creek sub-basin. Here, about 2,600 acres of land are irrigated with supplies derived almost exclusively from 50 wells (USBR, 1959). Although large quantities of water are stored in other formations such as the Ogallala and Brule, pumping from these aquifers for irrigation has not proven economical to any great extent.

According to Toups (1975) an average of 700,000 acre-feet of water was pumped from the basins alluvial aquifers in the 1950's and 1.25 million acre-feet was pumped in the 1960's. In 1970, it was found that a total of 1,589,830 acre-feet of water was pumped from the ground beneath the South Platte River basin, (Janonis and Gerlek, 1977, Janonis, 1977 and Patterson, 1977). The use of groundwater by sector was as follows:

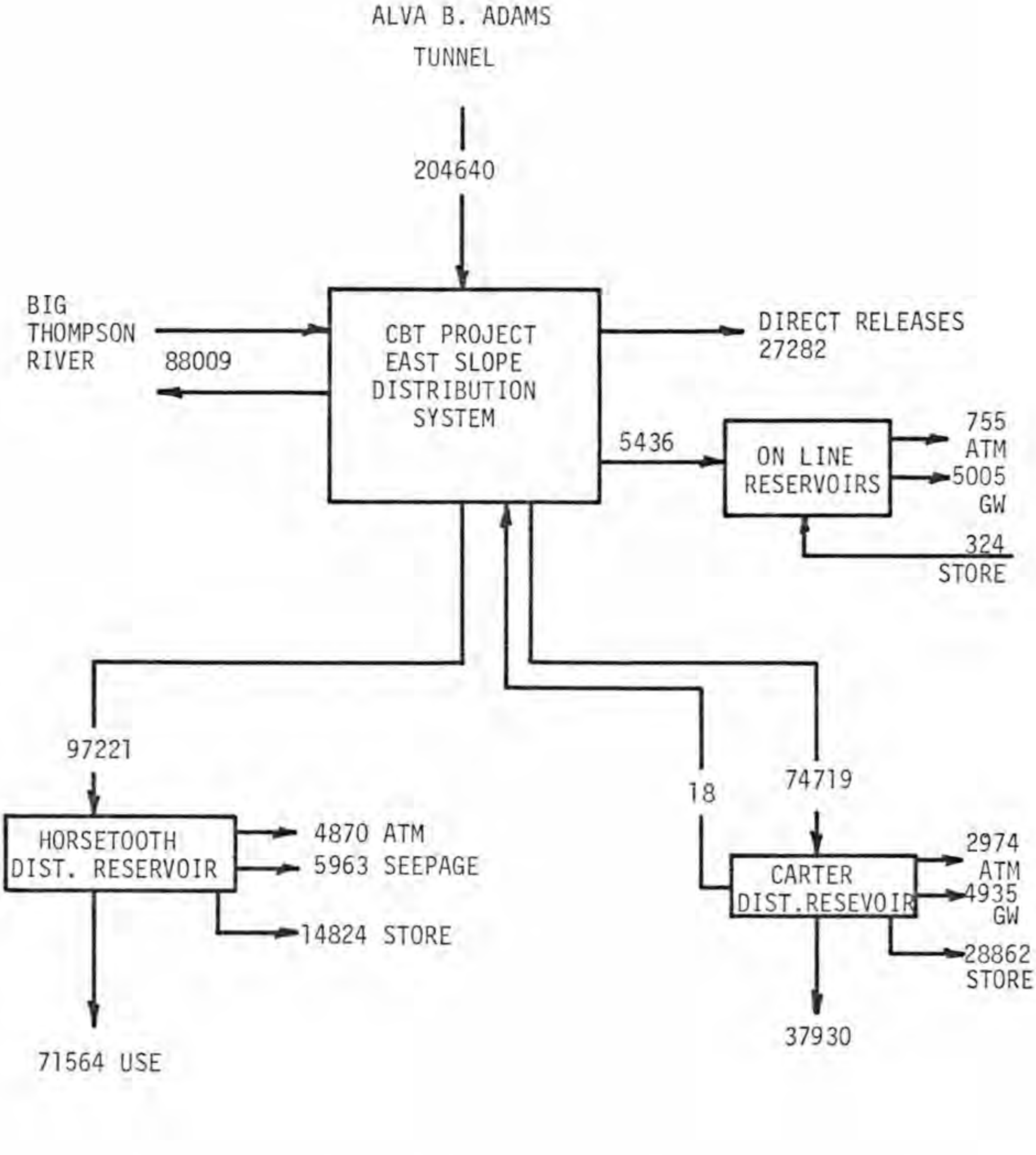


Figure 2-3: Project Reservoirs in the South Platte River Basin; East Slope CBT Project Storage Facilities and their 1970 water balance in acre feet.

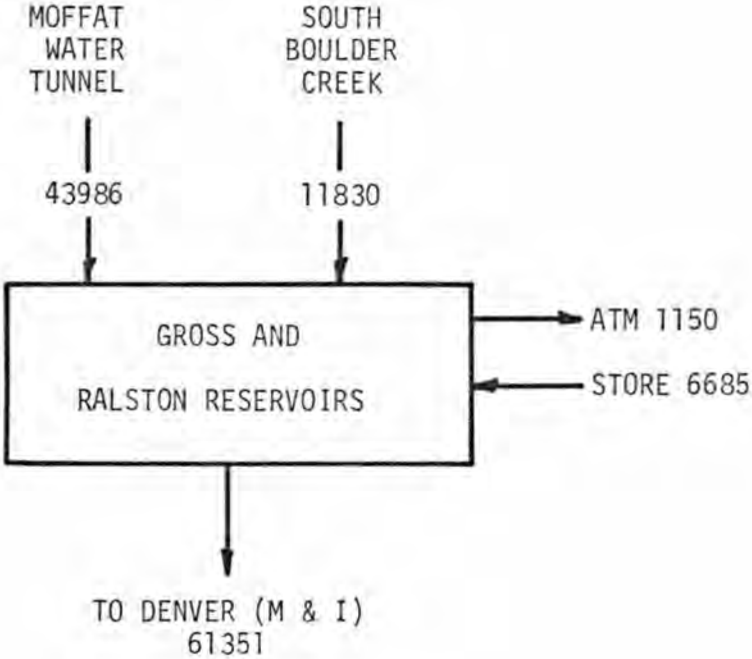


Figure 2-4: Project Reservoirs in the South Platte River Basin; East Slope Moffat Project Storage Facilities and their 1970 water balance in acre feet.

Acre-feet	Percent	Sector
1,471,940	92.6	Agriculture
83,170	5.2	Municipalities
34,720	2.2	Industries
1,589,830	100.00	Total

2.1.4 *Potential for Further Development of the Surface Water Runoff* - The surface water runoff in the South Platte River basin study area averages 1,355,919 acre-feet per year. By interstate compact, Colorado must let 47,166 acre-feet of this runoff flow into Nebraska each year (if it is available under certain stipulations). A highly complex water resources system has developed in the study area to allow for the use of the remainder. Its physical configuration and administrative institutions are a direct result of the natural availability of this water and of the needs and demands that have come to be placed on it.

However, this water is overappropriated. This is evidenced by the South Plattes long history of importing water from other river basins. The amount of water presently diverted from foreign watersheds by South Platte water users is equivalent to approximately one third of the average annual native surface water runoff in the basin. In addition, the amount of groundwater used in the basin on the average is almost equal to the amount that appears as runoff.

However, while the surface water allocated to the study area is diverted for use several times over, it is not all consumptively used. The historical outflow at the Colorado-Nebraska state line currently averages 351,752 acre-feet per year. This means that approximately 304,586 acre-feet per year is still available, (by subtraction of

Nebraska's allotment). The main reason why this legally available water escapes from Colorado is because of a lack of storage capacity. As seen in Table 2-10, the bulk of this water leaves in the spring when the demands of the major direct flow users (irrigators) are at a minimum and river flows are highest.

Table 2-10 shows that in May of 1973 more than one half million acre-feet of potentially divertable water was lost.

Several well known (and controversial) storage projects have been proposed to capture some of this water. They are summarized in Table 2-11. In addition to the projects listed in Table 2-11 there are many other conditional direct flow and storage rights held in the basin. However, the outlook for these is quite uncertain as many not being as actively pursued.

There have been no major direct flow diversion projects proposed in the basin for a number of years. Again, Table 2-10 shows that there would be little water available for such a scheme if it were to involve agriculture. While there is still room for some additional storage further up in the basin (as seen by the proposals in Table 2-11) only a reservoir in the plains reach can take advantage of the return flows continually accruing here. This would be the purpose of the proposed Narrows project. In addition, the return flow could increase significantly in the future, as there are proposals to bring more water into the basin from the west slope.

Table 2-10 Historical Flows of the South Platte River at the Colorado-Nebraska State Line (U.S. Bureau of Reclamation, 1976).

Month	Recorded discharge of the South Platte by USGS Gaging Station #06764000 (acre-feet)		
	Average (1947-74)	Wet Year (1973)	Dry Year (1954)
Jan.	29,200	41,000	17,900
Feb.	32,000	53,200	14,300
March	33,100	54,500	15,300
April	29,600	94,700	6,700
May	60,400	528,100	4,200
June	83,500	217,800	1,700
July	20,200	20,900	1,000
Aug.	8,700	7,400	1,000
Sept.	9,300	48,300	1,400
Oct.	18,100	86,100	2,300
Nov.	21,900	57,600	3,500
Dec.	24,200	40,100	6,200
Annual Total	370,200	1,249,600	75,500
Compact Time Period total1/	220,750	960,250	17,150

1/As stipulated by the 1926 South Platte River Compact, Nebraska has a right to 120 cfs of the South Platte River between April 1 and October 15 of each year; this amounts to 47,166 acre-feet per year. This right has a priority over all Colorado diverters with adjudication dates Junior to June 14, 1897 in the "Lower Section" only (that reach of the South Platte River in Colorado between the Washington County line and the State line (Water District #64)).

Table 2-11 The Major Water Resource Projects Proposed for Development of the Remaining Surface Water Supplies of the South Platte River Basin.

Project Name	Proposed by	Location	Description	Potential yield[1/] (acre-feet)	Status
Spinney Mountain Project	City of Aurora	Main Stem South Platte just above Eleven Mile Canyon Reservoir	48,000 acre-foot reservoir to regulate, store, and maximize the yields of Auroras various water supplies. These include South Platte direct flow rights (purchased from irrigators in South Park), Colorado River Basin imports (delivered through the Aurora-Homestake Pipeline) and a Spinney Mtn. Storage appropriation (filed for in June of 1973).	1,410 to 3,723	Construction delayed indefinitely due to funding uncertainties
Two Forks Project	Denver Water Department and U.S. Bureau of Reclamation	Main Stem South Platte just down stream from the confluence of the North Fork of the South Platte	975,000 acre-foot reservoir for flood control, Hydro-electric power development, and recreation. Also would provide terminal storage for Denvers (1) present and future Colorado River Basin imports (through the Roberts Tunnel), (2) releases from upstream reservoirs, and (3) would facilitate storage out of priority by replacement with unused tributary flows and sewage effluent. Two Forks has two conditional storage decrees worth 336,368 acre-feet with priorities 1/18/1905 and 5/1/1926.	20,000	Indefinite hold
Gross Reservoir Expansion	Denver Water Board	South Boulder Creek (mountainous reach)	Existing gross reservoir has a capacity of 43,065 acre-feet and is used to store and regulate Colorado River Basin imports (through the Moffat water tunnel) and exercise 3 absolutely decreed storage rights worth 152,931 acre-feet all with priorities of 5/10/1945. Enlargement would further facilitate the above functions.	N.A.	Low priority relative to other Denver Water Board alternatives (i.e., increased at slope imports and Two Forks)

Table 2-11 Continued.

Park and Bradley Ranch Reservoir Projects	City of Boulder	Mountainous portion of the Boulder Creek Sub-basin	Would store water for municipal uses. Both Park and Bradley Ranch Reservoirs have conditional storage appropriations with priority dates of 3/4/1964; these are for 6,767 acre-feet and 15,062 acre-feet respectively.	N.A.	Negotiations are under way with the U.S. Forest Service to aquire lands needed for Park Reservoir. None of the real property necessary for the proposed Bradley Ranch Reservoir is owned.
Coffin Top Reservoir Project	Saint Vrain and Left Hand Water Conservancy District	South Saint Vrain Creek just above confluence with North Saint Vrain Creek near mouth of Saint Vrain Canyon	Three sizings are under consideration, 42,000 acre-feet 58,000 acre-feet, and 84,000 acre-feet with a tunnel diverting from North South Vrain Creek. Project would be a multipurpose endeavor by municipal, industrial, and agricultural interests and would provide for flood control. Would involve transfer to it of some existing rights. New storage rights for this project have been filed.	8,000 at largest proposed size 3,000 at the two smaller sizes	Economic analysis show that this project would not be feasible until 1983-90. However, a series of dry years could make earlier construction a possibility.
Geer Canyon Project	Saint Vrain and Left Hand Water Conservancy District	Near Canyon mouth of Left Hand Creek (tributary to Saint Vrain Creek)	Preliminary estimates are at 25,000 acre-feet for flood control and 25,000 acre-feet for agricultural use.	N.A.	Potential yields from storage appropriations will be assessed and total storage capacity will be adjusted accordingly after correlation studies concerning flow variations of Left Hand Creek are complete.

Table 2-11 Continued.

Idylwilde and Livermore Reservoir Project	U.S. Bureau of Reclamation	Idylwilde Reservoir on the mainstem of Cache La Poudre in mountains and Livermore on North-Fork Cache La Poudre	Idylwide Reservoir would have a capacity of 148,500 acre-feet and Livermore 394,500 acre-feet. Project as originally proposed would generate hydroelectric power and provide municipal, industrial, and agricultural water supply, flood control, and fish, wildlife, and recreation.	24,500	Serious questions arose conserning the market for the developed power within the confines of reclamation law and policy. It was determined that agriculture in the Cache La Poudre valley had existing facilities and supplies to meet 95% of its theoretical water requirements. Municipal water developed would be 3 times as expensive as available alternatives (i.e., CBT project water). Therefore, investigations were terminated in 1965.
Narrows Project	U.S. Bureau of Reclamation	Mainstem South Platte in plains reach (near Fort Morgan)	1,609,000 acre-foot reservoir to provide for flood control, supplemental irrigation water, potential future municipal and industrial demands, flat water recreation, and fish and wildlife.	102,000	This project has been proposed in one form or another since at least 1905. Construction was to begin in 1977, however, a mandate from the Executive Bureau of the federal government has required further economic, social, and environmental investigations.
Total amount of developed water proposed	-	-	-	151,110 to 158,223	-

1/The potential yield of these projects is defined to be the amount of presently unappropriated water that their water rights filings and conditionally decreed storage rights would yield. However, these individual project yields are subject to change if a project with a prior right is built downstream.

It is the opinion of the Colorado Water Conservation Board that if and when the Narrows Reservoir is built, most of the economically usable water in the South Platte River Basin allocated to Colorado will be depleted. While this may be the case now, at some time in the future, water demands may grow to the point where it becomes necessary to capture more of this outflow.

If this occurs, the location of an additional reservoir, in addition to the proposed Narrows Project will be critical. The further downstream such a reservoir is located, the more return flows it can store and regulate. This must be weighed against the fact that, barring an upstream pumping scheme, the further towards the state line a reservoir is located, the less Colorado can benefit. In this case too, there would be less downstream diverters to provide exchanges for upstream appropriators.

In addition, if located in the "Compact Control Area," a new reservoir will always be forced to give way to the "lower section" of the South Platte River, it may operate like the Narrows with senior Colorado diverters downstream as its only concern.

An additional constraint regulating the basins outflow in the future over and above the compact might be the salinity question. The basin must maintain its salt balance which requires certain minimum flows to flush out excessive build upts. It has been shown that there is still some surface water runoff left in the South Platte River basin (albeit it generally appears in the form of return flows). However, it will be much more expensive to develop and political community values, i.e., growth, the environment, etc., are becoming more dominant than in past years when growth was desired and the physical problem was the main concern. Thus several of the projects listed in Table 2-11 are highly controversial and may never come to fruition, and if they do the decisions will be political ones. In lieu of developing new supplies, there are other forms of meeting new demands which involve internal adjustments. Such adjustments would require new capital investment, implementation of current technology, and possibly needs of apex development. Some of these internal adjustments are discussed in the following sections.

Ditch Consolidation - Many benefits would accure if it were possible to reconstruct the existing distribution systems to conform to present canal and lateral system design standards. Canals and laterals could be shortened with resulting savings in operations and maintenance of canals, bridges, and other structures. Some rights of way could be converted to aerable land. Reductions could be effectuated in the acerage of seeped land, in the number of turn outs, and in water losses. However, such reconstruction would be very difficult, if not impossible to accomplish. Present state laws, present decrees, opposition to changes in point of diversion, ditch company differences, and the financial aspects all add to the difficulties.

The following is from the USBR, 1959:

Complete reconstruction of canal and lateral systems in most areas would be impractical and probably financially infeasible. In certain localities, however, it might be possible to combine certain ditches by enlarging the highest and eliminating the lower ditches or converting them to laterals. In order to test this theory a sample area north of Saint Vrain Creek and west of Longmont was selected for study. This particular area was chosen because good topographic maps were available.

The sample area contains eight canals on the north side of Saint Vrain Creek, heading within a distance of about four miles. Two small private ditches were ignored. The upper four canals are within a distance of 300 feet. Two of those canals use the same diversion dam. The eight canals have a combined length of about 100 miles and a combined capacity of approximately 900 second-feet. The individual canals range in capacity from 20 second-feet to 425 second-feet. Several of the canals are larger than their decreed capacity to reduce the time required for filling reservoirs. Several other canals carry less than total decreed capacities because they have not been enlarged for later decrees. All of the canals have steeper grades than necessary and are eroded badly in places. The eight canals supply laterals that have an estimated combined length of 200 miles and serve approximately 54,000 acres of land.

The initial sections of the five highest canals could be combined, utilizing a single diversions structure from Saint Vrain Creek. The lead section of the highest canal would have to be enlarged to carry the combined flows. The diversion structures and lead section of one of the lower canals could also be abandoned and the remaining section supplied by a lateral. Only minor modifications would be required on the remaining two canals. Existing laterals and turnouts along the existing main canals could generally be retained, supplied by new feeder ditches. The unused portions of the old supply canals could then be filled and returned to cultivation.

In general, reorganization of the systems in the same area would require construction of seven-one half miles of new canal, enlargement of eleven one half miles of existing supply canals, 34 miles of new laterals and feeder ditches, and the filling of about 48 miles of old canal.

The reorganization would reduce the length of main canals by about 48 miles. About 150 acres of land could be returned to cultivation. Operation and maintenance costs could be reduced somewhat, including the probable elimination of two ditch riders. The recorganization undoubtedly would result in a significant saving of water. No estimate was made of the extent of reduction of seepage and other losses because of the lack of measuring devices.

Although no computations were made of costs, benefits, or the repayment of the sample ditch reorganization, judgement indicates that a favorable benefit-cost ratio might be attained but that difficulty would be encountered in reimbursement. The study merely points out one way to utilize more efficiently the present water supply. As the demand for water increases, its value will also increase and procedures such as those studied will undoubtedly receive serious consideration.

In May 1956 the Department of Civil Engineering, Colorado A and M College (since renamed Colorado State University), Fort Collins, Colorado, issued a report entitled: "A Limited Study of Proposals for Water Development and Utilization in the Valley of the Cache La Poudre River." For that study a sample area was selected in the Poudre Valley. It contained about 18,000 acres of irrigated land served by four major canals and five smaller ditches having an aggregate capacity exceeding 1,800 second-feet. The study encompassed consolidation of canals and the transfer of plains reservoir storage upstream. It was concluded that such improvements in the sample area would reduce water losses from about 40 percent to approximately 12 percent, that the length of canals could be reduced by 25 percent, that 20 percent more land could be irrigated as a result of the conserved water, and that operation and maintenance expenses could be reduced significantly. However, the estimated construction costs exceeded the estimated direct benefits. The report suggested that further studies be made.

Results of the study by Colorado State University correlate closely with the results of the Bureau's study of the sample area near Longmont.

Plains Storage Consolidation - The plains reservoirs store surplus flood flows that otherwise might be wasted. In many instances, however, the reservoirs and associated supply canals are responsible for water logged lands and high water losses due to excessive evaporation and evapo-transpiration. Many of the reservoirs and long supply canals are relatively expensive because of high operation and maintenance costs. The following is from a 1959 USBR report:

> Theoretically, many of the plains reservoirs could be consolidated, with improved efficiency and conservation of water. An even more efficient approach would involve not only consolidation of the storage systems but transfer of the storage upstream no longer potential reservoirs with smaller surface areas which would reduce evaporation and transpiration losses.
>
> Obviously, consolidation and transfer of reservoir storage pose numerous problems. They are substantially the same problems that would be encountered in ditch reorganization. Eventually, as the demand for water increases, consolidation and transfer of storage in the interest of greater efficiency undoubtedly will be more seriously considered.
>
> As an example of the complexity of the problem, the Cache La Poudre Valley alone has more than 70 existing storage reservoirs, ranging in capacity from approximately 100 acre-feet to about 18,000 acre-feet, with a combined capacity of some 200,000 acre-feet. Only 25 of the reservoirs are reported to have capacities of 1,000 acre-feet or more. In the search for more water, an extensive and complex system of exchanges has been developed in the Cache La Poudre Valley. This system relies upon accounting of water rather than upon strict application of priorities. It is an ingenious system and a splendid example of cooperation. However, it is complicated and does not solve fully the problems associated with plains reservoirs.
>
> A limited reconnaissance study was made of various reservoirs in the Cache La Poudre Valley as part of the basin investigations. This reconnaissance was conducted to explore the possibilities and consequences of reservoir consolidation.
>
> It was realized that not all plains storage was susceptible to transfer. It would not be advisable to eliminate reservoirs serving as regulators or equalizers, reservoirs supplied principally from return flows, and small recreation lakes. Such reservoirs were excluded from the study.

Hydrologic studies for the potential Cache La Poudre Unit covering the 1930-1947 period disclosed that river flows were adequate for the transfer of about 90,000 acre-feet of plains storage rights. The study was then limited to a group of plains reservoirs having approximately that capacity. Eighteen reservoirs in the vicinity of Fort Collins were selected for analysis. They range in capacity from 172 acre-feet to 17,689 acre-feet and in surface area from 16 acres to 1,000 acres. One of the reservoirs—capacity 207 acre-feet—currently is not in use. Data on reservoir capacities and surface areas were obtained from the State Engineer's office and from the ditch companies. Several field reconnaissances were made to examine the systems, to check the reservoir perimeters, and to assess the possibilities of reclaiming land.

The studies first determined that all the irrigated lands supplied from the study reservoirs could be served physically by common upstream storage. It was then determined that no change would be required for any headgate or supply canal although minor adjustment of canals in the present reservoir areas would be necessary to reclaim lands.

The 18 study reservoirs, including the one not in use, have a total capacity of 91,425 acre-feet and a surface area reported to be 5,110 acres. The reservoir perimeters have 106 acres in trees and 385 acres in shrubs and grass—a total of 491 acres below the reservoirs are seeped. Reconnaissance land classification estimates disclose that the following lands might be reclaimed and converted to farm land if the 18 reservoirs were moved:

	Acres
Reservoir area (17).	4,622
Reservoir perimeter.	486
Seeped areas	384
Severed (associated) lands . . .	120
Total	5,612

None of the land in or adjacent to one reservoir was deemed arable. All or part of the flooded area of all other reservoirs was considered arable. It was estimated that the seeped lands consume water at the rate of three acre-feet per acre annually and that the perimeter lands in trees, shrubs, and grasses consume two acre-feet per acre annually. Thus, elimination of the 18 plains reservoirs would result in the following estimated savings of water each year:

	Acre-feet
Seeped lands.	1,152
Perimeter lands	982
Total (rounded)	2,000

Evaporation from the plains reservoirs has been estimated to average 1.78 feet per year per acre of water surface area. Assuming that two-thirds of the total plains reservoir surface area of 5,110 acres represents the average operational water surface area, evaporation from the reservoirs would average 6,100 acre-feet annually. Evaporation at the potential Idylwilde Reservoir (Cache La Poudre Unit) is estimated at one foot per year per acre of water surface area. Assuming the transfer of approximately 90,000 acre-feet of plains storage to Idylwilde Reservoir and assuming also that two-thirds of that capacity in Idylwilde would represent the average operating level, the exposed surface area of 60,000 acre-feet of water in Idylwilde Reservoir would be about 1,000 acres. The resulting evaporation would average 1,000 acre-feet annually. The difference of 5,100 acre-feet between plains reservoir evaporation of 6,100 acre-feet and Idylwilde Reservoir evaporation of 1,000 acre-feet represents evaporation savings that would be attributed to the transfer of storage.

The total savings of water attributable to the transfer of plains storage would thus be in the order of 7,100 acre-feet annually, derived as follows:

Savings	Acre-feet
Evapo-transpiration.	2,000
Reservoir evaporation.	5,100
Total	7,100

Although the preceding computations are rough and not supported by technical studies or data, they provide a general approximation of how much water could be saved by transfer of storage from plains to mountain reservoirs. A ready market undoubtedly would be available for such "new" water.

No estimate was made of the cost of transferring storage for the 18 study reservoirs. It is probable that such a project alone would be financially infeasible at the present time when related to irrigation benefits only. However, such a transfer might well be financially feasible as a part of a larger unit or project having other functions.

Cloud Seeding - In the winter of 1976-1977 there was wide-spread application of cloud seeding in the South Platte basin and other selected areas throughout Colorado. Application of such weather modification techniques in the western United States has shown that the snow pack can be increased by 10 to 15 percent (Grant, 1976). Such practices are already operational realities in many parts of the arid west.

The Bureau of Reclamation has done weather modification studies for the Central Colorado Rockies for the period 1952 through 1972. By adjusting this data to the South Platte River drainage, they estimate that the average annual contribution from a winter program to be 115,000 acre-feet (Kahan, 1976). However, the societal and environmental effects of such a program must be considered carefully. Some of these possible side effects include: increased costs of snow removal, effects on foraging wildlife, different flood patterns, etc. There are also legal problems. Present restrictions on weather modification research projects have included suspensions on cloud seeding operations "during periods of above normal precipitation where there are flood and avalanche potentials, during big-game hunting seasons, and during critical harvest periods" (U.S. Department of the Interior, 1975).

The results of the recent cloud seeding program in Colorado, which was authorized by the state legislature and funded with state money, have not yet been assessed. Weather modification as a source of new water for the basin should be considered in the future—especially in the context of its possible strategic value during drought periods. Even though the storm fronts are fewer, cloud seeding on those storms that do appear might have a large marginal difference for the basin.

Snow Reservoirs and Watershed Management - In the high alpine valleys at the headwaters of the basin, snow fences can be erected to capture winter snows. Instead of blowing into the warmer lower valleys, the snow is held back at the cooler higher altitudes in large drifts, or snow reservoirs. In this manner, the snow pack melts slowly throughout the summer instead of at once during the spring. This practice has been implemented at the headwaters of the Arkansas River in the San Isabel National Forest near Independence Pass, Colorado.

Similar benefits would accrue with forest management in the high mountain watersheds. The following was written by Ansel Watrous (1911) over sixty years ago:

> The relations between forestry and irrigation are very intimate. Thirty-five years ago the streams were at a flood during most of the irrigating months. Now they run low in July at least. The mountain forests which protected the snow banks have been depleted; these snow banks which formerly melted gradually and did not disappear until August, are now gone by the first of July. Hence the more sudden floods in the springtime, and the lower stages of water in July, August and the autumn months. It is not the irrigation ditches of Colorado that causes the Platte to run dry in Nebraska, the Arkansas in Kansas, and the Rio Grande in Mexico; it is rather the destruction of the forests which deprived the sources of supply of their natural protection, and thus permanently changed the character of our mountain streams. No one act of the federal government is more largely in the interest of agriculture and irrigation than the establishment of forest reservations about the sources of the great rivers which flow from the mountains out on to the Plains.

Presently, the South Platte River basin can boast four National Forest's and one National Park are within its mountains zone. From north to south they are; Medicine Bow National Forest, Roosevelt National Forest, Rocky Mountain National Park, Arapahoe National Forest, and Pike National Forest. However, there is still room for improvement in increasing the yield of the basins most important and productive watersheds. Keeping the available water locked up in the snow pack decreases the need for storage on the plains with its resulting high evaporation and seepage losses.

2.1.5 *Potential for Further Development of the Groundwater*

The High Plains Aquifers - In general, the effects of groundwater pumping in the South Platte River basin has been a gradual lowering of the water table in areas where the groundwater recharge is from natural precipitation only. Several such areas, as in the Big Beaver and Bijou Creek valleys (South Plains Tributaries sub-basin) and areas north of Wellington near Greeley (near the Cache La Poudre River - Crow Creek sub-basins divide) are known to be over developed and are considered critical areas.

Prospect Valley (between the Boxelder and Kiowa Creek drainages in the Southern Plains Tributaries sub-basin) relies heavily on groundwater pumping to supplemental surface water diversions. The direct flow rights for lands in Prospect Valley allow for very little diversion in drought years. Hence, in such years the drawdown exceeds the recharge from natural precipitation. In the 1930's the water table had been lowered to the point where the lands were critically short of supply (USBR, 1959). The water gradually rose during the 1940's but again was critically lowered during the drought of the 1950's. Figure 2-5 is a hydrograph of a representative well in the Prospect Valley area. It can be seen that the water table has not been given a chance to respond to natural recharge and therefore, it continues to be lowered. The aquifers in the basin that are recharged by direct population contain vast quantities of water that have accrued over geological time. Recognizing that its yearly recharge represents only a small fraction of its total supply, it must be managed accordingly. Management for use only during drought periods would be a strategic type of use.

<u>The Alluvial Aquifers</u> - In 1959 the United States Bureau of Reclamation reported that:

> The water table apparently has been quite stable in the alluvium aquifers along the mainstem of the South Platte below Denver and the lower portion of the tributary valleys. This area, in general, has a large recharge to the groundwater

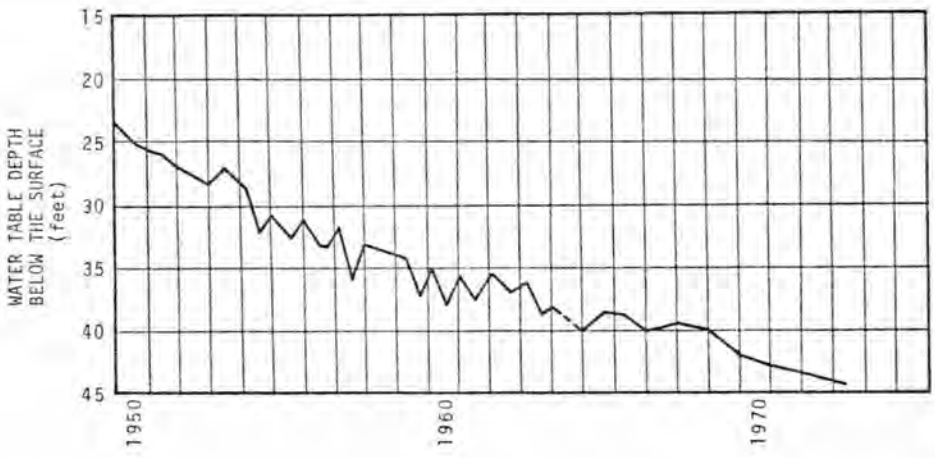


Figure 2-5 Hydrograph of a Representative Well in the Prospect Valley (C.S.U., 1973).

> reservoir from canal and reservoir seepages, from irrigation losses, and from the river during high flows. A large number of pumps are used to supplement the direct flow water in the late summer. The winter return flow recharges the groundwater reservoir, resulting, in general, in only seasonal fluctuation of the water table.

Since 1959, more than 1,000 new wells have been put down in the alluvium of the South Platte and tributaries (Toups, 1975). As the number of wells increased, the effects of groundwater withdrawal became evident to surface water diverters in these areas where groundwater was tributary to surface flows. Each year, a larger number of surface diverters had to stop diverting water earlier in the irrigation season to meet senior surface water appropriations. Due to the seasonal fluctuations in runoff and the complexities of percolation and flow in alluvial aquifers, it was difficult to identify the wells or even quantify their effects on the surface water flows other than in broad general terms.

Moreover, the different treatment of surface and groundwater by traditional law hampered an immediate resolution of this problem. The classic legal statement concerning groundwater, and the conclusion that it could not and thus ought not be regulated, is summed up in this much repeated judicial statement:

> Houston, and T.C.R. Co. vs. East 98 Tex. 146, 81 S.W. 279, 281 (1904).
>
> Because the existence, origin, movement and course of such waters, and the causes which govern and direct their movement, are so secret, occult, and concealed that an attempt to administer any set of legal rules in respect to them would be involved in hopeless uncertainty and would, therefore, be practically impossible.

However, the situation eventually became serious enough to warrant legislative action. The 1969 Water Rights Determination and Legislation Act states that is State policy "to integrate the appropriation, use and administration of the underground water tributary to a stream with the use of all the waters of the state." However, in 1973 the Colorado Assistant State Solicitor Generals, Mr. Donald H. Hamburg and Mr. Loren L. Swick, stated that the manner in which this law is being executed conflicts with the expressed state policy.

The administration of groundwater has been integrated with surface water by applying the same priority system to wells as exists for surface diversions. The result has been to make most groundwater users junior appropriators. In addition, under the existing law continued development of the groundwater reservoir is severely inhibited by the moritorium on new well construction (Toups, 1975). The restrictions have been imposed to insure senior surface water appropriators their legal entitlement. No consistent decline in the alluvial groundwater levels has been noted (Toups, 1975), suggesting that the development of these supplies is below optimum. In essence, an ocean of groundwater is being used to float a river.

The primary problems for groundwater producers in the tributary basins is to comply with the State Engineer's requirements for augmentation during periods of insufficient flows. Recurrent water shortages in the basin have had few obvious effects on groundwater pumpers. Many of the irrigators that rely exclusively or heavily on groundwater possess inferior surface diversion rights. During dry periods, groundwater levels in the alluvial aquifers usually decline, but not sufficiently to damage the pumpers. Since nearly all wells have rights which are junior to the surface diversion rights, any call on the river could result in a complete shutdown of upstream pumping by the State Engineer.

In order to avoid a complete shutdown, the State Engineer allows an augmentation program. When there is a call on the river, pumpers are required to augment stream flow by an amount equivalent to their depletion effect as estimated by the State Engineer. This amount is usually considered to be five percent of the groundwater pumpage.

Groundwater pumpers in the tributary basins have partially solved the problem of compliance with this requirement by forming organizations which can collectively supply augmentation water to satisfy surface diversion rights when a call goes out on the river. One of these organizations is the Ground Water Appropriators of the South Platte River Basin (GASP), a nonprofit corporation representing perhaps 70 percent of the wells in the main South Platte alluvial basin.

The strategy used by GASP is to appropriate, buy, manage, and lease water to be used for replacement purposes to reduce injury to senior appropriators, thereby reducing the necessity for State regulation of member wells.

The problems associated with such an organization are presented below:

(1) The system has not been subjected to a dry year or series of dry years. If surface diverters anticipate a dry year or have problems filling their reservoirs, they may decide not to sell their water for replacement purposes.

(2) The State Engineer may decide to raise the five percent depletion figure.

(3) The groundwater reservoir is not being effectively used.

(4) Surface water should be used early in the season and groundwater should be used later. This reduces evaporation losses. The purchase of reservoir storage for use during calls does not accomplish this.

Therefore, the appropriation system, as presently applied to groundwater users, does not make efficient use of the groundwater reservoir. Although the system is conjunctively managed, in effect, all groundwater rights are managed to meet surface water rights. Under this type of management, it is impossible to make the best of the groundwater reservoir. Moreover potential yield capabilities of the alluvial aquifers in the South Platte River basin are not utilized because the complex relationships between surface and groundwater are not fully understood. Until a component model of the water system, including groundwater, is developed, prior appropriated surface rights will block the effective use of groundwater.

However, how this additional water, which might be developed through conjunctive management, is used is an important policy question. Whether it should be managed as a strategic resource in order to stabilize the water supply of existing users during drought periods, or whether it should be used for new lands, should be carefully weighed.

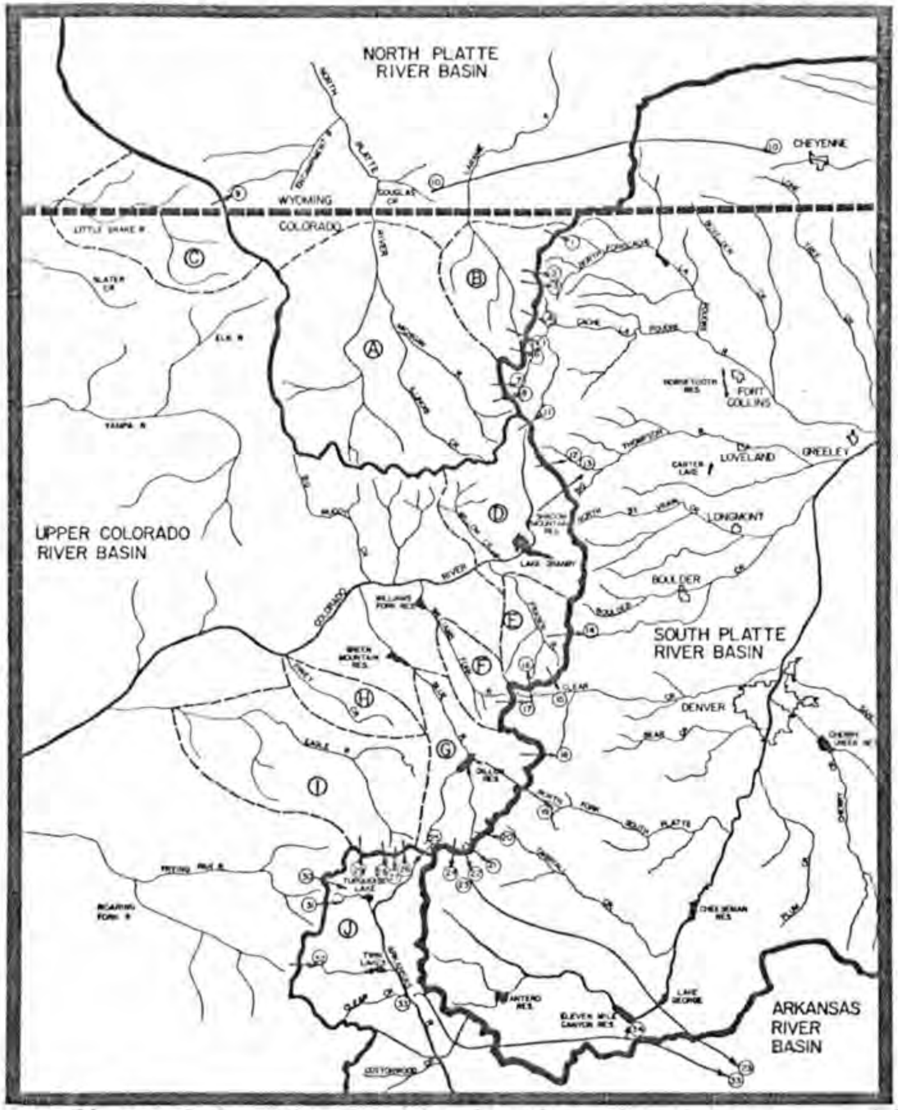
2.2 Foreign Water Supplies

As seen in Figure 2-6, the present physical infrastructure which imports water to the basin consists of nine tunnels, two pipelines, eight ditches, miles of collection ditches and canals, and tens of thousands of acre-feet of storage and regulating capacity on both the east and west slopes.

Five additional ditches which had previously imported water to the South Platte River basin have been closed. In addition, one tunnel and two pipelines cross the basin boundaries to bring Colorado River water to users in the Arkansas River Basin. Figure 2-7 shows the historical total yearly imports for foreign water to the South Platte River basin since 1885. The large increase in the 1950's was due to the CBT project which came on line then. In the mid 1960's diversions began through the Harold D. Roberts Tunnel; owned by Denver.

Table 2-12 shows the individual transbasin diversion structures, their source, destination, years of operation, and current average annual imports. Figure 2-8 shows the source distribution by river basin of the 373,122 acre-feet of foreign water currently imported to the South Platte River basin in an average year.

2.2.1 *The North Platte River Basin* - The North Platte River, originating in Colorado and flowing into Wyoming, borders the South Platte River basin to the north and northwest. As seen in the previous



THE NORTH PLATTE RIVER BASIN

Subbasins:

A - North Platte River-Mountains
B - Laramie River

Transbasin Diversion Structures:

1 - Wilson Supply Ditch
2 - Columbine Ditch (closed)
3 - Gob Creek Ditch (closed)
4 - Laramie-Poudre Tunnel
5 - Skyline Ditch
6 - Lost Lake Outlet (closed)
7 - Cameron Pass Ditch
8 - Michigan Ditch

THE COLORADO RIVER BASIN

Subbasins:

C - Little Snake River
D - Colorado River-Mountains
E - Fraser River
F - Williams Fork River
G - Blue River
H - Piney River
I - Eagle River

Transbasin Diversion Structures:

9 - Cheyenne Tunnel (Provides replacement water for diversions by the Cheyenne Pipeline]
10 - Cheyenne Pipeline
11 - Grand River Ditch
12 - Eureka Ditch
13 - Alva B. Adams Tunnel
14 - Moffat Water Tunnel
15 - Berthoud Pass Ditch
16 - Vasquez Tunnel (Part of the collection system for the Moffat Water Tunnel)
17 - Jones Pass Tunnel (Part of the Collection system for the Moffat Water Tunnel)
18 - Vidler Tunnel
19 - Harold D. Roberts Tunnel
20 - Boreas Pass Ditch
21 - East Hoosier Pass Ditch (closed)
22 - Hoosier Pass Tunnel
23 - Montgomery Pipeline (All imports through the Hoosier Pass Tunnel are subsequently exported by this pipeline)
24 - West Hoosier Pass Ditch (closed)
25 - Freemont Pass Ditch (closed)
26 - Columbine Ditch
27 - Ewing Ditch
28 - Wurtz Ditch
29 - Homestake Tunnel
30 - Busk-Ivanhoe Tunnel
31 - Charles H. Bonstead Tunnel
32 - Twin Lakes Tunnel

THE ARKANSAS RIVER BASIN

Subbasins:

J - Arkansas River-Mountains

Transbasin Diversion Structures:

33 - Homestake Pipeline (All imports through the homestake tunnel are subsequently exported by this pipeline. Occassionally, native Arkansas River water is exported also)
34 - Aurora -Homestake Pipeline (Turn-out from the Homestake Pipeline

Figure 2-6: The Transbasin Diversion Structures which Import Water to the South Platte River Basin

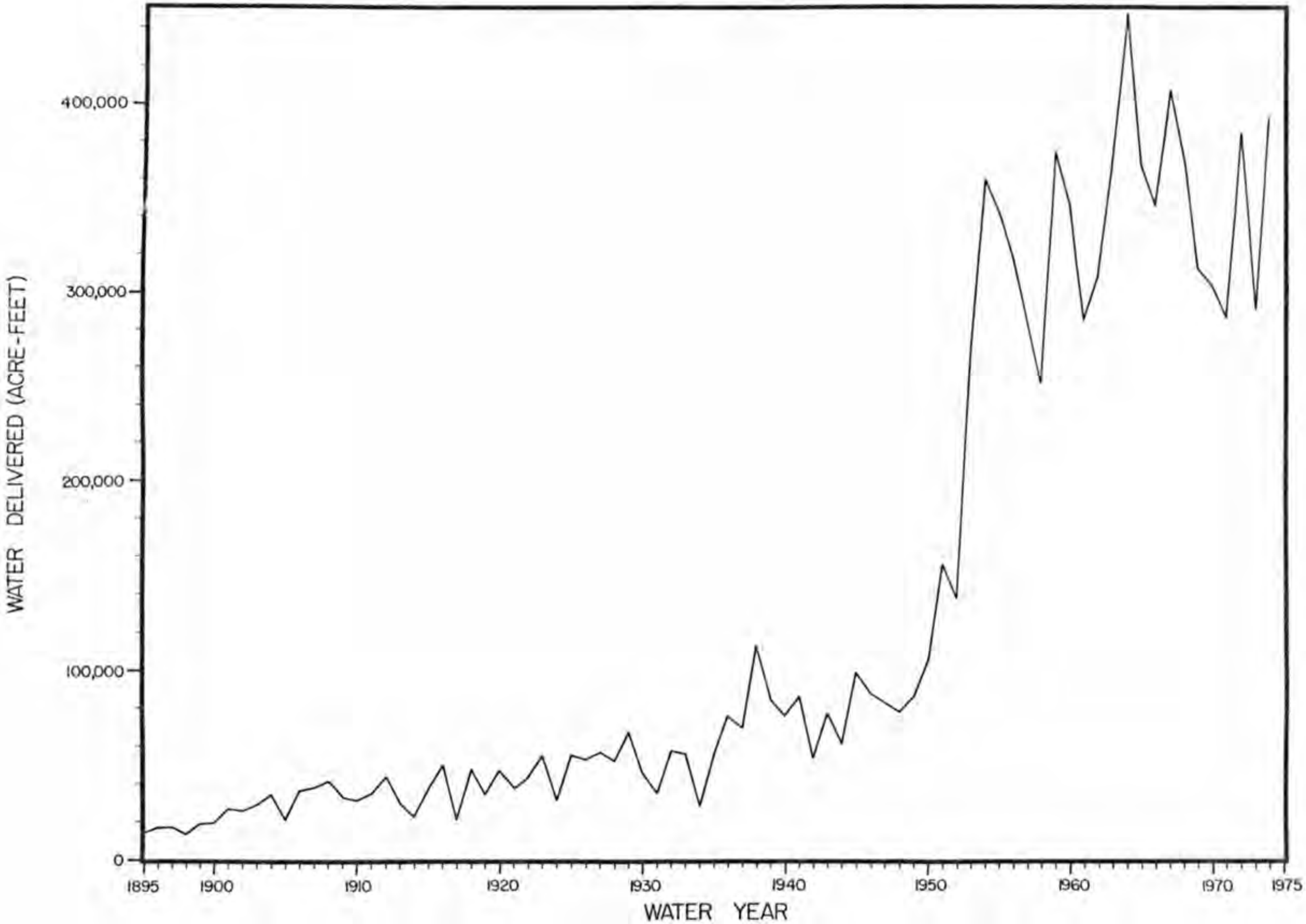


Figure 2-7: Historical Total Yearly Imports of Foreign water to the South Platte River Basin since 1895.

Table 2-12: The Transbasin Diversion Structures Which Import Water to the South Platte River Basin.[1]

Transbasin Diversion Structure		Source		Destination	Years of Operation (water years)	Current Average Annual Imports (acre-feet)
Wilson Supply Ditch	NORTH PLATTE RIVER BASIN	Laramie River sub-basin	SOUTH PLATTE RIVER BASIN	Cache La Poudre River Sub-basin	1902-present	2,381
Columbine Ditch		" " "		"	1921-1956	0[5]
Bob Creek Ditch		" " "		"	1920-1956	0[6]
Laramie Poudre Tunnel		" " "		"	1914-present	15,630
Skyline Ditch		" " "		"	1893-present	1,707
Lost Lake Outlet		" " "		"	1899-1950	0[7]
Cameron Pass Ditch		North Platte River-Mountains Sub-basin		"	1913-present	107
Michigan Ditch		" "		"	1905-present	1,190
Grand River Ditch	COLORADO RIVER BASIN	Colorado River-Mountains Sub-basin		"	1892-present	21,513
Eureka Ditch		" "		Big Thompson River Sub-basin	1940-present	80
Alva B. Adams Tunnel		" "		"	1947-present	227,626
Moffat Water Tunnel[2]		Fraser River Sub-basin		Boulder Creek Sub-basin	1936-present	59,322
Berthoud Pass Ditch		" "		Clear Creek Sub-basin	1910-present	612
Vidler Tunnel		Blue River Sub-basin		"	1971-present	48
Harold D. Roberts Tunnel		" "		North Fork South Platte Sub-basin	1964-present	28,654
Boreas Pass Ditch		" "		South Platte River-Mountains Sub-basin	1913-present	103
East & West Hoosier Pass Ditches		" "		"	1935-1940	0[8]
Aurora-Homestake Pipeline[3]		Eagle River Sub-basin		"	1967-present	6,450
Cheyenne Pipeline[4]		Little Snake River Sub-basin		Crow Creek Sub-basin	1965-present	7,316
Aurora-Homestake Pipeline[3]	ARKANSAS RIVER BASIN	Arkansas River-Mountains Sub-basin		South Platte River-Mountains Sub-basin	1973-present	381
Total	-	-	-	-	-	373,122

1/All of this information is from Appendix B. Current average annual imports are since the most recent legal constraint or since the last physical expansion or water rights aquisition.

2/The Moffat water tunnels collection system includes the Jones Pass Tunnel (which diverts water from the Williams Fork River Sub-basin, Colorado River Basin, to the Clear Creek Sub-basin, South Platte River Basin) and the Vasquez Tunnel (which diverts all of the Jones Pass Tunnel imports back under the Continental Divide to the Fraser River Sub-basin, Colorado River Basin and to the Moffat Tunnels intake portal. See Figure 2-6).

3/The Homestake Tunnel diverts water from the Eagle River Sub-basin, Colorado River Basin to the Arkansas River-Mountains Sub-basin. There this water, along with some native surface water runoff of the Arkansas River Basin, is diverted by the Homestake Pipeline. The Aurora-Homestake Pipeline is the turn out from the Homestake Pipeline which delivers this water to the South Platte River Basin (See Figure 2-6).

4/The Cheyenne Tunnel diverts water from the Little Snake River Sub-basin, Colorado River Basin to the North Platte River Basin. There this water is exchanged for native North Platte runoff diverted to the Crow Creek Sub-basin, South Platte River Basin by the Cheyenne Pipeline (See Figure 2-6).

5/The average annual import prior to closure was 121 acre-feet.

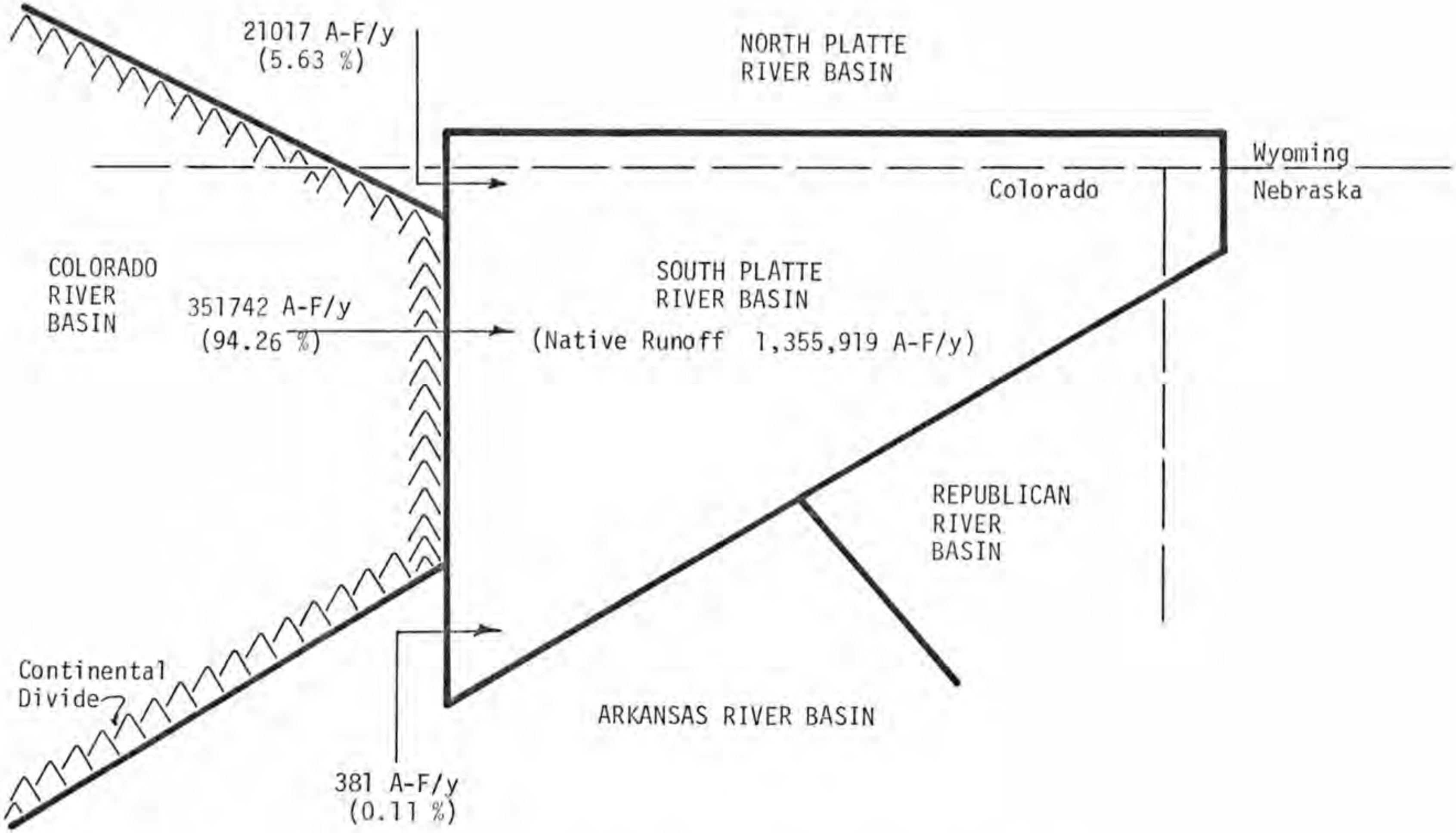


Figure 2-8: Present Average Annual Imports to the South Platte River Basin

figures and tables, five transbasin diversion structures presently export 21,017 acre-feet of North Platte water to the South Platte basin in an average year. All of this is exported to the Colorado portion of the South Platte River basin. There are presently no exports of water from the Wyoming portion of the North Platte River basin to the Wyoming portion of the South Platte drainage.

Table 2-13 shows the disposition of the native surface water runoff of the sub-basins of the North Platte River basin. An average of 3.22 percent of this water is exported to the South Platte.

Colorado Exports - The amount of water the Colorado portion of the South Platte River basin can import from the Colorado protion of the North Platte basin has been fixed by litigation at 25,875 acre-feet. Some 6,000 acre-feet per year can be imported from the North Platte River-Mountains sub-basin by the North Platte River Decree of 1945, and 19,875 acre-feet per year can be imported from the Laramie River sub-basin by the Laramie River Decree of 1957.

Present exports are 4,858 acre-feet per year less than the legal allotment. There are Colorado water right holders downstream in the North Platte River basin which are senior to the diversion priorities of these transbasin diversion ditches. Thus diversions are generally allowed only during the high spring runoff, when plenty of water is available and calls on the river are few. This is also the time when South Platte River basin demands (principally by agriculture) are at a minimum and when its streams are above their base flows. Under Colorado water law unless diversions can be put directly to use or storage they are not permitted. Thus the priority of these ditches combined with the lack of sufficient storage has kept exports from

Table 2-13 Disposition of the Average Annual Native Surface Water Runoff of the North Platte River Basin1/

Surface Water Disposition Category	AMOUNT (ACRE-FEET)			
	North Platte River-Mountains Sub-basin2/	Laramie River Sub-basin3/	Total North Platte River Basin	
			Amount	Percent
Total Average Annual Exports	1,297	19,720	21,017	3.22
Average Annual in Sub-basin Consumptive Uses	169,000	6,032	175,032	27.64
Average Annual Outflow	317,029	120,126	437,155	69.04
Total Average Annual Native Surface Water Supply	487,326	145,878	633,204	100.00

1/All data is from Part III, Chapter 7.
2/Drainage area is 1,431 square miles.
3/Drainage area is 294 square miles.

reaching the legal allowable. However, the biggest problem has been the rising cost of upkeep of these ditches, which has caused them to fall into disrepair.

The Michigan Ditch was bought by Fort Collins in 1971 and plans for its rejuvenation and the enlargement of its storage facility, Joe Wright Reservoir, are under way.

There are presently no plans to increase diversions through the other ditches through the aquisition of more senior water rights or through the improvement or expansion of their physical structures.

The planned upgrading of the Michigan Ditch, along with the creation of additional storage capacity to contain its diversions when they can be made, will allow the combined diversions to approach closer to the total decreed limit. However, if rigths with higher priorities were obtained for all these structures, the full 25,875 acre-feet could be diverted regardless of dry years.

Wyoming Exports - The amount of water Wyoming and the Wyoming portion of the South Platte River basin, may divert from the North Platte River Basin is also fixed by litigation. Presently there are no imports of this water to the South Platte in Wyoming as it is all being used in that state within the North Platte drainage. For this water to be imported it must be acquired from its present users and an appeal to the Wyoming State Engineer must be made to change the place of use. However, only the average annual consumptive use may be exported as downstream users have a vested right to the historical return flows. In addition, appropriate transbasin diversion structures would have to be built.

The Cheyenne pipeline diverts water from Douglas Creek, a tributary of the North Platte, and exports it to the Crow Creek sub-basin for municipal use by Cheyenne. However, this water is replaced with equal amounts imported to the North Platte River Basin from the Colorado River Basin by the Cheyenne Tunnel.

2.2.2 *The Colorado River Basin* - The Colorado River, originating in Colorado and draining parts of seven states and Mexico, borders the South Platte River Basin to the west.

As seen in Figure 2-6 and Table 2-12 ten transbasin diversion structures (and related support facilities) presently export 351,724 acre-feet of Colorado River Basin water to the South Platte Basin in an average year. Of this total, 7,316 acre-feet is exported from the Wyoming portion of the Colorado River Basin to the Wyoming portion of the South Platte (by exchange). The remainder of these exports happen in Colorado.

The disposition of the native surface water runoff of the sub-basins of the Colorado River basin is seen in Table 2-14. This table shows that about 21.4 percent is exported to the South Platte as a long term average. Water available for use in Wyoming and Colorado from this river is limited by the Mexican Water Treaty, the Colorado River Compact, the Upper Colorado River Basin Compact, and by the water laws of Colorado and Wyoming. The exact shares of Colorado River water to Colorado and other states, as set out in the Mexican Treaty and the interstate compacts, are in dispute. The disputes not withstanding, an estimate is derived herein showing that the presently unused and uncommitted share of Colorado River allotment for Wyoming amounts of 187,000 acre-feet annually. Also shown are estimates of Colorado's unused portion of its Colorado River allotment; these range from 1,321,650 acre-feet in a wet year to 348,750 acre-feet in a dry year. However, conditional decrees already

Table 2-14 Disposition of the Average Annual Native Surface Water Runoff of the Colorado River Basin[1/]

Surface Water Disposition Category	AMOUNT (ACRE-FEET)								
	Colorado River-Mountains Sub-basin[2/]	Fraser River Sub-basin[3/]	Williams Fork River Sub-basin[4/]	Blue River Sub-basin[5/]	Piney River Sub-basin[6/]	Eagle River Sub-basin[7/]	Little Snake River Sub-basin[8/]	Total Colorado River Basin	
								Amount	Percent
Total Average Annual Exports to the South Platte Basin (to other River Basins)	249,219	55,394[9/]	4,540[10/]	28,805 (8,249)	0	6,450 (28,818)	7,316	351,724 (37,067)	21.4 (2.3)
Average Annual in Sub-basin Consumptive Uses (includes Reservoir Evaporation)	31,850	12,620	8,640	7,800	520	22,100	2,600	86,130	5.2
Average Annual Outflow	97,405	93,130	96,729	278,627	54,616	388,064	158,817	1,167,388	71.1
Total Average Annual Native Surface Water Supply	378,474	161,144	109,909	323,481	55,136	445,432	168,733	1,692,309	100.0

1/All data is from Part III, Chapter 8 and Appendices A and B.
2/Drainage Area is 540 square miles.
3/Drainage Area is 285 square miles.
4/Drainage Area is 184 square miles.
5/Drainage Area is 511 square miles.
6/Drainage Area is 86.2 square miles.
7/Drainage Area is 944 square miles.
8/Drainage Area is 285 square miles.
9/Includes Moffat Tunnel diversions from the Fraser River Sub-basin only.
10/These exports are diverted by Moffat Tunnel Collection Facilities (they arrive in the South Platte Basin via the Jones Pass Tunnel, the Vasquez Tunnel, and finally the Moffat Tunnel, See Figure 2-6).

far exceed anyones guess of Colorado's unused share of the Colorado River.

The City of Cheyenne is the only South Platte River Basin water user in Wyoming that imports Colorado River water. As presently envisioned, these diversions will increase to approximately 37,000 acre-feet per year as Cheyenne's demand for this water grows. Wyoming apparently has committed this water to Cheyenne; the City has water rights permits for it and is presently expanding her importation facilities.

Within Colorado, it appears that no new transbasin diversion structures will be built to import additional water from the Colorado River basin. It does seem probable, however, that the collection systems for the existing facilities will be expanded as long as there is water available (i.e., in terms of the seniority of one's right and in terms of what has already been diverted relative to the total supply).

Table 2-5 shows projected future average annual imports to the Colorado portion of the South Platte River basin from the Colorado portion of the Colorado River basin. The estimates were obtained compiling the envisaged expansion plans of the controlling interests of the presently existing transbasin diversion structures. By 2020, the amount imported from the Colorado River would be 704,798 acre-feet per year according to Table 2-15, or 110.1 percent more than the amount presently imported.

Table 2-16 shows estimates of Colorado River depletions in Colorado, projected by several groups. These include the Colorado River Basin Salinity Forum, the Pacific Southwest Interagency Committee, and the Committee on Fourteen (representing the seven Colorado River Basin

Table 2-15 The Historical and Future Average Annual Imports of Colorado River Basin Water to the Colorado Portion of the South Platte River Basin.

Diversion Structure	Pre-1975 Historical Annual Average Diversion (acre-feet)	Future Annual Average Diversions (acre-feet)					
		1975	1980	1990	2000	2020	Date Uncertain
Grand River Ditch	17,523[1/]	21,523[2/]	21,523	21,523	21,523	21,523	?[3/]
Eureka Ditch	82	82	82	82	82	82	0
Alva B. Adams Tunnel	227,626[4/]	227,626	281,626[5/]	281,626	281,626	281,626	0
Moffat Tunnel	54,322[6/]	59,322[7/]	59,322	77,322[8/]	77,322	77,322	0
Berthoud Pass Ditch	615	615	615	615	615	615	0
Vidler Tunnel	48	48	48	48	48	48	365,000[9/]
Harold D. Roberts	28,654	28,654	28,654	28,654	28,654	287,654[10/]	0
Boreas Pass Ditch	103	103	103	103	103	103	0
Aurora-Homestake Pipeline	6,450	6,450	6,450	35,825[11/]	35,825	35,825	0
Four Counties	-	-	-	-	-	-	40,000[12/]
Total imports from the Colorado to the South Platte River Basin	335,423	344,423	398,423	445,798	445,798	704,798	405,000
% increase over the historical annual average	-	2.7	18.8	32.9	32.9	110.1	-

1/ Annual average diversion subsequent to the enlargement of the main intercepting canal in 1930 (Table B3-1).

2/ The 1975 increase in storage capacity of Long Draw Reservoir will provide an additional 4,000 acre-feet per year through the Grand River Ditch (U.S. Department of the Interior, 1973).

3/ Further enlargement of Long Draw Reservoir is possible and would allow increased average annual diversions through the Grand River Ditch without the acquisition of additional water rights. When this might be done and how much it would yield is uncertain.

4/ Annual average was taken between 1953 and 1974 excluding the first 6 years which were not representative of the systems potential (Table B3-3).

5/ Windy Gap Project to come on line in 1980 (NCWCD, 1975) and provide an additional 54,000 acre-feet per year (Engineering Consultants, Inc., 1974).

6/ Annual average was taken subsequent to the addition of the Jones Pass-Vasquez Tunnel infrastructure to the Moffat Collection System in 1959.

7/ Englewoods Development of their Ranch Creek Collection System in 1975 will provide an additional 5,000 acre-feet per year through the Moffat Tunnel (Denver Water Department, 1975).

8/ Expansion of the Williams Fork collection system will provide an additional 18,000 acre-feet per year through the Moffat Tunnel by 1986 at the latest (Robert Fischer, 1976).

9/ The Vidler Tunnel Corporation has filed with the courts to deliver 365,000 acre-feet per year to the South Platte River Basin (Roland Fischer, 1976). This project has not acquired any water rights or land and its feasibility has yet to be assessed. Therefore, the date of initial diversion is uncertain.

10/ The expansion of the Harold D. Roberts Collection system will at least be on line by 2020 with the proposed projects contributing the following amounts; (Robert Fischer, 1976), Straight Creek 9,000, East Gore 70,000, Eagle-Piney 100,000, Eagle-Colorado 80,000, Total 259,000.

11/ The Homestake Project Collection System expansion (including the Eagle-Arkansas Division) is to be on line by 1982 providing Aurora with an additional 20,515 acre-feet per year through the Aurora-Homestake Pipeline (Beck, 1974). Also includes presently unused share of existing yield, 8860 acre-feet.

12/ The Four Counties Water Association Project recently under the direction of a firm called Sproule, would deliver to the South Platte River Basin 40,000 acre-feet per year (Roland Fischer, 1976). When this project will start diversions and how they will get to the South Platte River Basin is uncertain at this time.

Table 2-16 Estimated Future Annual Colorado River Depletions in Colorado (From Laren D. Morrils' Personal Files, 1976).

Colorado River Depletions in Colorado by Use (In Thousands of acre-feet per year)[1/]	Colorado Water Conservation Board	Pacific Southwest Interagency Committee	Committee of 14	U.S. Department of the Interior Energy Report	Salinity Forum Low	Salinity Forum Moderate	Salinity Forum High
1980							
Out of Basin Export	672	682	630	606	605	650	680
(To the South Platte River Basin, 72%)	(484)	(491)	(454)	(436)	(436)	(468)	(490)
In Basin Agricultural Use	1,245	-	1,248	-	1,245	1,245	1,250
In Basin Coal Development	53	55	55	54	35	40	50
In Basin Oil Shale	20	20	15	45	15	20	45
Other In Basin Uses	41	43	22	-	24	34	44
Total	2,031	-	1,970	-	1,924	1,989	2,069
1985							
Out of Basin Export	713	723	665	643	640	680	715
(In the South Platte River Basin, 72%)	(513)	(521)	(479)	(463)	(461)	(490)	(515)
In Basin Agricultural Use	1,342	1,342	1,264	-	1,255	1,295	1,345
In Basin Coal Development	56	47	56	32	40	55	55
In Basin Oil Shale	60	45	25	45	25	50	60
Other In Basin Uses	67	46	37	-	39	54	69
Total	2,238	2,206	2,047	-	1,999	2,134	2,244
1990							
Out of Basin Export	728	-	700	725	700	730	730
(To the South Platte River Basin, 72%)	(524)	(-)	(504)	(522)	(504)	(526)	(526)
In Basin Agricultural Use	1,384	-	1,337	1,492	1,335	1,365	1,495
In Basin Coal Development	64	-	106	119	65	105	120
In Basin Oil Shale	125	-	95	108	95	110	125
Other In Basin Uses	88	-	42	-	39	69	89
Total	2,389	-	2,280	-	2,234	2,379	2,559

1/ Does not include Colorado's pro rata share of evaporation from main stem reservoirs (51.75% of 520,000 or 269,100 acre-feet per year). Does not include Colorado's share of Mexican water treaty obligations.

States), the Department of the Interior's Energy Report, and the Colorado Water Conservation Board.

Of the 1970 total exports from the Colorado River Basin within Colorado, transfers to the South Platte River Basin accounted for approximately 72 percent. If this is true in the future, then the South Platte River basin will receive 524,000 acre-feet per year by 1990 according to the Colorado Water Conservation Board. The Salinity Forum, in Table 2-16, estimates that it should receive no less than 504,000 but no more than 526,000 acre-feet per year by 1990. These estimates represent a 55 percent and a 49 percent and 56 percent respectively over the present annual average.

The U.S. Department of the Interior, in their 1975 Westwide study estimate that the annual maximum diversions from the Colorado River Basin to the South Platte River Basin will be 935,000 acre-feet per year. This represents a 177 percent increase or approximately 600,000 additional acre-feet per year over the historical annual average.

Water use with the east slope river basins in Colorado, i.e., the South Platte and the Arkansas, already is an excess of their respective native supplies. Barring weather modification and drastic climatic changes, the presently unused Colorado River water, the remains of the Colorado portion of that basins alloted endogenous supplies, represents virtually the final unappropriated source of exogenous water available to other river basins within Colorado.

Once this water is absolutely decreed, there will be no more unappropriated endogenous water left for the Colorado portion of the Colorado River basin and there will be no more unappropriated exogenous water left for other basins in Colorado. Realizing this fact, interests seeking this water for uses within that basin, and without, have secured conditional decrees worth several times the amount in question. Obviously, somebody who wants this water is not going to get it. This state of affairs, the rumbling of which were heard as early as the 1950's, is rapidly approaching a head.

Prevailing sentiment in the Colorado portion of the Colorado River basin is that future transbasin diversions would seriously hamper, if not prevent, the development of western Colorado. The eastern slope counters with the observation that their development is an accomplished fact and that their pace of development is increasing. They ask should the growth in this area, the center of the states economy, be cut short by the lack of water?

2.2.3 *The Arkansas River Basin* - The Arkansas River, originating in Colorado and flowing into Kansas, borders the South Platte River basin to the south and southwest.

As seen in the previous Table 2-12 and Figure 2-6, the Aurora-Homestake Pipeline is the only transbasin diversion structure operating between the Arkansas and South Platte Basins. While the main purpose of this pipeline is to bring in Colorado River Basin water, the City of Aurora also uses it to import somewhat less than 400 acre-feet per year or native runoff from the Arkansas River.

A litigated agreement between Kansas and Colorado has apportioned equitable amounts of the flows of this river to each. While there is no set legal maximum that may be exported from this basin, there also is no unappropriated water feasibly available for export.

Water users within the Arkansas River Basin are faced with much the same situation as water users in the South Platte River basin.

They lie in the "rain shadow" of the Continental Divide and are similarly confronted with the pressures of rapid growth along the Front Range. Endogenous surface water supplies have been appropriated to the point where they too must look elsewhere for water. This has led them also to the Colorado River Basin where most, if not all, of the unappropriated water in the State of Colorado is to be found (Note the poliferance of transbasin diversion structures importing water to the head of the Arkansas River from the Colorado River Basin as shown in Figure 2-6). To be an exogenous source of water for the South Platte River Basin, Arkansas River water must first be obtained, within the constraints of Colorados water laws, from its present users. Because virtually all of its native flows have been appropriated, exports from this basin must be cognizant of the ruling set out in Green vs. Chaffee Ditch Company (Colorado, 1960);

> The well-recognized right to change either the point of diversion of the water rights or its place of use is always subject to the limitation that such change shall not injure the rights of subsequent appropriators.

In this basin therefore, as with others within Colorado, while a water right may be purchased by an out of basin users, exports may not exceed the historical consumptive use as downstream appropriators have a vested right to the return flows.

So far, the only South Platte River basin water user that has looked to the Arkansas River Basin for water is the City of Aurora. She has purchased a right to the endogenous supplies of this basin that had been used for irrigation near Leadville. (Her imports are only of this rights historical consumptive use). She has also purchased, and is scheduling to acquire more, shares in the exogenous water supplies that are being developed by Arkansas River Basin water interests (Twin Lakes

Reservoir and Canal Company imports from the Colorado River Basin through the Twin Lakes Tunnel).

Other South Platte River Basin water users seeking Arkansas River basin water may proceed as Aurora has. However, this may be economically prohibitive as appropriate importation facilities must be built, the water must be purchased from its present owners, and then only the historical consumptive use may be diverted. Of course, they may set up an agreement for use of the existing Homestake project facilities, but the amount of imports will be limited also by the capacity of the Homestake Pipeline.

2.2.4 *Other River Basins* - In addition to the adjacent basins, other rivers such as the Columbia, Missouri, and Mackenzie have been examined from time to time as potential exogenous sources of water. Some of these proposed projects are rather grand schemes attempting to solve the basins and indeed the whole arid wests water supply problem for good. Others are a bit more modest in comparison. In any case, water transfers over such distances and in the magnitudes envisioned raise many legal, social, economic, materials, and environmental questions. They cannot realistically be counted on as potential sources of supply in the near future, if at all.

PART II

NATIVE WATER SUPPLIES OF THE SOUTH PLATTE BASIN

That water of a given river basin which is not imported from another basin is called native water. The task of this group of chapters assembled as Part II is to assess the amount of native water supplies of each of the sub-basins of the South Platte, to investigate their present usage, and to determine what if any amounts remain that could be developed.

The sub-basins of the basin are grouped into four geographic categories: (1) the headwaters of the mainstem South Platte (2) the tributaries which drain the Front Range and the mainstem South Platte from Denver to Greeley, (3) Plum Creek and Cherry Creek, and (4) the ephemeral plains tributatires and the mainstem in the plains from Greeley to the state line. These groupings of sub-basins are the basis for the four chapters of Part II. They are seen in Figure 3-1.

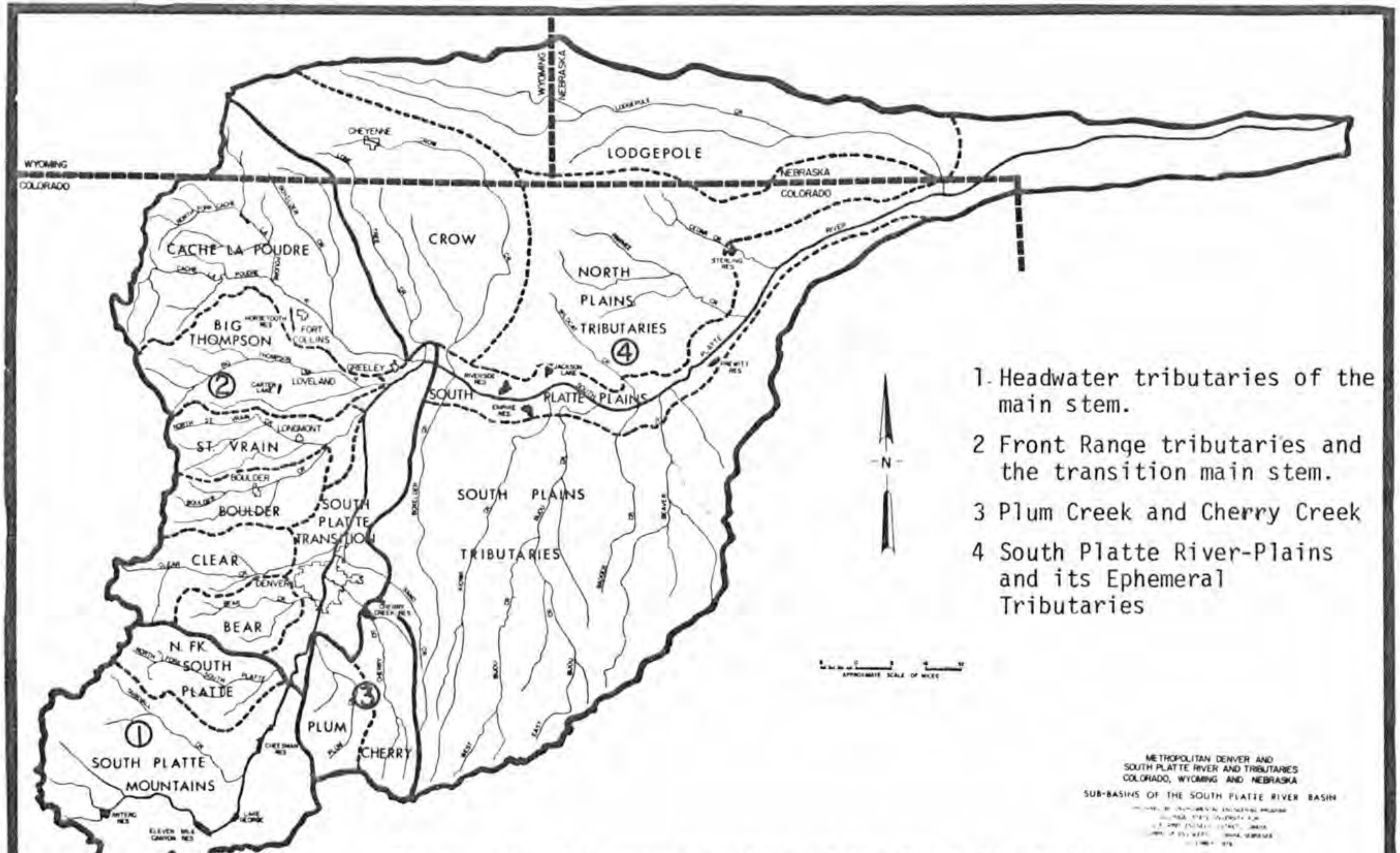


Figure 3-1: Subbasin Groupings of the South Platte River Basin

CHAPTER 3

HEADWATER TRIBUTARIES OF THE MAINSTEM SOUTH PLATTE

The headwaters of the South Platte River are in the Front Range mountains. There are eight major headwater streams; all have similar hydrologic characteristics. Also they are all mountain streams draining high elevation terrain, the streams flow through rather deep canyons which end abruptly at the base of the mountains. Here, the streams flow across the plains several miles to join the mainstem of the South Platte River.

Only two of these headwaters streams are discussed in this chapter. They are, using their respective sub-basin designations: the South Platte River-Mountains, and the North Fork of the South Platte River. These two sub-basins are seen as Groups #1 in Figure 3-1. The other headwaters streams are included as Group #2. The two sub-basins in this group encompass 2,621 square miles, draining 12.2% of the South Platte River Basin study area. Their native surface water runoff averages 313,815 acre-feet per year, or 23.5% of the total estimated average annual native runoff of the entire study area.

3.1 The South Platte River - Mountains Sub-basin

The South Platte River-Mountains is defined as the drainage area of the South Platte River above USGS Gaging Station #0670800, "South Platte River at Waterton, Colorado," excluding the drainage area of its North Fork above gaging station, #067007000, "North Fork South Platte at South Platte, Colorado." This sub-basin definition coincides approximately with the boundaries of Irrigation District #23, which permits the use of diversions records from this unit. Figure 3-2 is a schematic of the sub-basin, showing its major features.

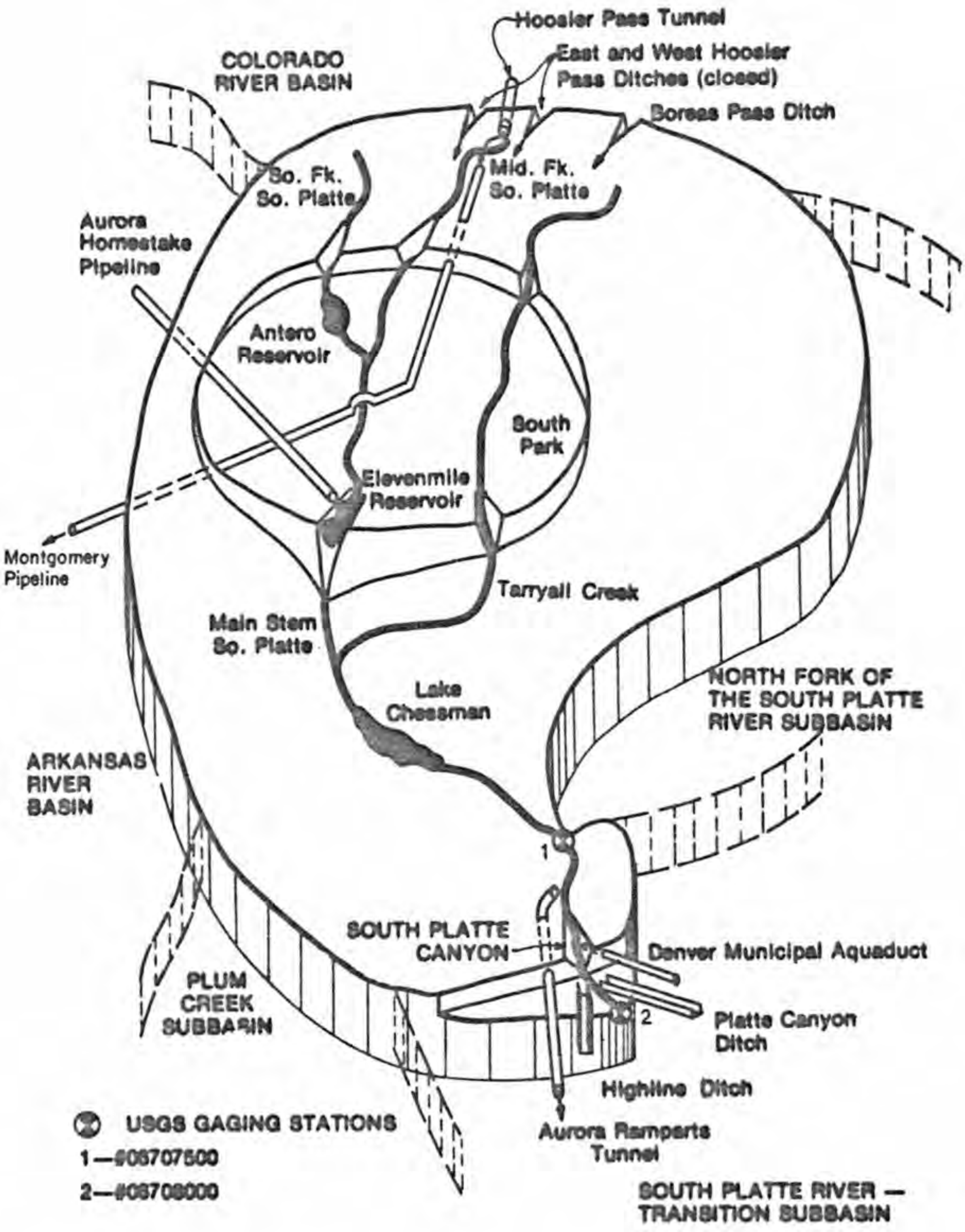


Figure 3-2: Schematic of the South Platte River-Mountains Subbasin

3.1.1 *Physical Characteristics and Surface Water Runoff* - The southern and western boundaries of the sub-basins are the high mountain divides with the Colorado and Arkansas River basins. These divides are rugged mountains, several of which rise to 14,000 feet. The South Platte originates in the snow fields of these mountains, developing its identity in a broad valley called South Park. From here the river flows generally northeast, towards Denver. The mouth of this sub-basin is at Watertown, Colorado, elevation 5,484 feet, and about one-half miles downstream from the mouth of the South Plattes Canyon in the foothills. This sub-basin drains 2,142 square miles.

The principal tributaries are the middle and south forks of the South Platte and Tarryall Creek. Also there are about 150 small streams, most of which are intermittent. The North Fork of the South Platte, discussed in the following section, is also a major tributary, but it is excluded from the definition of the sub-basin.

Precipitation in the higher elevations of the sub-basin averages up to 40 inches per year, and about 12 inches per year in the lower elevations and South Park (NOAA, United States Department of Commerce, 1974). Most of this occurs as snow during the winter. The spring runoff from this snowpack constitutes about 70 percent of the annual runoff. Summer rainfall is usually insufficient to produce significant runoff (McCain, Jarrett, 1976), though there are occasional summer flood flows.

The native surface water runoff of the South Platte River-Mountains sub-basin was estimated from the flow records of the United States Geological Survey gaging station number 06707500, "South Platte River at South Platte, Colorado, given in Appendix C, Table C4-2. This gaging station is located just below the confluence of the mainstem with the

North Fork, about eight miles upstream from Watertown. Surface water accruing to the South Platte River-Mountains sub-basin from the 42 square mile drainage area between the South Platte and Watertown gaging stations was assumed negligible. In addition, evaporation and storage due to reservoirs, and diversions and return flows were considered. An adjustment was made also to account for flows of the North Fork, measured at USGS gaging station number 06707000, "North Fork of the South Platte at South Platte, Colorado," seen in Appendix C, Table C4-1. Although the Watertown gaging station was at the mouth of the sub-basin, the number of diversions between South Platte and Watertown, as seen in Figure 3-2 make the use of the upper gaging station preferable.

The 1914-1975 average native surface water runoff of the South Platte River-Mountains sub-basin is estimated in Table A4-1. Appendix A, to be 201,211 acre-feet per year. Table A4-2, Appendix A gives the native surface water runoff for the water year 1970 as 402,235 acre-feet, or 199.9% of average. The native surface water runoff during the 1953-1956 four year drought period averaged 105,354 acre-feet per year, or 52.4% of average, (Appendix A, Table A4-3).

The surface water outflow of the South Platte River-Mountains sub-basin contributes to the surface water supplies of the South Platte River-Transition sub-basin. The net runoff contributed, including the flows from the North Fork, amount to about 150,000 acre-feet per year. The difference between this net outflow from the sub-basin and the average annual native flows is due mostly to the several diversions above Watertown, (seen in Figure 3-2) and the consumptive use of irrigation in South Park. Also some flows are held over from one year to the next in the upstream reservoirs.

3.1.2 *Existing Development of Surface Water Runoff* - The Colorado water rights tabulation of October 10, 1974 lists the absolutely and conditionally decreed ditch rights and storage rights for the surface flows of the Middle Fork, South Fork, and mainstem of the South Platte River above Watertown as: 63 ditch rights and 5 storage rights for the Middle Fork; 32 ditch rights and 3 storage rights, for the South Fork; and 50 ditch rights and 6 storage rights for the mainstem. It also lists 53 ditch rights and 5 storage rights absolutely and conditionally decreed for the surface flows of Tarryall Creek. In addition, the surface flows of the minor tributaries in this sub-basin support over 200 decreed ditch rights and about 20 decreed storage rights.

While the majority of these rights are for irrigation, about 15 percent of them are for municipal use (especially by Denver), which control about 60 percent of all the surface water diversions in the sub-basin. Figure 3-2 shows some of the major diversions.

Direct Diversion Structures - There have been five diversion structures built to import water to the South Platte River-Mountains sub-basin. Three of these are operating today, while two structures have not been used since 1940. Table 3-1 lists these structures, showing the amounts of water imported. There are no diversion structures which import water to this sub-basin from other sub-basins of the South Platte River basin.

There are six major diversion structures which export water from the South Platte River-Mountains sub-basin. They are: the Montgomery Pipeline, the Platte Canyon Ditch, the Highline Ditch, the Aurora-Ramparts Tunnel, and the Denver Municipal Aqueduct and the Kassler Pipeline to the Kassler Water Treatment Plant. These structures are seen in Figure 3-2. All but the Montgomery Pipeline have their points of diversion within the eight mile reach between South Platte and Watertown.

Table 3-1 Diversion Structures Importing Water to the South Platte River-Mountains Sub-Basin

Diversion Structure	Source	Destination within the South Platte River-Mountains Sub-basin	Years of Operation	Imports (acre-feet)	
				Average Annual	1970
Boreas Pass[1/] Ditch	Blue River Sub-basin, Colorado River Basin	Tarryall Creek	1933 to present	103	0
East Hoosier[2/] Pass Ditch	Blue River Sub-basin, Colorado River Basin	Middle Fork South Platte	1935-40	297	-
West Hoosier[3/] Pass Ditch	Blue River Sub-basin, Colorado River Basin	Middle Fork South Platte	1935-39	142	-
Hoosier Pass[4/] Tunnel	Blue River Sub-basin	Middle Fork South Platte	1952 to present	8,249	6,100
Aurora-Homestake Pipeline[5/]	Eagle River Sub-basin, Colorado River Basin via the Homestake Tunnel	Eleven Mile Canyon Reservoir	1967 to present	6,831	3,370
	Arkansas River-Mountains Sub-basin, Arkansas River Basin	Eleven Mile Canyon Reservoir	1975 to present	341	-
Total of Presently Active Diversion Structures	-	-	-	15,524	9,470

1/Appendix B, Table B3-9. 2/Appendix B, Table B3-10. 3/Appendix B, Table B3-10.
4/Appendix B, Table B3-11. 5/Appendix B, Table B4-5. This water is not available to the sub-basin as it is diverted again, by the Montgomery Pipeline, and exported to Colorado Springs in the Arkansas River basin.

The Montgomery Pipeline exports water out of the South Platte River Basin, to Colorado Springs in the Arkansas River Basin; all of the water exported comes from the Blue River through the Hoosier Pass Tunnel. The Montgomery Pipeline originates at Montgomery Reservoir on the Middle Fork of the South Platte. According to the October 10, 1974 Colorado Water Rights tabulation, there is no legal right for the export of any native surface flows of the South Platte-Mountains sub-basin through the Montgomery Pipeline (Wilkinson, 1974).

The Denver Municipal Aqueduct diverts water from the South Platte River about one mile upstream from Watertown. It has 17 separate absolutely decreed direct diversion rights totaling 213.9 cfs, (Denver Water Department 1975). This water is exported to the Marston Water Treatment Plant in the South Platte River-Transition sub-basin and is used for municipal and industrial purposes. Denver's diversion point for its Kassler water treatment plant is at the mouth of the South Platte Canyon. This pipeline has numerous direct flow rights to water from this sub-basin dating back as early as the 1870's. The 1959-1975 combined average diversions by Denver's Aqueduct and the Kassler Water Treatment Plant were 107,060 acre-feet per year (Denver Water Board, 1975).

The Aurora-Ramparts Tunnel diversion point is on the South Platte River about one mile downstream from South Platte, Colorado. It has an absolutely decreed direct diversion right for 100 cfs with an appropriation date of May 18, 1964 (Wilkinson, 1974). This water, along with the imports through the Aurora-Homestake Pipeline that have been released upstream from Eleven Mile Canyon Reservoir, are exported to Aurora to the South Platte River-Transition sub-basin. The tunnel also delivers South Park irrigation rights that Aurora has purchased. The 1963-1972 average diversions by the Aurora-Ramparts Tunnel was 9,068 acre-feet (Toups, 1975).

The Platte Canyon Ditch and the Highline Ditch divert within one mile of each other at the mouth of the South Platte Canyon. The Platte Canyon Ditch diverts from the North Bank of the South Platte and has 15 separate absolutely decreed ditch rights worth nearly 170 cfs (Wilkinson, 1974). The Highline Ditch diverts higher up, and from the south bank of the South Platte River. It has two absolutely decreed ditch rights for 250 and 584 cfs respectively; the appropriation dates for both are January 18, 1879 (Wilkinson, 1974). The Platte Canyon Ditch and the Highline Ditch export this water to the South Platte River Transition-Sub-basin, where it is used for irrigation. The Highland Ditch traverses the lower portions of the Plum Creek and Cherry Creek drainages on its way to Agricultural lands in the South Platte River- Transition sub-basin. Diversion data by these ditches were not available. These diversion amounts were calculated by a water balance determination between the South Platte and Watertown gaging stations, which is depicted in Figure 3-3. It was assumed that the 17 year period, 1959-1975, was representative of the long term average annual conditions. Through this analysis, the average annual and 1970 export of surface water from the South Platte River-Mountains to the agricultural sector in the South Platte River-Transition sub-basin through both the Platte Canyon and Highline Ditches was found to be 24,935 and 43,214 acre-feet respectively.

Numerous other ditches having absolutely decreed rights divert water for use within this sub-basin, primarily for irrigation in the

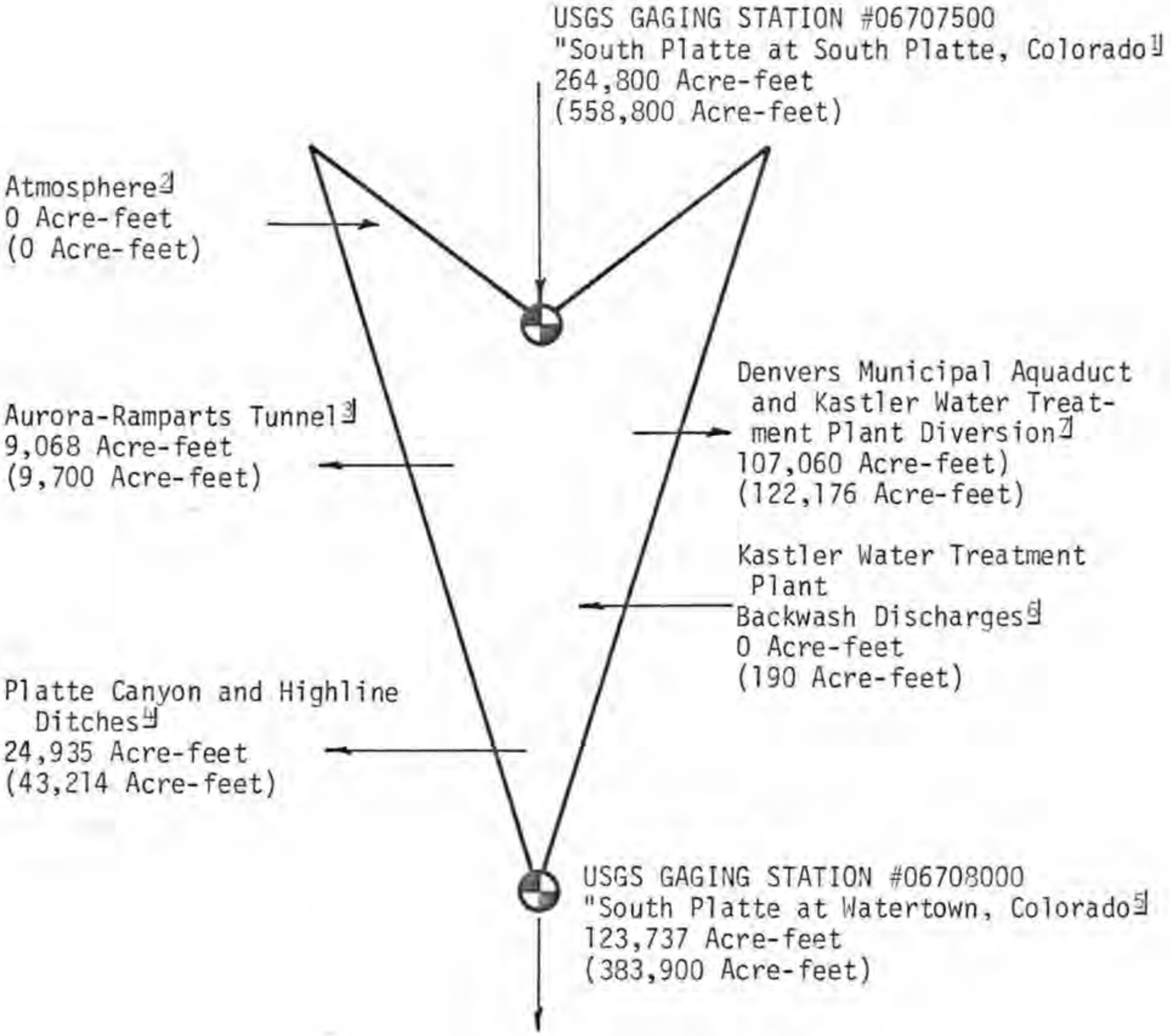


Figure 3-3: Mass balance of the lower 8 mile reach of the South Platte River within the South Platte River Mountain Subbasin (values in parenthesis are for the 1970 water year, others are average annual during the 1954-75 water year period)

[1]Appendix C, Table C4-2
[2]Assumed negligible
[3]Toups, 1975
[4]Determined by Mass Balance
[5]Appendix C, Table C4-3
[6]Janonis, 1977
[7]Denver Water Department, 1975

South Park area. The 1970 report of the State Engineer showed that 62 ditches reported diverting 92,839 acre-feet of water from the mainstem of the South Platte and its tributaries above South Platte, Colorado (Division I, Water Commissioners Report, 1970). While this list is not complete, it does include all the major diverters. Many of these ditches are in close proximity with each other and the diversions probably include some return flows from prior uses.

Storage Facilities - There are two major reservoirs located outside of this sub-basin that have storage rights for the native surface runoff diverted from it; these are the Platte Canyon Reservoir and Marston Reservoir.

Marston Reservoir is located on the edge of the Bear Creek drainage in the South Platte River-Transition sub-basin. It has an absolutely decreed storage appropriation for 19,739 acre-feet with an appropriation date of April 1, 1911 (Wilkinson, 1974). This water is delivered by the Denver Municipal Aquaduct and is used for municipal and industrial purposes. The reservoir serves as a settling pond and regulation reservoir for the Marston Water Treatment Plant. This treatment plant treats water that has been yielded by the Marston Reservoir storage rights, the direct flow rights of the Denver Municipal Aquaduct, and Denver's upstream storage rights and west slope imports through the Harold D. Roberts Tunnel.

Platte Canyon Reservoir is located in the South Platte River transition sub-basin immediately below the Watertown Gaging Station. The reservoir has an absolutely decreed storage right for 963 acre-feet, with an appropriation date of September 5, 1902 (Wilkinson, 1974). This water is delivered by a small ditch diverting just upstream from

from Watertown Gaging Station. The Platte Canyon Reservoir serves as a settling basin for the Kassler Water Treatment Plant. Water rights for the treatment plant include the Platte Canyon Reservoir's storage right, the direct flow rights for the Kassler intake structure, and Denver's upstream storage rights and west slope imports through the Harold D. Roberts Tunnel delivered through the Kassler intake pipeline.

Two storage facilities in this sub-basin are used to store imported water; these are the Montgomery Reservoir and the Elevenmile Canyon Reservoir. The Montgomery reservoir is located on the middle fork of the South Platte River about four miles upstream from Alma, Colorado. The reservoir both collects and stores Hoosier Pass Tunnel imports from the Colorado River basin before they are transported to the Arkansas River basin via the Montgomery Pipeline, and stores native surface flows as permitted by an absolutely decreed storage right. Elevenmile Canyon Reservoir is located on the mainstem of the South Platte at the eastern edge of South Park. Its primary function is to regulate the native surface water runoff of the South Platte. However, it also provides storage for water imports through the Aurora-Homestake Pipeline.

The bulk of the available storage capacity within the sub-basin for regulation of the native surface water runoff is provided by three large reservoirs; Antero, Elevenmile Canyon, and Cheesman. They are all owned by the City of Denver. Their total capacity is 292,743 acre-feet, which exceeds the average annual native surface water yield of this sub-basin by almost 50%. When full, these reservoirs inundate about one-fifth of the total original stream miles of the upper South Platte River (International Engineering Company, Inc., et al., 1973). Four other reservoirs provide an additional 63,576 acre-feet capacity for which there are absolutely decreed storage rights; they are Tarryall, Montgomery, Garo, and Red Hill Reservoirs.

Antero Reservoir was constructed at the turn of the century; completed in 1909. It is located on the South Fork of the South Platte, at an elevation of about 8,900 feet, in the gently sloping southwest portion of South Park. The dam creating this reservoir is a 46 foot high earth embankment, 4,090 feet long. The reservoir has a potential storage capacity of 115,900 acre-feet, (International Engineering Company, Inc., et al., 1973), and inundates what may have been the crater of an extinct volcano (Denver Board of Water Commissioners, 1969). It has a decreed storage appropriation for 85,564 acre-feet, with an appropriation date of October 8, 1907 (Denver Water Department, 1975). For safety reasons, the Colorado State Engineer's Office has limited storage in the reservoir to 15,878 acre-feet. Because of this restriction, the reservoir provides very little in the way of regulation, it is considered reserve storage (Beck, 1974).

Elevenmile Canyon Reservoir was built in 1932 and is located on the mainstem of the South Platte in the southeast portion of South Park. The dam is a concrete arch structure located at an elevation of about 8,500 feet with a maximum height of 135 feet and length of 496 feet. The reservoir capacity is 97,779 acre-feet and the maximum surface area is approximately 3,400 acres (Denver Water Board, 1969). Elevenmile Reservoir is fed mainly by the South Platte River which drains an area of 963 square miles at the dam site. Allowing for upstream consumptive uses, it can contain almost two years of the average annual runoff. The reservoir has three decreed storage rights totaling 115,589 acre-feet. Two are absolutely decreed and are for 81,917 and 15,862 acre-feet, with appropriation dates of July 10, 1926 and October 7, 1957 respectively. The third is conditionally decreed and is for 17,810 acre-fet with an appropriation date of December 7, 1957, (Wilkinson, 1974). This reservoir also stores water imported through the Aurora-Homestake Pipeline.

Lake Cheesman, the first large reservoir to be built in this subbasin, was also the first reservoir to be built on the mainstem of the South Platte. Cheesman Dam was the world's highest at the time of construction and for many years thereafter. Completed in 1905, it is located east of South Park in a rugged canyon. Its about 40 miles upstream from Denver at an elevation of about 6,800 feet. The dam is a gravity arch masonary type with a length of 700 feet and a height above the streambed of 231 feet. The reservoir has a capacity of 79,064 acre-feet and the maximum surface area is 871 acres (International Engineering Company, Inc., et al., 1973). Its drainage area, encompassing 1,766 square miles, includes Tarryall Creek which joins the mainstem South Platte about ten miles upstream from the dam. Additional water comes from Goose and Turkey Creeks, which empty directly into the reservoir. Their average annual contributions are about 19,771 and 9,000 acre-feet, respectively (International Engineering Company, Inc., et al., 1973). A torrential flood on May 3, 1900 washed away the first partially constructed dam to occup this site (Denver Water Board, 1969). Cheesman Reservoir has two absolutely decreed storage appropriations totaling 79,064 acre-feet. Individually they are for 48,373 acre-feet and 30,691 acre-feet with appropriation dates of September 24, 1893 and June 27, 1889 respectively (Wilkinson, 1974).

The average annual yield of the storage rights associated with Antero and Elevenmile Canyon Reservoirs and Cheesman Lake is 22,000 acre-feet (United States Department of the Interior, 1959). The average annual evaporation from these is estimated to total 9,898 acre-feet per year (Appendix A, Table A4-2).

There are four other storage facilities in this sub-basin with absolutely decreed storage appropriations worthy of note. Montgomery and Garo Reservoirs are located on the Middle Fork of the South Platte. Their storage rights are for 12,833 acre-feet and 19,600 acre-feet, each with appropriation dates of October 5, 1930 (Wilkinson, 1974). Montgomery reservoir serves a duel purpose, however, storing water imported through the Hoosier Pass Tunnel. Redhill Reservoir, located on Montgomery Creek, has a storage right for 18,008 acre-feet with an appropriation date of October 5, 1930 (Wilkinson, 1974). Tarryall Reservoir is located on Tarryall Creek about 20 miles upstream from its confluence with the South Platte. It has a storage appropriation for 13,135 acre-feet with an appropriation date of June 10, 1925 (Wilkinson, 1974). This reservoir is used for a fishery. The other reservoirs in this sub-basin have absolutely decreed storage rights generally worth less than 50 acre-feet (Wilkinson, 1974).

3.1.3 *Proposed Development*

The Spinney Mountain Project - The Spinney Mountain Dam and Reservoir, proposed by the City of Aurora, would be located 2.5 miles upstream from Elevenmile Canyon Reservoir and on the mainstem of the South Platte River. The Dam would be an earth fill structure 4,100 feet long with a maximum height of 95 feet above the streambed. It would have a crest elevation of 8,713 feet. The active storage of the reservoir created would be 48,000 acre-feet (Beck, 1974).

The Spinney Mountain Project would help to maximize yields of Aurora's various water supplies. These include South Platte River direct flow irrigation rights from South Park, Colorado River and Arkansas River Basin imports through the Homestake Project (which would be stored by exchange) and a Spinney Mountain storage appropriation right filed for in June of 1973. Water from this storage right will be available only during periods of no demands from its downstream senior appropriators. This condition occurs at infrequent intervals, but when it does, water is usually available in large quantities. An analysis of the monthly runoff of the South Platte River at the USGS Gaging station at Hartsel, Colorado for the period 1950-1970 indicated nine months when water would have been available to this storage right (Beck, 1974). Table 3-2 shows what the yield of this water right would have been. However, what the proposed Spinney Mountain Reservoir can impound would depend on how full it was with other water at the time this water was available.

In 1974, Beck Associates developed a computer model to evaluate the effectiveness of Spinney Mountain Reservoir's regulation of its available water supplies under various operational regimes. This model used the 1942-1975 historic flows of the South Platte River at the project site. They concluded that for 28 years of reservoir operation, the lower limit of appropriations available under the 1973 storage right would be equivalent to 1,410 acre-feet per year with the upper limit being equivalent to 3,723 acre-feet annually. In any case, the amount this right yields will depend on the construction of the proposed Two Forks Reservoir which would have a senior storage appropriation if built. The City of Aurora purchased 5,000 acres of land for the Spinney Mountain Reservoir

Table 3-2 Potential 1950-70 Yield of the South Platte River Storage Right filed for the Spinney Mountain Reservoir Project in 1973 (Beck, 1974).

Year	Month		Storage Amount (acre-feet)
1958	May		3,886
	June		+4,393
		Total	8,279
1962	April		+2,872
		Total	2,872
1965	July		17,402
	August		22,470
	September		+ 4,056
		Total	43,928
1970	April		30,667
	May		27,032
	June		+ 6,082
		Total	63,781

site in 1973 but has delayed construction indefinitely due to funding uncertainties (Griswold, 1976).

The Two Forks Project - The Two Forks Dam and Reservoir, proposed by the Denver Water Department and the United States Bureau of Reclamation, would be located near South Platte, Colorado one mile downstream from the confluence of the North Fork with the mainstem of the South Platte River.

The dam would be a thin concrete double curvature arch type. It would have a maximum height of 584 feet, a crest length of 1,635 feet, and a spillway capacity of 38,000 cfs. The reservoir created would extend 19.3 miles upstream along the South Platte and 7.7 miles upstream along the North Fork. The total controlled capacity proposed is 860,000 acre-feet, with a corresponding to a surface area of 6,215 acres. A power plant to be associated with this structure would be a two unit installation with a name plate capacity of 138,000 kw.

This project also includes Turkshead Dam, located 1.9 river miles downstream from the Two Forks Dam. It would have a maximum height of 265 feet, a crest length of 750 feet and a spillway capacity of 40,370 cfs. This thin arch dam would create a reservoir having a total controlled capacity of 5,570 acre-feet with a surface area of 78 acres. Turkshead Dam would function as a diversion dam to deliver municipal and industrial water to existing and proposed municipal owned pipelines, and would serve as an after bay for the Two Forks Power Plant. Table 3-3 summarizes the pertinent statistical information.

The primary function of the project would be to provide terminal storage regulation for the present and future Colorado River Basin imports of Denver, which are diverted through the Harold D. Roberts Tunnel

Table 3-3 Two Forks Project Reservoir Data (U.S. Department of the Interior, 1974)

Item	Elevation (feet)	Capacity (acre-feet)	Surface Area (acres)
Top of flood pool	6533.0	975,000	6769
Top of conservation pool	6515.3	860,000	6215
Average annual maximum pool	6455.5	543,800	4449
Average annual minimum pool	6413.9	378,400	3523
Minimum pool	6339.7	175,000	2003
Dead storage	6250.0	55,000	847
Streambed	6015.0	-	-

Contributing drainage area: 2,585 square miles.
Design Flood: Peak inflow 99,300 cfs, 20-day volume 600,300 acre-feet.
100-year estimate of sediment: 3,900 acre-feet.
South Platte River miles from Cheesman Dam downstream to top of active capacity: 2.9 miles.
South Platte River miles from Cheesman Dam downstream to top of inactive capacity: 8.1 miles.

and which presently flow unregulated down the North Fork of the South Platte to the mainstem, and then to the Kassler and Marston Water Treatment plants. In addition, Two Forks would capture releases from Denver's upstream storage facilities on the South Platte and any unappropriated runoff as it occurs in this part of the basin.

The Denver Water Board owns two conditional decrees for the right to store South Platte River water in Two Forks Reservoir. It has gone to court at Fairplay, Colorado every two years to prove diligence by its continued planning and engineering studies and aquisition of property at the project site. The storage rights are for 145,133 and 191,235 acre-feet, with appropriation dates of January 18, 1905 and May 1, 1926 respectively (United States Department of the Interior, 1974).

In 1972, an operational study was made by the United States Bureau of Reclamation to portray Denver's water supply and demand conditions in the future with Two Forks in operation. The hydrologic and climatic data for the years May 1947 through April 1965 were used because this 18 year study period included important floods and droughts which resulted in the Two Forks controllable storage pool being operated through its full range of capacity.

Other assumptions applied to this model operation were:

1. There would be a demand for all water managed by the project, which was determined to average about 764,800 acre-feet per year.
2. The South Platte River, Bear Creek, and Clear Creek were managed as a part of the project water supply.
3. The storage capacities of Standley Lake and Gross Reservoir were increased to 42,000 and 113,100 acre-feet, respectively, by non-Federal development.

4. The operation of the existing system, consisting of reservoirs, tunnels, and other facilities, was completely integrated with the operation of Two Forks Reservoir.
5. The Denver Metropolitan Area distribution system included facilities for interchanging supplies from the several different sources.
6. Preliminary recommendations (1968) of streamflows by the Bureau of Sport Fisheries and Wildlife were utilized in the operation study.
7. Water rights in the Denver Metropolitan Area that are currently used for purposes other than municipal and industrial will be converted to M & I use in the future.

In the attempt of the Bureau of Reclamation to maximize the South Platte River water supplies through regulation, the historic and future "with project" South Platte River flows below the metropolitan area were also analyzed to determine when it would be possible to store water out of priority by replacing this stored water with unused tributary flows and sewage effluent from the metropolitan area. This procedure resulted in the exchange of these unused flows from the metropolitan area into Two Forks Reservoir for regulation to optimize Denvers available supplies.

It was found that Denver's total system would regulate an annual supply of 871,600 acre-feet of which 456,800 acre-feet would be from in basin sources (endogenous water) and 414,800 acre-feet would be from Colorado River imports (exogenous water) through the Moffat and Harold Roberts Tunnel. Losses from spills, required by passes, evaporation, and transportation would amount to 106,800 acre-feet per year, thus dropping the usable supply to 764,800 acre-feet per year.

Of the endogenous portion of this usable supply at Two Forks Reservoir, 79,700 acre-feet per year would be available from the North

Fork of the South Platte River, and 109,000 acre-feet per year would be available from the mainstem of the South Platte River. Therefore, with its existing conditional and absolutely decreed rights, and Two Forks on line, Denver could realize a total yield of 188,700 acre-feet per year from the South Platte-Mountains and the North Fork sub-basins. The Denver water department in 1975 stated that their existing absolutely decreed storage and direct flow rights on the South Platte River presently yield 104,500 acre-feet in an average year.

It appears then that with the construction of Two Forks Reservoir (combined with the other assumptions stipulated in the USBR's operational study, including the exchange of unused flows), an additional 84,200 acre-feet, which would otherwise have appeared as excess flows above and below Two Forks, can be realized from this project.

Engineering Consultants, Inc., stated in 1974 that Two Forks will better regulate the South Platte supplies available to Denver and will increase yields by approximately 20,000 acre-feet annually. This would be due to the storage rights associated with this project which would allow interception of flood waters otherwise unavailable to Denver. Therefore, for construction of Two Forks would allow Denver to exchange for its effluent and unused tributary flows, 64,200 acre-feet of the native surface water runoff of this sub-basin per year.

According to Mr. Larry Nelson of the Bureau of Reclamation, the Two Forks Reservoir is presently on an indefinite hold status. By his estimate, under the best of conditions, the project could come on line in 10 to 15 years.

Tarryall Creek Conditional Decree - In the October 10, 1974 revised tabulation of Colorado water rights, a conditional storage appropriation for 107,000 acre-feet of water from Tarryall Creek is listed. The priority date of this decree is April 28, 1891 and the uses filled for are irrigation, industrial, and domestic (Wilkinson, 1974). The status of this project is unknown.

3.1.4 *Potentially Developable Surface Water Runoff Remaining* - While there is adequate storage to regulate a substantial part of the flow of the South Platte River above Cheesman Reservoir, there are additional unappropriated peak flows downstream from both the North Fork and the mainstem (United States Department of the Interior, 1974). During nine months of the historic flows between 1950 and 1970, a free river condition existed above South Platte, Colorado (Beck Associates, 1974). A free river condition is issued by the State Engineer according to water districts. When the flows in a district are such that all of its absolutely decreed rights can be satisfied, a free river is called and all who can, may divert.

If Denver perfects her presently inactive rights by the construction of Two Forks, the physical storage capacity available to the South Platte River basin above South Platte, Colorado (includes both the North Fork and South Platte River-Mountains sub-basins), will have expanded to the point where virtually all of the excess flood flows presently occurring could be captured. Spills from the proposed Two Forks Reservoir would be rare and releases would be only to satisfy prior downstream rights or for use by Denver.

3.2 The North Fork of the South Platte River Sub-basin

The North Fork sub-basin encompasses the entire drainage area of 479 square miles of the North Fork of the South Platte River above USGS gaging station #06707000, "North Fork South Platte at South Platte, Colorado." Figure 3-4 depicts the sub-basin schematically. The gaging station is located 0.3 miles upstream from the confluence of the North Fork and the mainstem of the South Platte. The boundaries of the sub-basin coincide approximately with Irrigation District #80, which was partitioned from Irrigation District #23 in 1969.

3.2.1 *Physical Characteristics and Surface Water Runoff* - The North Fork of the South Platte River starts on the Continental Divide at elevations ranging to 14,000 feet. The river flows generally south-east to its confluence with the mainstem of the South Platte River near the town of South Platte (elevation 6,000 feet).

Its principal upper tributaries are Scott Gomer Creek and Geneva Creek, the lower tributaries are Elk, Deer, Buffalo, and Craig Creeks. The middle reach passes through a narrow valley and is fed by about ten intermittant gulches. The terrain is completely mountainous.

The average annual precipitation in the headwaters of the sub-basin is about 40 inches per year, and about 20 inches per year in the lower elevations (NOAA, United States Department of Commerce, 1974).

Most of the annual runoff occurs between May and July from the melting snowpack. Figure 3-5 shows the 1956-1961 maximum, mean and minimum daily flows of the North Fork near the town of South Platte, Colorado. These composite hydrographs are typical of the Front Range mountain streams.

Table 3-4 shows the average, maximum and minimum instantaneous discharges (in cfs), and the average and maximum and minimum yearly runoffs (in acre-feet) recorded at the gaging station at the mouth of this sub-basin. These values provide indications of the natural variability of the surface water runoff of this sub-basin as there is very little water

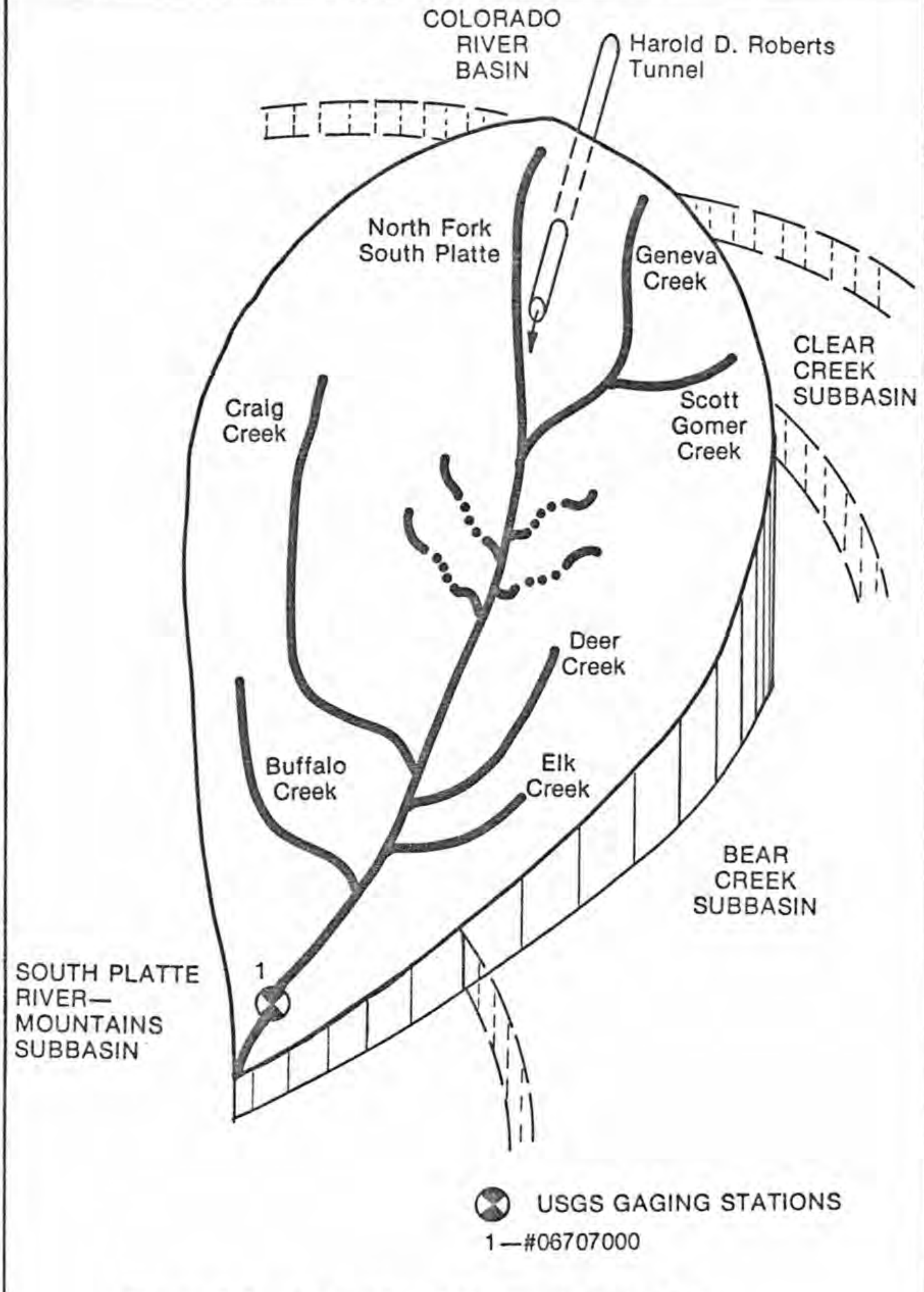


Figure 3-4: Schematic of the North Fork of the South Platte River Subbasin.

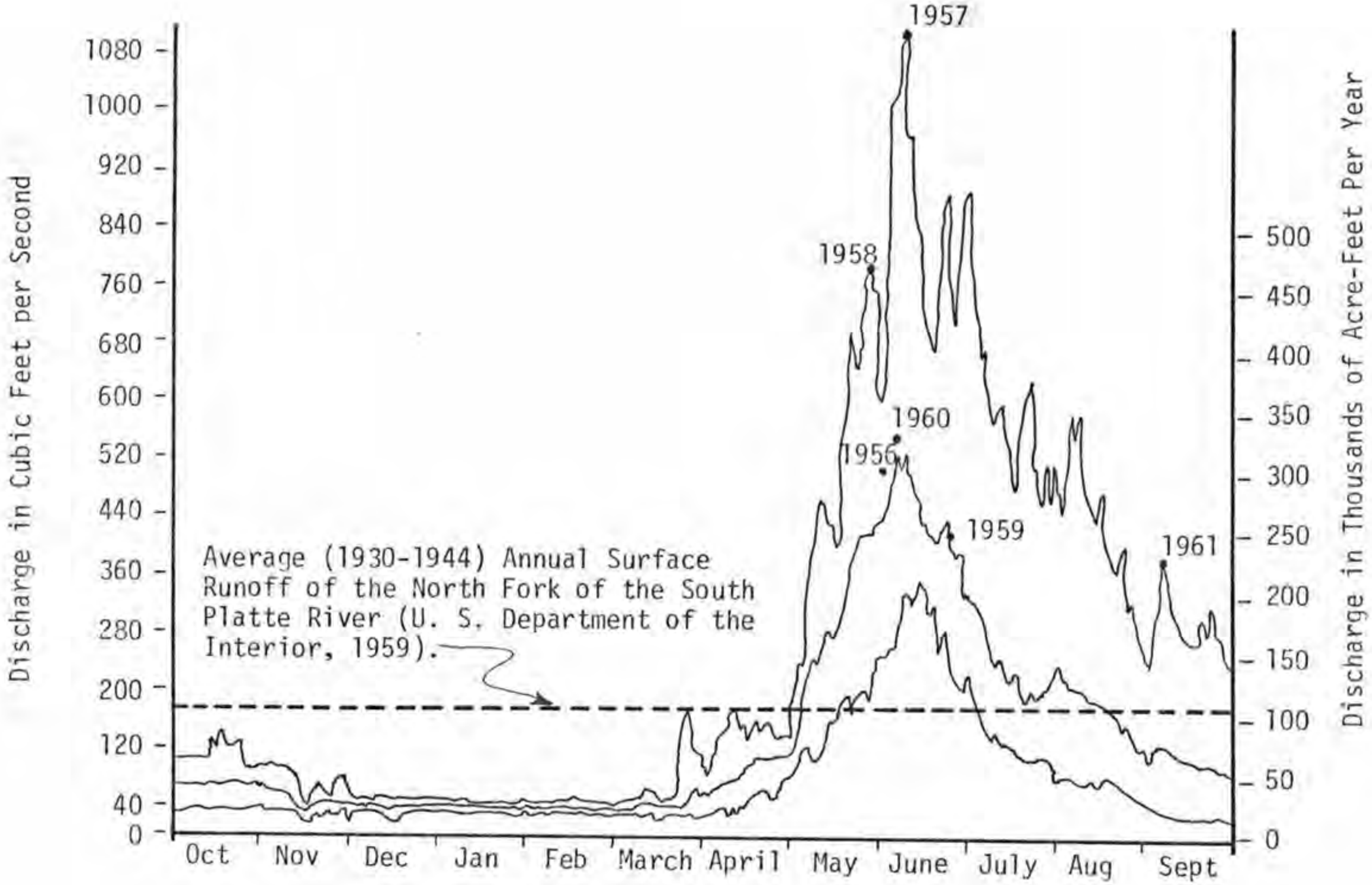


Figure 3-5: Maximum, Mean, and Minimum Daily Flows of the North Fork of the South Platte River between 1956 and 1961 (International Engineering Company, Inc. et. al. April, 1973)

Table 3-4. Surface Water Runoff Variability within the North Fork of the Surface Platte River Sub-basin as Indicated by the Extremes of the Flow Records of the USGS Gaging Station #06707000.

Gaging Station Location	Period of Record	Recorded Discharge					Annual Runoff				
		Average	Maximum instantaneous		Minimum instantaneous		Average	Maximum		Minimum	
		Cfs	Cfs	Date	Cfs	Date	Acre-feet	Acre-feet	Water Year	Acre-feet	Water Year
#06707000, "North Fork South Platte River at South Platte, Colorado"1/	June 1909-Sept. 1910, April 1913-Sept. 1975	163.6	2,050	June 13, 1949	4.0	Dec. 8, 1932	118,366	247,000	1914	40,650	1961

1/Appendix C, Table C4-1

resources development above this gaging station. However, its flow records include some imports from the Colorado River Basin, through the Harold D. Roberts Tunnel.

Table 3-5 shows the North Fork of the South Platte's probable flood discharges at Grant, Colorado for various frequencies of occurrence. The river at this point drains approximately the upper third of the sub-basin.

Table 3-5. Flood Characteristics of the North Fork of the South Platte River at Grant, Colorado (McCain and Jarrett, 1976).

[Flood discharges for each gaging station are: (first line) values used in multiple regression analysis, (second line) weighted averages]

Station Number	Station Name	Period of record, in years	Drainage area, in square miles	Gage datum, in feet above mean sea level	Basin slope, in feet per mile	Streambed slope, in feet per mile	Mean annual precipitation, in inches	10-Year flood discharge, in cubic ft per second	50-Year flood discharge, in cubic ft per second	100-Year flood discharge, in cubic ft per second	500-Year flood discharge, in cubic ft per second	100-Year flood discharge in feet
06706000	North Fork South Platte River Below Geneva Creek, at Grant, Colo.	30	127	8561	220	69	26	778	1100	1240	1550	2.6

The native surface water runoff of the North Fork of the South Platte River was estimated from the 1914-1975 flows recorded at the USGS Gaging Station #06707000, "North Fork South Platte at South Platte, Colorado, "seen in Appendix C, Table C4-1. In assessing the native surface water runoff the man-caused upstream effects were taken into account. Table A4-4 Appendix A shows the computations involved. From this process, the long term average native surface water runoff of this sub-basin is estimated to be 112,604 acre-feet per year.

The 1970 water year native surface water runoff of the North Fork of the South Platte River Sub-basin was estimated in Table A4-2, Appendix A to have been 198,680 acre-feet, or 176.4% of the long term average. The native surface water runoff of this sub-basin during the 1953-1956 four year drought period was estimated in Table A4-3, Appendix A to have averaged 64,286 acre-feet per year, or 57.1% of the long term average.

The outlfow from this sub-basin, the unused portion of its native surface water runoff, plus imports through the H. D. Roberts Tunnel contributes to the surface water supplies of the South Platte River-Mountains sub-basin. The upstream depletions are very minor and have little effect on runoff.

3.2.2 *Existing Development of the Surface Water Runoff* - According to the Colorado water rights tabulation of October 10, 1974 there are approximately 300 absolutely decreed water rights dependent of the surface flows of this sub-basin. Generally, the direct flow rights of this sub-basin are for less than 2.0 cfs. Storage rights, comprising approximately 15 percent of the total number of decrees, generally for less than 50 acre-feet. Most of these water rights are for irrigation; the acreage irrigated is very minor. United States Soil Conservation land use maps (1972-1973) show no irrigated acreage within the North Fork of the South Platte River sub-basin at all. Table 3-6 lists the number of absolutely decreed ditch and storage rights on the mainstem of the North

Fork of the South Platte River and on some of its more heavily appropriated tributaries.

Table 3-6 Absolutely Decreed Water Rights on the More Heavily Appropriated Streams of the North Fork of the South Platte River Sub-basin (Wilkinson, 1974).

Stream	Number of Absolutely Decreed Water Rights	
	Ditch	Storage
Scott Gomer Creek	3	0
Geneva Creek	3	4
Starvation Gulch	8	5
Deer Creek	23	1
Elk Creek	17	1
Mainstem of the North Fork of the South Platte River	25	3
Total	79	14

There are no diversion structures which export the native surface water runoff of this sub-basin to other watersheds. There is one diversion structure which imports water to this sub-basin, the Harold D. Roberts Tunnel, which diverts water from the Blue River Sub-basin in the Colorado River Basin to the mainstem of the North Fork of the South Platte River just above Grant, Colorado. This structure is owned by Denver and its imports are used by that city for municipal and industrial purposes. While these imports have presently averaged 31,585 acre-feet per year (Appendix B, Table B3-8), proposed imports could be substantially larger, i.e., equivalent to two and one-half times the average annual native surface runoff of this sub-basin.

3.2.3 *Potentially Developable Surface Water Runoff Remaining* - Very little of the surface runoff naturally accruing the North Fork of the South Platte River is used within its sub-basin boundaries. Rather, this sub-basin generates the surface flows that satisfy appropriators downstream along the mainstem of the South Platte. Occasionally, excess flows occur in the spring, and because demands are not great enough at that time, the flow may reach the Colorado-Nebraska state line and be lost to Colorado. Storage could, of course, capture such flows for beneficial use.

Within this sub-basin there are nine conditional decrees for this water. The largest of these has been claimed for a proposed Craig Meadows Reservoir. This reservoir would be located on Craig Creek which drains approximately 20 percent of the middle southern edge of the sub-basin. Its storage right for 15,000 acre-feet has an appropriation date of June 12, 1962, an adjundication date of November 15, 1971, and a previous adjudication date of March 29, 1953 (Wilkinson, 1974). The status of this project is unknown.

Since this sub-basin is located near the head of the South Platte River Basin, when unappropriated water does occur, there are several hundred river miles downstream in Colorado where it is also potentially available for appropriators. Denver presently has a conditional storage right for this water. It proposes to capture these flows, along with others, in the proposed Two Forks Reservoir which would be located on the mainstem of the South Platte just below the mouth of this sub-basin (see Section 1.3.3).

CHAPTER 4

FRONT RANGE TRIBUTARIES ON THE TRANSITION MAINSTEM

The Front Range tributaries are identified in Figure 3-1 under the sub-basins of Group 2. They are: Bear Creek, Clear Creek, Boulder Creek, Saint Vrain Creek, the Big Thompson River and the Cache La Poudre River. These tributaries, along with the mountains mainstem and Plum Creek and Cherry Creek, all feed into the South Platte River - Transition. The latter is defined as that reach of the South Platte mainstem between Waterton and Kersey. The above named sub-basins of the Front Range Tributaries group encompass 5,790 square miles, draining 26.93% of the South Platte River basin study area. About 160 square miles of one of the sub-basins in this group, the Cache La Poudre, is in Wyoming. As summarized Table 4-1, their native surface water supply averages 854,077 acre-feet per year, or 63.9% of the total estimated average annual native runoff of the entire study area. All of the tributaries of this group start among the high peaks of the Continental Divide. They generally flow east to the foothills and out through narrow canyons, and then flow over broadly terraced plains, meeting the "Transition - South Platte" which flows generally north from Waterton to Greeley.

Most of the precipitation in the Front Range tributaries occurs as winter snowfall in the higher elevations, which may reach as high as 200 inches. These streams are perennial; most of their annual runoff occurs during the spring snow melt.

The precipitation in the plains portion of these sub-basins is about 14 inches per year. About 70 percent occurs during the spring and summer.

The Transition - South Platte, it should be noted, is mainly a collector stream whose hydrologic characteristics reflect the flows from

Table 4-1 Average Annual Native Surface Water Runoff of the South Platte River-Transition and its Front Range Tributaries in Sub-basin Grouping Number Two[1/]

		Average Annual Native Surface Water Runoff (acre-feet/year)				
			1970 Water Year		1953-56 Drought Period Average	
Sub-basin	Drainage Area (square miles)	Long Term Average	Annual Flow	% of Long Term Average	Annual Flow	% of Long Term Average
Bear Creek	214	44,927	76,244	169.7	19,817	44.1
Clear Creek	448	173,944	225,362	129.5	114,784	60.0
Boulder Creek	439	122,832	162,914	132.6	83,824	68.2
Saint Vrain Creek	537	117,600	131,549	111.9	74,820	63.6
Big Thompson River	828	147,600	177.066	119.9	93,903	63.6
Cache La Poudre River	1,877	234,833	321,220	136.8	158,066	67.3
South Platte River-Transition	1,447	12,341	9,074	73.5	5,133	41.6
TOTAL	5,790	854,077	1,103,429	129.2	550,347	66.4

1/ Appendix A

its tributaries as well as the effects of numerous diversions and return flows.

4.1 The Bear Creek Sub-basin

The Bear Creek sub-basin is defined here as that drainage area of Bear Creek above USGS gaging stations #06710500, "Bear Creek at Morrison, Colorado," and #7110, "Turkey Creek near Morrison, Colorado." Figure 4-1 is a schematic drawing of Bear Creeks entire hydrological drainage area. The portion of Bear Creek drainage below these gaging stations, which amounts to about 18% of the total drainage, is included in the South Platte - Transition sub-basin, however, it will be discussed here. The hydrological drainage of Bear Creek coincides fairly closely with the boundaries of Irrigation District #9.

4.1.1 *Physical Characteristics and Surface Water Runoff* - Bear Creek originates near the Clear Creek-North Fork South Platte divide on the east slope of Mount Evans. From elevations of approximately 14,000 feet, the stream flows about 44 miles east to the plains where it joins the South Platte. The confluence occurs just above Denver, at an elevation of 5,295 feet. The streams upper 33 miles within the Front Range and foothills, above elevations of 5,700 feet, are included in the Bear Creek sub-basin.

Clear Creek has three major tributaries. Two of them, Vance and Pedee Creeks, are located entirely within the sub-basin boundaries. The third, Turkey Creek, joins the mainstem of Bear Creek in the plains. Only the lower reach of Turkey Creek is excluded from the definition of the Bear Creek sub-basin.

Bear Creek drains an area of 260 square miles. The upper 82% or that portion above USGS Gaging Stations 7110 and 06710500 drains 214

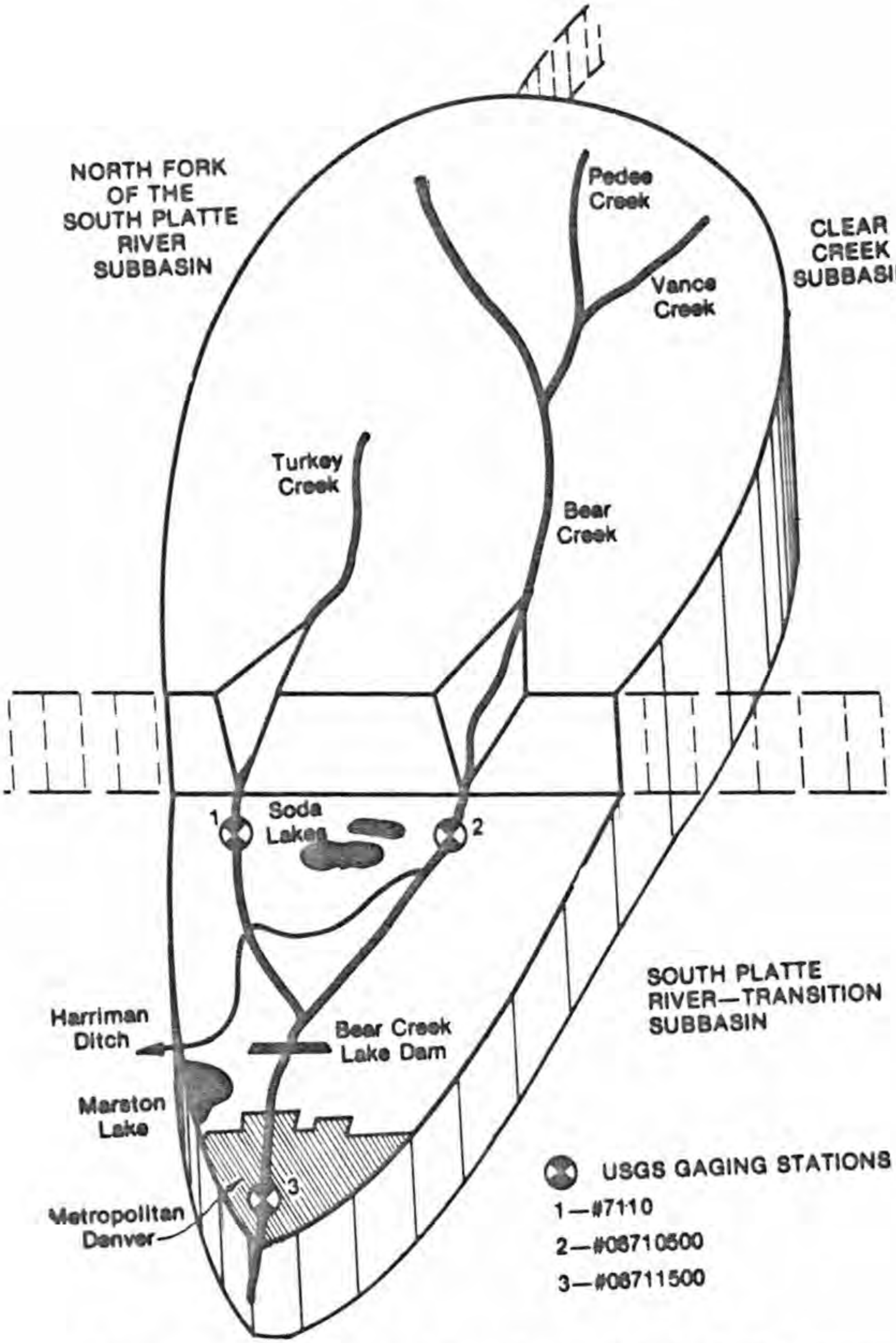


Figure 4-1: Schematic of Bear Creeks Hydrological Drainage Area

square miles of rugged mountainous terrain. The lower 46 square miles is comprised of rolling plains; it contributes only a small amount of flow. Most of the diversions and consumptive uses occur in the plains reach.

The average annual precipitation in the headwaters is about 40 inches per year and about 14 inches per year in the plains (NOAA, United States Department of Commerce, 1974). The surface water runoff of Bear Creek is characteristic of all the Front Range tributaries. It is derived principally from melting snow at high elevations and occurs during the May-July period.

A small portion of lower Bear Creek is highly urbanized, lying within metropolitan Denver. As a result of this development within the watershed, much of the precipitation in this portion becomes surface runoff.

Since 1876 22 floods have been recorded on the mainstem of Bear Creek in its plains reach. The most devastating of these occurred on September 2, 1938 and was caused by the rapid runoff of a high-intensity rainfall in the foothills area. It caused damages of $648,000 and claimed six lives (United States Army Corps of Engineers, 1975).

Table 4-2 shows the average, maximum instantaneous and minimum daily discharges (in cfs) and the average, maximum and minimum yearly runoffs (in acre-feet) recorded at the three gaging stations within the Bear Creeks drainage area. The extremes of the records of the gaging stations located in the foothills near the canyon mouths of Bear Creek and its tributary Turkey Creek, provide indications of the natural variability of the surface water runoff of these creeks. There is very little water resource development above these gaging stations.

Table 4-2 Surface Water Runoff Variability Within the Bear Creek Sub-basin as Indicated by the Extremes of the Flow Records of Several Key Gaging Stations.

Gaging Station and Location	Period of Record	Recorded Discharge					Recorded Annual Runoff				
		Average	Maximum instantaneous		Minimum Daily		Average	Maximum		Minimum	
		Cfs	Cfs	Date	Cfs	Date	Acre-feet	Acre-feet	Water Year	Acre Feet	Water Year
#06710500, "Bear Creek at Morrison, Colorado" (near its canyon mouth)1/	Sept. 1887-Sept. 1891, May 1895-Dec. 1901, Feb. 1902, Oct. 1919-Sept. 1975	53.8	8,600	July 24, 1896	0.8	Nov. 26, 1939	38,932	90,490	1942	10,550	1954
#7110, "Turkey Creek near Morrison, Colorado" (near its canyon mouth)2/	June 1942-Sept. 1946 March 1947 Sept. 1953	4.3	1,200	Aug. 24, 1946	0.0	Various Dates	3,079	7,900	1944	503	1945
#06711500, "Bear Creek at mouth, at Sheridan, Colorado"3/	April-Nov. 1914, March 1927-Sept. 1975	38.8	8,150	May 7, 1969	0.0	July 13, 1954	28,103	98,490	1942	4,730	1954

1/Appendix C, Table C4-4
2/Appendix C, Table C4-5
3/Appendix C, Table C4-6

Comparison of the records of the gaging station at the mouth of Bear Creeks to those of the two at the edge of the foothills, reveal the role of diversion in the plains reach.

The native surface water runoff of the Bear Creek sub-basin was estimated from the flow records of the USGS Gaging Stations number 06710500, "Bear Creek at Morrison, Colorado" (Appendix C, Table C4-4), and number 7110 "Turkey Creek near Morrison, Colorado" (Appendix C, Table C4-5). Below these gaging stations, the surface water runoff is negligible. In assessing the native surface water runoff man-caused upstream effects (i.e., diversions and return flows) were taken into account.

The long term average native surface water runoff of the Bear Creek sub-basin was estimated, from Table A4-13, Appendix A, to be 44,927 acre-feet per year. This was determined by adjusting the records of gaging station #06710500 for the period of water years 1920-1975 and gaging station #7110 for 1930-1949, to account for man-caused effects.

The native surface water runoff of the Bear Creek sub-basin for the 1970 water year was estimated to be 76,244 acre-feet, or 169.7% of the long term average, as seen in Table A4-14, Appendix A.

The native surface water runoff during the 1953-1956 four year drought period was estimated to be 19,817 acre-feet per year, or 44.1% of the long term average, as seen in Table A4-15, Appendix A. The records of these gaging stations for the water years 1953-1956 were used in making this determination, along with information relative to man-caused effects upstream.

The surface water outflow of the Bear Creek sub-basin contributes to the surface water supplies of the South Platte River-Transition sub-basin. As there is very little consumptive use within the Bear Creek sub-basin, virtually its entire native surface water supply flows out and is available to users downstream.

The surface water outflow from Bear Creeks hydrological drainage can be measured at the USGS gaging station #06711500, "Bear Creek at Mouth, near Sheridan, Colorado," (Appendix C, Table C4-6). The 1928-1975 48 year average annual recorded discharge of this gaging station was 28,103 acre-feet.

4.1.2 *Existing Development of the Surface Water Runoff*

Direct Diversion Structures - In 1959 the United States Bureau of Reclamation reported that there were 21 major decreed direct flow rights for the surface water supplies of Bear Creek. These appropriations totaled 1,167 cfs, which is equivalent to approximately 844,900 acre-feet per year.

The 1974 revised tabulation of Colorado water rights lists nearly 250 absolute and conditional ditch right decrees for the surface flows of the Bear Creek drainage. Water from the mainstem of Bear Creek is appropriated by 86 of these direct flow rights decrees, whereas 18 pertain to Turkey Creek. Vance and Pedree Creeks are appropriated by 18 and six ditch rights respectively. The remainder of the direct flow rights in Beer Creeks hydrological drainage are supported by its various minor tributaries.

There are no diversion structures which import water to the Bear Creek drainage from other watersheds. There are no major diversion structures which export the native surface water runoff of the mainstem of Bear Creek or its tributaries to uses outside of the Bear Creek drainage area.

However, at the fringes of the lowe Bear Creek drainage area irrigation in the area may use water diverted from neighboring South Platte tributaries. In this area also, some agricultural ditches which divert suface water from Bear Creek and tributaries extend just over the boundary and irrigate a few small tracks of land in the outer fringes of the neighboring drainage areas. These amounts of water involved are small. Diversions of surface water from Bear Creeks hydrological drainage therefore, are for uses almost exclusively within its boundaries.

The 1970 State Engineers annual report showed that a total of 16,814 acre-feet of water had been diverted from the Bear Creek drainage (Irrigation District #9) in the 1969-1970 water year. Fifteen ditches were responsible for these diversions which represents approximately 22% of the estimated 1970 native surface water runoff of this drainage area. While the list is not complete, it does include all major diversions. Most of the water diverted was used for irrigation. The diversions probably include some return flows from prior uses. A minor portion of this diverted water was exported from the drainage area.

The most important diversion structure on Bear Creek is the Harriman Ditch, which has 12 absolutely decreed direct flow rights for water from Bear and Turkey Creeks totaling 488.9 cfs; Table 4-3 lists these rights. Six of these rights have been decreed permission for an alternative point of diversion.

The McBroom Ditch is another important one. It has the second most senior direct diversion water right in the entire South Platte River Basin, having a priority date of November 1, 1859 for 11.58 cfs from the mainstem of Bear Creek (Wilkinson, 1974). The uses that have been filed for this water are irrigation and municipal.

Table 4-3 Water Rights Held by the Harriman Ditch (Wilkinson, 1974).

Source	Type	Use	Amount	Type Adjudication	Adjudication Date	Previous Adjudication Date	Appropriation Date	Basin Rank
Turkey Creek	D	I	14.4150 cfs	S	09/24/1935	02/04/1884	02/01/1890	995
Turkey Creek	D	MD	4.8050 cfs	0	09/24/1935		02/01/1890	995
Turkey Creek	D	MD	29.9700 cfs	0	09/24/1935		02/01/1890	995
Turkey Creek	D	I	13.5300 cfs	S	09/24/1935	02/04/1884	08/15/1892	1067
Turkey Creek	D	MD	4.5000 cfs	0	09/24/1935		08/15/1892	1067
Turkey Creek	D	MD	18.0300 cfs	0	09/24/1935		08/15/1892	1067
Bear Creek	D	I	76.5000 cfs	S	09/24/1935	02/04/1884	12/05/1889	991
Bear Creek	PL	I	76.5000 cfs	S,AP	09/24/1935	02/04/1884	12/05/1889	991
Bear Creek	PL	MD	25.5000 cfs	0,AP	09/24/1935		12/05/1889	991
Bear Creek	D	MD	25.5000 cfs	0	09/24/1935		12/05/1889	991
Bear Creek	PL	MD	148.35 cfs	0,AP	09/24/1935		12/05/1889	991
Bear Creek	D	MD	148.35 cfs	0	09/24/1935		12/05/1889	991
Bear Creek	PL	I	57.4900 cfs	S,AP	09/24/1935	02/04/1884	08/15/1892	1067
Bear Creek	D	I	57.4900 cfs	S	09/24/1935	02/04/1884	08/15/1892	1067
Bear Creek	D	MD	19.1600 cfs	0	09/24/1935		08/15/1892	1067
Bear Creek	PL	MD	19.1600 cfs	0,AP	09/24/1935		08/15/1892	1067
Bear Creek	PL	MD	76.6500 cfs	0,AP	09/24/1935		08/15/1892	1067
Bear Creek	D	MD	76.6500 cfs	0	09/24/1935		08/15/1892	1067

<u>Key</u> Type: D = Ditch, PL = Pipeline
Use: I = Irrigation, M = Municipal, D = Domestic.
Type Adjudication: S = Supplemental, 0 = Original, AP = Alternate Point.

Denver presently owns 29 absolutely decreed direct flow rights to water from Bear and Turkey Creeks worth about 490 cfs. This includes 409.56 cfs of the rights to the Harriman Ditch (Denver Water Department, 1975). Most of these rights were formerly owned by agricultural irrigators. Presently these rights are not interfaced with Denver's water supply system, but they are a reserve water supply source.

Storage Facilities - In 1959 the United States Bureau of Reclamation reported that there were 16 reservoirs whose rights were dependent on the native surface water runoff from the Bear Creek drainage area. Their decreed storage rights were worth 31,000 acre-feet.

The 1974 revised tabulation of Colorado water rights lists over 60 absolute and conditional storage decrees for the surface flows of the Bear Creek drainage. Some 32 of these rights are for water from the mainstem of Bear Creek, while nine are for water from the mainstem of Turkey Creek. There are no reservoirs having decrees for surface water runoff from Vance or Pedee Creeks. The remainder of the storage appropriations in the Bear Creek drainage are supported by various minor tributaries.

Table 4-4 lists the major reservoirs having absolutely decreed storage rights to the Bear Creek drainage and their amounts in storage during the 1970 water year. These 17 reservoirs comprise most of the existing storage capacity associated with the runoff from Bear Creek. The amount of storage in these reservoirs on May 1, 1970 totaled 9,576 acre-feet, which represents about 21% of the estimated average annual native surface water yield of the drainage area.

These reservoirs are used primarily for the storage of irrigation water supplies. Most of them are located within the Bear Creek drainage

Table 4-4 Amounts of Water in Storage During the 1970 Water Year of the Major Reservoirs with Absolutely Decreed Storage Rights to the Native Surface Water Runoff of Bear Creeks Hydrological Drainage Area (Division 1 Water Commissioners, 1970).

Name	Source	Amount in Storage (Acre-feet)		
		11-1-64	5-1-70	10-31-70
Harwood	Turkey Creek	110	-100	100
Deane	Turkey Creek	400	-518	315
Bergen No. 1 (East)	Turkey Creek	250	-512	70
Bergen No. 2 (West)	Turkey Creek	490	-890	490
Subtotal	Turkey Creek	1,250	1,980	975
Soda No. 1 (West)	Bear Creek	240	245	240
Soda No. 2 (East)	Bear Creek	1,280	1,500	1,450
Kendrick	Bear Creek	50	150	120
Carmody	Bear Creek	0	0	0
Johnston	Bear Creek	340	650	500
Bowles	Bear Creek	1,500	2,000	1,700
Ward	Bear Creek	900	950	850
Harriman	Bear Creek	525	550	515
Henry Lake	Bear Creek	150	165	150
Grant A (West)	Bear Creek	30	70	58
Grant B (South)	Bear Creek	130	150	130
Grant C (East)	Bear Creek	60	66	66
Patrick	Bear Creek	230	1,100	750
Subtotal	Bear Creek	5,435	7,596	6,529
Grand Total	Entire Bear Creek Drainage Area	6,685	9,576	7,504

Note: Some of these reservoirs are located outside of Bear Creeks hydrological drainage area and have additional absolutely decreed storage appropriations to the surface water runoff of other water sheds. Therefore, the amounts in storage above do not necessarily reflect only the yield from these reservoirs rights to surface water from the Bear Creek drainage.

area, in off-stream shallow depressions in the plains area. The largest is the Bowles Reservoir located to the south and just outside of the Bear Creek drainage area. It has an absolutely decreed storage right for 2,110 acre-feet of water from Bear Creek with an appropriation date of May 10, 1876. The basin priority rank of this right is 425 and the use filed for this water is irrigation (Wilkinson, 1974). The Bowles reservoir also has an absolutely decreed storage right for an enlargement of its storage capacity made in the 1880's. This right is for 363 acre-feet of water from Bear Creek and its appropriation date is March 9, 1883 (Wilkinson, 1974). This water is also used for irrigation. The water yielded by these rights is delivered by the Bowles Lateral off of the Harriman Ditch. The next largest reservoirs are the Soda Lakes, located inside of the Bear Creek Drainage next to the foothills between Bear Creek and Turkey Creek. These two reservoirs are presently owned by Denver; they have absolutely decreed storage appropriations for 589 and 1,794 acre-feet from Bear Creek, both with appropriation dates of February 2, 1893.

From USGS topographic maps it was found that in addition to the Bowles Reservoir, the Johnson, and Grant A, B, and C Reservoirs lie on or outside the southern boundary of Bear Creeks drainage area. The Kendrick Reservoir lies to the north and also outside of this drainage area. While the primary source of water for these reservoirs is from Bear Creek (which is delivered by agricultural ditches and canals), some depend also on storage appropriations of water from the minor intermittant South Platte tributaries of the drainage areas in the plains where they are located.

There are no reservoirs located entirely inside of Bear Creeks hydrological drainage that store water imported from other watersheds. However, Marston Reservoir is located near the southern edge of the Bear Creek drainage area. It receives water through the Denver municipal aquaduct which diverts water from the mainstem of the South Platte. This reservoir, which stores and regulates water to be treated at Denvers Martson water treatment plant also has a conditional storage right for water from the mainstem of Bear Creek. The decreed amount is 19,800 acre-feet and the appropriation date is August 15, 1892 (Wilkinson, 1974). Denver presently considers this right on active reserve.

In October of 1973, construction began on the 143 foot high, 4,100 foot long Bear Creek Lake Dam. This earth filled structure is located on the mainstem of Bear Creek just below its confluence with Turkey Creek, about eight miles upstream from the South Platte River. The impoundment will have a total capacity of 52,000 acre-feet. This includes 26,000 acre-feet for flood control, 2,400 acre-feet for sediment control, and 23,600 acre-feet for recreation (United States Army Corp of Engineers, 1975). This project is 95 percent complete.

4.1.3 *Potentially Developable Surface Water Runoff Remaining* - The United States Department of the Interior reported in 1959 that demands for surface water within Bear Creeks drainage area had generally been met. However, these appropriators are required to leave enough water flowing to meet prior downstream rights on the South Platte River.

Additional surface water supplies, in the form of unappropriated flood flows, occur within the Bear Creek drainage on the average of once in every five years. The United States Army Corp of Engineers (1975) state that 22 floods have occurred here since 1876. However, their is not sufficient storage in the Bear Creek drainage area to impound these flows.

Bear Creek Lake will impound most of these flows to prevent flood damage; however, they will be released immediately afterwards in accordance with operational policies. Thus the additional water will not be available for users in the Bear Creek Drainage during times of low flows. Downstream appropriators, along the mainstem South Platte, may benefit if they can capture these regulated releases before they leave the basin at large.

The nature of water use in Bear Creeks drainage area is rapidly changing as urban expansion from the metropolitan Denver area displaces irrigated agriculture. Denver is acquiring both direct flow and storage rights to the water from Bear Creek and to the tributaries that had formerly been used by irrigators. These rights are on active reserve and presently are not interfaced with Denver's water supply system.

4.2 The Clear Creek Sub-basin

The Clear Creek sub-basin is defined here as the Clear Creek drainage area located above USGS gaging station #06719500 "Clear Creek at Golden, Colorado," plus that of its tributary, Ralston Creek, above where it issues onto the plains. Figure 4-2 is a schematic drawing of Clear Creek's entire drainage area. That portion of the Clear Creek drainage below these points, about 22% of the total, is included in the South Platte River Transition sub-basin, but will be included in the present discussion. The Clear Creeks drainage coincides approximately with the boundaries of Irrigation District #7.

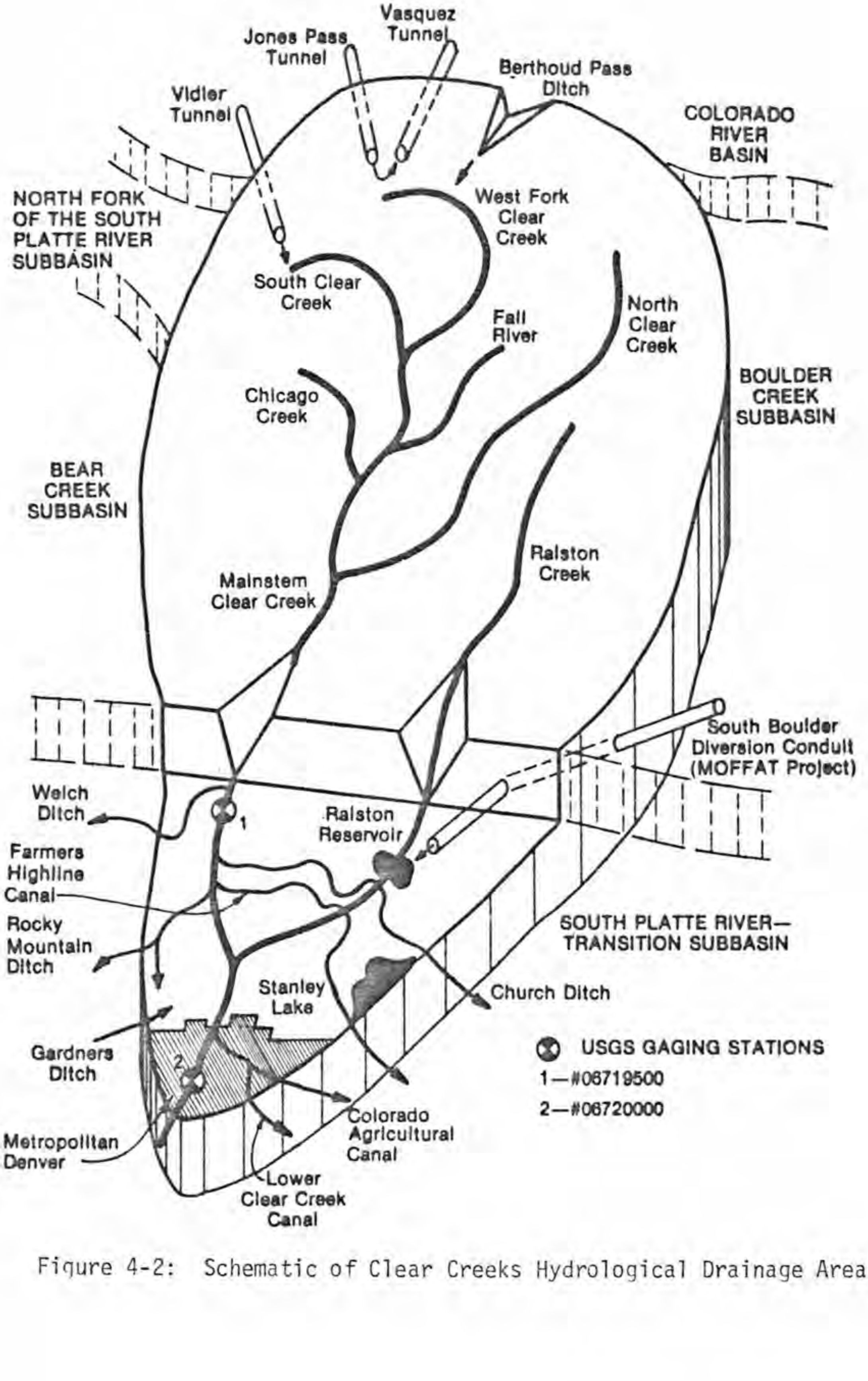


Figure 4-2: Schematic of Clear Creeks Hydrological Drainage Area

4.2.1 *Physical Characteristics and Surface Water Runoff* - Clear Creek, the second largest tributary of the South Platte River, has its origin on the east slope of the Continental Divide. From elevations of about 14,000 feet it flows generally east, through narrow valleys and steep rocky canyons, to the plains and its confluence with the South Platte. This juncture occurs about three miles downstream from Denver at an elevation of 5,110 feet. In its 67 mile course, Clear Creek loses more than 8,500 feet elevation. The upper 50 miles within the Front Range Mountains and the foothills, above elevation of 5,735 feet, are included in the Clear Creek sub-basin definition.

Clear Creek has six major tributaries. Five of them, North Clear Creek, South Clear Creek, the West Fork of Clear Creek, Chicago Creek, and Fall River, are located entirely within the sub-basin. The other tributary, Ralston Creek, joins the mainstem of Clear Creek in the plains. Only the portion of Ralston Creek above Ralston Reservoir is included in the Clear Creek sub-basin definition.

Clear Creek drains in area of 575 square miles of which the upper 78% or 448 square miles, are located within the above definition of the Clear Creek sub-basin. This portion is comprised of rugged mountainous terrain. The other 127 square miles of the Clear Creek drainage is comprised of rolling plains, and is defined as a part of the South Platte River Transition sub-basin. Most of the diversions from Clear Creek are from these lower reaches.

The average annual precipitation in the headwaters of the Clear Creek drainage is about 40 inches per year, and about 14 inches per year in the lower elevations on the plains (NOAA, United States Department of Commerce, 1974). Clear Creek and its major tributaries are snow-fed from high altitudes where the annual snowfall averages from 70 inches upward. About 75 percent of the annual runoff occurs in the May-July period.

Very little water accrues to the plains reach of Clear Creek. However, a portion of the Clear Creek sub-basin in the plains is highly urbanized (i.e., Arvada and Wheatridge). As a result of this development within the watershed, much of the rainfall here becomes surface runoff.

Table 4-5 shows the average, maximum instantaneous and minimum daily discharges (in cfs), and the average maximum and minimum yearly runoffs (in acre-feet) recorded at two key gaging stations within Clear Creeks drainage area. These records are indicative of the natural variability of the surface water runoff of this creek. There is very little water resource development above the gaging station at Golden. However, its flow records include some minor imports from the Colorado River Basin. There are also some minor diversions from the Clear Creek drainage above this gaging station. Considerable diversions occur in the plains reaches which is seen by comparing flow data between the two gaging stations in Table 4-5.

Table 4-6 shows the probable flood discharges of Clear Creek at Lawson, Colorado. The river at this point drains approximately the upper 25% of Clear Creeks drainage area.

The native surface water runoff of the Clear Creek sub-basin was estimated from the flow records of the USGS gaging station #06719500, "Clear Creek at Golden, Colorado," these records are seen in Table C4-10 of Appendix C. Below this gaging station, located near Clear Creeks canyon mouth, the surface runoff accruals were assumed negligible.

Table 4-5 Surface Water Runoff Variability Within the Clear Creek Sub-basin as Indicated by the Extremes of the Flow Records of Several Key Gaging Stations.

Gaging Station and Location	Period of Record	Recorded Discharge					Recorded Annual Runoff				
		Average	Maximum instantaneous		Minimum Daily		Average	Maximum		Minimum	
		Cfs	Cfs	Date	Cfs	Date	Acre-Feet	Acre-Feet	Water Year	Acre-Feet	Water Year
#06719500, "Clear Creek near Golden, Colorado" (near its canyon mouth[1/]	Oct. 1908-Dec. 1909, June 1911-Sept. 1975	230.4	5,890[3/]	Sept. 9, 1933	10.0	March 4, 1966	166,819	306,000	1914	66,630	1954
#06720000, "Clear Creek at mouth, near Derby, Colorado"[2/]	April-Nov. 1914, March 1927-Sept. 1975	93.6	5,070	July 24, 1965	0.4	March 11, 1943	67,741	179,800	1965	12,100	1954

1/Appendix C, Table C4-10.
2/Appendix C, Table C4-11.
3/Maximum discharge since at least 1867, 8,700 cfs. August 1,1888, from reports of State Engineer of Colorado for station 5.5 miles upstream, (USGS, 1975).

Table 4-6 Flood Characteristics of Clear Creek at Lawson, Colorado (McCain & Jarrett, 1976).

Flood discharges for each gaging station are: (first line) values used in multiple regression analysis, (second line) weighted averages.

Station Number	Station Name	Period of record, in years	Drainage area, in square miles	Gage datum, in feet above mean sea level	Basin slope, in feet per mile	Streambed slope, in feet per mile	Mean annual precipitation, in inches	10-Year flood discharge, in cubic ft per second	50-Year flood discharge, in cubic ft per second	100-Year flood discharge, in cubic ft per second	500-Year flood discharge, in cubic ft per second	100-Year flood depth, in feet
06716500	Clear Creek near Lawson, Colo.	25	145	8080	170	327	26	1750 1710	2280 2220	2490 2420	2950 2890	6.2

There is not now and has never been a USGS gaging station to measure the flows of Ralston Creek. The surface water runoff from Ralston Creek was estimated from records of diversions from the stream.

The long term average annual native surface water runoff of the Clear Creek sub-basin was estimated to be 173,994 acre-feet per year; Table A4-16, Appendix A shows the computations. The 1912-1975 records of the gaging station at Golden were adjusted by adding the computed average annual contribution of Ralston Creek, and allowing for diversions and other man-caused effects.

The native surface water runoff for water year 1970 was estimated to have been 225,362 acre-feet, or 129.5% of the long term average; computations are seen in Table A4-17, Appendix A.

The average annual native surface water runoff for the 1953-1946 four year drought period was estimated to be 114,784 acre-feet per year, or 66.0% of the long term average; computations are seen in Table A4-18, Appendix A. This was determined by adjusting the gaging station records for the 1953-1956 water years, a selected percentage of the computed average annual contribution of Ralston Creek was added.

The surface water outflow of the Clear Creek sub-basin contributes to the surface water supplies of the South Platte River-Transition sub-basin. As there is very little consumptive use within the sub-basin, virtually its entire native surface water supply, flows out and is available to the South Platte River-Transition sub-basin. While the majority of this water leaves through the natural stream channels of Clear and Ralston Creeks, it was found that on the average, about 4,644 acre-feet per year leaves the Clear Creek sub-basin through agricultural ditches, by-passing the gaging station on Clear Creek, Appendix A Table A4-17, Footnote 4).

The surface water outflow from the Clear Creek drainage area can be measured at the USGS gaging station #06720000, "Clear Creek at Mouth, near Derby, Colorado," (Appendix C, Table C4-11). The 48 year average annual recorded discharge of this gaging station for the period 1928-1975 was 67,741 acre-feet.

4.2.2 *Existing Development of the Surface Water Runoff*

Diversion Structures - In 1959 the United States Department of the Interior reported that there were 72 major decreed direct flow rights for the surface water runoff in the Clear Creek drainage. These appropriations totaled 4,950 cfs, which is equivalent to about 3,583,800 acre-feet per year. The 1974 Revised Tabulation of Colorado Water Rights lists almost 290 absolute and conditional ditch rights decreed for the surface water runoff of the Clear Creek drainage (153 to the mainstem of Clear Creek and 32 to Ralston Creek). North Clear Creek and South Clear Creek are appropriated by 11 and 6 ditch rights, respectively. The remainder are supported by the various minor tributaries within this drainage area.

There are three diversion structures which import water to the Clear Creek drainage from watersheds outside of the South Platte River Basin. These are: Berthoud Pass Ditch, the Jones Pass Tunnel, and the Vidler Tunnel. There is one diversion structure which imports water to the Clear Creek drainage from a watershed outside of the South Platte River basin, but via the Boulder Creek sub-basin; this is the South Boulder Diversion Conduit. Occasionally, this conduit also imports some of the native surface water runoff of the Boulder Creek sub-basin. Information about these four diversion structures is given in Table 4-7. Their water is used primarily for municipal and industrial purposes.

A minor agricultural import structure, the Gardner's Ditch, carries water to small tracks of land in the plains, at the edges of the Clear Creek hydrological boundaries. It diverts water from the mainstem of the South Platte and is shown in Figure 4-2.

There are several major ditches which export surface water from the Clear Creek drainage to areas outside. The ditches include, among others, the Rocky Mountain Ditch, Welch Ditch, Farmers Highline Ditch, Church Ditch, the Colorado Agricultural Canal, and Lower Clear Creek Canal. These are seen schematically in Figure 4-2. The water is used mostly for irrigation. These direct diversion structures also have turnouts within the Clear Creek drainage area.

In 1959, the United States Department of the Interior reported that about 80,000 acres have been irrigated in the area; about 42,000 acres of land land lie outside the Clear Creek drainage (to the north) in Big Dry Valley but receive water from Clear Creek.

The 1970 State Engineer's annual report showed that 27 ditches diverted a total of 117,097 acre-feet of water from the Clear Creek drainage. This represents approximately 52% of the 1970 native surface water runoff estimated for this drainage area. While the list is not complete it does include all major diverters. These diversions will include some return flows from prior uses. A portion of the water diverted was transported out of this drainage area for use elsewhere.

Table 4-8 is a listing of the major diverters of the surface flows from the Clear Creek drainage, and their 1973 diversions.

Table 4-7 The Major Diversion Structures Importing Water to Clear Creeks Hydrological Drainage Area.

Name	Source	Destination	Years of Operation	Average Annual Import (acre-feet)
Berthoud Pass Ditch1/	Fraser River Sub-basin, Colorado River Basin	Hoop Creek, tributary to the West Fork of Clear Creek	1910-Present	615
Jones Pass Tunnel2/	Williams Fork River Sub-basin, Colorado River Basin	West Fork of Clear Creek	1940-1957	6,596
Vidler Tunnel3/	Blue River Sub-basin, Colorado River Basin	Leavenworth Creek, Tributary to South Clear Creek	1971-Present	48
South Boulder Diversion Conduit4/	Fraser River & Williams Fork River sub-basin Colorado River Basin via the Moffat Water Tunnel to South Boulder Creek	Ralston Reservoir on Ralston Creek	1936-Present	54,322
	South Boulder Creek	Ralston Reservoir on Ralston Creek	1936-Present	6,280

1/Appendix B, Table B3-5.

2/Appendix B, Table B3-6. There was no diversion through the Jones Pass Tunnel in 1958. Since 1959 all imports through this tunnel have been subsequently exported back to the Colorado River Basin by the Vasquez Tunnel. This water is then collected and brought back into the South Platte River Basin through the Moffat water tunnel, this time to the Boulder Creek Sub-basin. There this water is transported back to the Clear Creek sub-basin, this time via the South Boulder Diversion Conduit.

3/Appendix B, Table B3-7.

4/Appendix B, Table B3-4. The average annual import from the Colorado River Basin is the average for water years 1960-74. Prior to this period and since, the Moffat Water Tunnels Collection System has been in various states of expansion. The average annual import from South Boulder Creek is the average for water years 1959-75. This was the only period where records of these diversions were available.

Table 4-8 The Major Direct Diversion Structures in the Clear Creek Drainage and Their 1973 Diversions (Toups, 1975).

Structure Name	Stream Source (Diversion Point)	1973 Diversion (acre-feet)
Church Ditch	Clear Creek	N.A.
Farmers Highline Ditch	Clear Creek	32,000
Agricultural	Clear Creek	8,100
Clear Creek and Platte	Clear Creek	7,600
Fisher	Clear Creek	9,400
Rocky Mountain	Clear Creek	13,600
Southside	Clear Creek	6,700
Wannemaker	Clear Creek	5,700
Total	-	83,100

Note: Some of these ditches also have direct flow rights to the various tributaries of Clear Creek that they intercept on their way to outlying agricultural acreages. In addition, some of the water diverted was applied to lands lying outside of Clear Creeks drainage area.

Storage Facilities - In 1959 the United States Bureau of Reclamation reported that there were 47 reservoirs whose storage rights were dependent on the native surface water runoff from the Clear Creek drainage (Irrigation District #7). In aggregate their decreed storage rights were worth 113,000 acre-feet.

The 1974 revised tabulation of Colorado water rights lists about 200 absolute and conditional storage rights decreed for the surface flows of Clear Creeks drainage area. Water from the mainstem of Clear Creek is decreed to 168 of these storage rights, while eight are for water from the mainstem of Ralston Creek. There are no reservoirs with decrees for the surface water runoff of North Clear Creek. South Clear Creek supports ten decreed storage appropriations. The remainder have been adjudicated for the various other minor tributaries within this drainage area.

Table 4-9 lists the major reservoirs with absolutely decreed storage rights to the native surface water runoff from Clear Creek drainage; their storage history during the 1970 water year is listed also. These 69 reservoirs have most of the existing storage capacity for the runoff of this drainage area. These reservoirs are used mostly for the storage of irrigation water. Most are located within the plains area of the Clear Creeks drainage in shallow off stream depressions. The largest is Stanley Lake, located on the Northern boundary of this drainage area; it is owned by the Farmers Reservoir and Irrigation Company. It has an absolute and a conditional storage right for water from the mainstem of Clear Creek in the amounts of 32,361 and 16,699 acre-feet respectively. The appropriation date both of these rights is March 4, 1902 (Wilkinson, 1974). The uses filed for these storage appropriations are irrigation

Table 4-9 Amounts in Storage During the 1970 Water Year of the Major Reservoirs with Absolutely Decreed Storage Rights to the Native Surface Water Runoff of Clear Creeks Hydrological Drainage Area (Division of Water Commissioners, 1970).

		Amount in Storage (acre-feet)		
Name	Source	11-1-64	5-1-70	10-31-70
Church's Lower	Clear Creek	242	242	242
Copeland	Clear Creek	120	N.A.	N.S.
Croke	Clear Creek	190	190	190
Crown Hill	Clear Creek	291	291	291
Davy	Clear Creek	2	2	2
Dewey	Clear Creek	35	10	10
Downing	Clear Creek	38	38	38
East No. 1	Clear Creek	25	60	0
East No. 2	Clear Creek	0	400	700
East No. 3	Clear Creek	40	N.A.	0
Erie	Clear Creek	260	290	290
Furrer	Clear Creek	2	4	4
Guthrie No. 1	Clear Creek	25	25	N.A.
Guthrie No. 2	Clear Creek	25	25	N.A.
Hansen Nos. 1 & 2	Clear Creek	9	9	9
Harris	Clear Creek	N.A.	N.A.	0
Hartley	Clear Creek	60	60	30
Home	Clear Creek	N.A.	10	10
Hyatt	Clear Creek	300	900	300
Koleski	Clear Creek	6	38	38
Leyden	Clear Creek	460	800 est.	680
Linscott	Clear Creek	20	5	0
Little Tynon	Clear Creek	2	2	2
Mayhem	Clear Creek & Seepage	1,288	1,288	1,288
Morgan #1	Clear Creek	0	30	20 est.
Morgan #2	Clear Creek	27	38	30 est.
Moxley	Clear Creek	2	0	N.A.
Myers No. 1, 2 & 3	Clear Creek	103	103	103
Nissen No. 2	Clear Creek		140	N.A.
Oberon No. 1 & 2	Clear Creek	50	50	50
Ohio	Clear Creek	27	70	70
Poitz	Clear Creek	7	20	50
Bright View No. 2	Clear Creek	0	10	0
Bright View No. 1		0	15	0
Broad	Clear Creek	30	40	10
Broomfield	Clear Creek	90	40	0
Brown	Clear Creek	30	30	30
Calkins H.D.	Clear Creek	540	2,699	2,699
Pomona No. 1	Clear Creek	150	150	150
Wadley No. 1	Clear Creek	0	40	0
Wadley No. 2	Clear Creek	40	20	0
Wadley No. 3	Clear Creek	5	120	110

Table 4-9 Continued

Name	Source	Amount in Storage (acre-feet)		
		11-1-64	5-1-70	10-31-70
Ward No. 1	Clear Creek	900	900 est.	900 est.
Watts No. 1	Clear Creek	2	9	9
Wiesel	Clear Creek	10	15	27
Richards	Clear Creek	10	20	10
Savery Ponds	Clear Creek	8	8	8
Signal No. 1	Clear Creek	30	340	
Signal No. 2	Clear Creek	20	110	
Main	Clear Creek	0	750	830
East	Clear Creek	120	150	0
Smith	Clear Creek	560	200	550
Smith, J. B.	Clear Creek	39	230	260
Soper Nos. 1,2,3 & 4	Clear Creek	7	24	0
Standley	Clear Creek	27,778	37,893	30,480
Talbot	Clear Creek	25	27	33
Tom Frost	Clear Creek	60	25	15
Subtotal	Clear Creek	36,681	49,545	41,108
Kelley	Little Dry Creek	N.A.	N.A.	3
Coal Ridge (Sand-hill	Little Dry Creek	696	486	603
Pamona No. 2	Dry Creek	0	0	0
Tucker	Ralston Creek	0 est.	584	218
Campbell No. 1	Ralston Creek	1,164	1,016	1,016
Subtotal	Clear Creek Tributaries	1,860	2,086	1,840
Grand Total	Entire Clear Creek Drainage	38,541	51,631	42,948

Note: Some of these reservoirs are located outside of Clear Creeks hydrological drainage area and have additional absolutely decreed storage appropriations to the surface water runoff of other watersheds. Therefore, the amounts in storage above do not necessarily reflect only the yield from these reservoirs rights to surface water from the Clear Creek Drainage.

and domestic. Water yielded by the absolute decree is delivered by the Farmers Highline Canal. Stanley Lake also has an absolutely decreed storage right for water from the stream it is located on Woman Creek, a tributary to Big Dry Creek, which is a minor intermittant plains tributary of the South Platte River. The storage appropriation, used for irrigation, is decreed for 940.36 acre-feet and its priority date is September 1, 1869, (Wilkinson, 1974). In addition, Stanley Lake has an absolutely decreed storage right for water from Coal Creek, a tributary of Boulder Creek. The decreed amount is for 940 acre-feet with a priority date of September 1, 1869; this water is used for irrigation too. The Kinnear Ditch, also owned by the Farmers Reservoir and Irrigation Company, delivers the water.

From USGS topographic maps it was found that the Ward #1, Smith, Main, and East #1, 2, and 3 Reservoirs are located to the south and outside of Clear Creeks drainage area. Calkins, Churches Lower, Croke, Broomfield, Erie, Nissen #2, Sandhill, Tom Frost, Signal #1, and 2 and Wadley #1, 2, and 3 Reservoirs also have absolutely decreed storage rights to water from Clear Creeks drainage, but are located outside of the boundaries, to the north. While the primary source of water for these reservoirs is the yield from their rights held within the Clear Creek drainage (which is delivered by agricultural ditches and canals), some also depend on the storage appropriation of water from the minor intermittant South Platte tributaries of the drainage areas in the plains where they are located.

Of the major reservoirs located inside the Clear Creek drainage, one is used to store water foreign to this watershed. This is the 11,272 acre-foot Ralston Reservoir on Ralston Creek. It is the largest reservoir within the Clear Creek drainage but it has no rights to the native surface water runoff. It is used as a terminal storage facility for Denver's Moffat Tunnel and South Boulder Creek water that is delivered from the Boulder Creek drainage via the South Boulder Division Conduits.

4.2.3 *Potentially Developable Surface Water Runoff Remaining* - In 1959, the United States Bureau of Reclamation stated that the native surface water runoff of the Clear Creek drainage area was over appropriated. They reported that irrigators holding rights to this water have faced critical shortages due to uses by downstream appropriators on the South Platte River who have senior rights which are dependant on the tributary flows of Clear Creek. However, the irrigated acreage within this sub-basin is fast being converted to suburban residential areas. Generally, the water rights for these lands are being transferred from irrigation to municipal and suburban domestic use. The quantities of unappropriated surface water potentially developable in the Clear Creek drainage area are extremely small; in fact they are non-existent in most years.

4.3 The Boulder Creek Sub-basin

The Boulder Creek sub-basin is defined here as the drainage area of Boulder Creek above USGS gaging station #7305 "Boulder Creek at Mouth, near Longmont, Colorado." The gaging station is located 2.25 miles upstream from the confluence of Boulder Creek with Saint Vrain Creek. The boundaries of this sub-basin coincide approximately with those of Irrigation District #6. Figure 4-3 is a schematic drawing showing the pertinent features of the sub-basin.

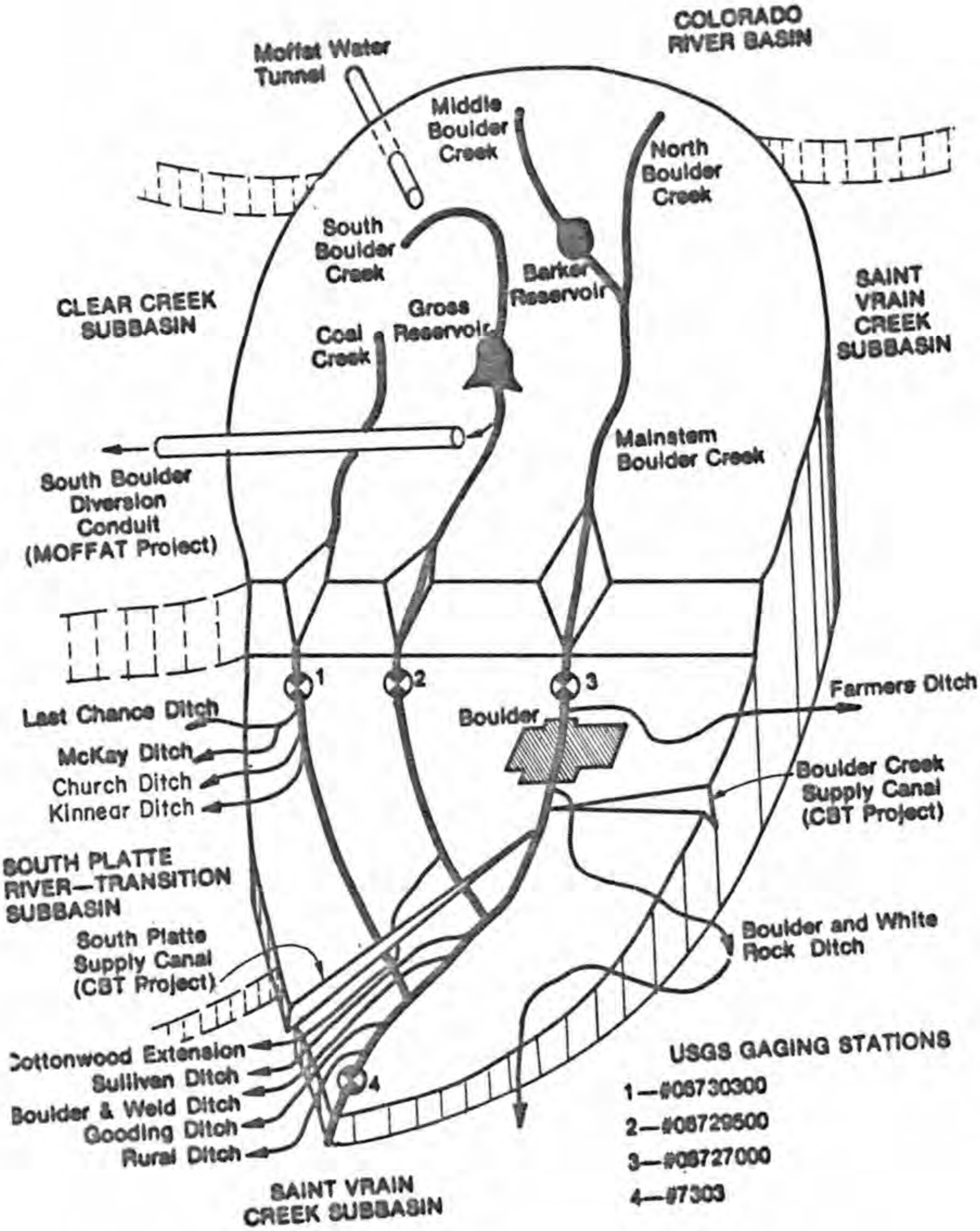


Figure 4-3: Schematic of the Boulder Creek Subbasin

4.3.1 *Physical Characteristics and Surface Water Runoff* - Boulder Creek originates on the Continental Divide at elevations exceeding 14,000 feet. The stream flows about 50 miles northeast to the plains and its confluence with the Saint Vrain Creek. This juncture occurs at an elevation of 4,875 feet and about 12 miles upstream from the confluence of Saint Vrain Creek with the South Platte River.

The principal mountain tributaries of Boulder Creek are the Middle and North Boulder Creeks and Fourmile Creek. South Boulder Creek and Coal Creek head in the mountains and join the mainstem of Boulder Creek in the plains.

The Boulder Creek drainage is about 14 miles wide, 40 miles long, and encompasses 439 square miles. The upper one half of this sub-basin is rugged mountainous terrain. The lower portion of the sub-basin is comprised of rolling plains. Most of the diversions from the stream occur in its lower reaches.

The average annual precipitation in the headwaters of Boulder Creek is about 40 inches per year, and about 12 inches per year in its lower elevations (NOAA, United States Department of Commerce, 1974). About 70 percent of the annual runoff is from spring snowmelt from the higher elevations. Very little water accrues to the surface flows of the Boulder Creek drainage after the main stem and tributaries leave their canyons.

Table 4-10 shows the average, maximum instantaneous, and minimum daily discharges (in cfs), and the average, maximum and minimum yearly runoffs (in acre-feet), recorded at four key gaging stations within the Boulder Creek sub-basin. The extremes of the records of the gaging stations located in the foothills near the canyon mouths of Boulder

Table 4-10 Surface Water Runoff Variability Within the Boulder Creek Sub-basin as Indicated by the Extremes of the Flow Records of Several Key Gaging Stations.

Gaging Station and Location	Period of Record	Recorded Discharge					Recorded Annual Runoff				
		Average	Maximum instantaneously		Minimum Daily		Average	Maximum		Minimum	
		Cfs	Cfs	Date	Cfs	Date	Acre-Feet	Acre-Feet	Water Year	Acre-Feet	Water Year
#06727000, "Boulder Creek Near Ordell, Colorado" (near its canyon mouth)1/	Aug.-Oct. 1887, April-Oct. 1888, Oct. 1906-Nov. 1914, March 1916-Sept. 1975	90.0	2,500	June 6, 1921	1.0	Jan. 29, Feb. 1-3, 16-24, 1933	65,190	105,700	1957	33,240	1966
#06729500, "South Boulder Creek near Eldorado Springs, Colorado," (near its canyon mouth)2/	April 1888-Oct. 1892, May 1845-Sept. 1901, Aug. 1904-Sept. 1975	76.1	7,390	Sept. 2, 1938	0.0	Oct. 15, 1932	53,374	99,100	1909	16,370	1966
#06730300, "Coal Creek near Plain-view, Colorado," (near its canyon mouth)3/	Aug. 1959-Sept. 1975	4.53	2,060	May 7, 1969	0.0	Many days in most years	3,283	7,820	1973	398	1966
#7303, "Boulder Creek at mouth, near Longmont, Colorado"4/	March 1927-Sept. 1949, May 1951-Sept. 1955	55.9	4,410	Sept. 3 1938	0.0	at times in 1934-36, 1942, 1946, 1954	40,527	149,400	1942	2,850	1954

1/Appendix C, Table C4-13.
2/Appendix C, Table C4-12.
3/Appendix C, Table C4-14.
4/Appendix C, Table C4-15.

Creek and tributaries, South Boulder and Coal Creeks, are indications of the natural variability of the surface water runoff of this sub-basin. Except for South Boulder Creek there is very little water resources development above these three gaging stations. The Moffat Project utilizes South Boulder Creek. The recorded flows of the South Boulder Creek gaging station include minor amounts of water imported from the Colorado River Basin, but exclude some of the native runoff which is held back in Gross Reservoir and some which is exported, above the gaging station from the drainage area.

The records of the Boulder Creek gaging station near Longmont in comparison to those of the three upstream gaging stations, are indicative of the amount of diversions in between in the plains reaches.

Table 4-11 shows the probable flood discharges of South Boulder Creek near Rollinsville, Colorado and of Middle Boulder Creek at Nederland, Colorado for various frequencies of occurrence. The gaging stations at these sites are located approximately in the middle of the mountainous portion of this sub-basin. This expected runoff data provides a further index to the surface water supply characteristics of this sub-basin.

The native surface water runoff of the Boulder Creek sub-basin was estimated from the flow records of the USGS gaging stations #06729500, "South Boulder Creek near Eldorado Springs, Colorado," #06727000, "Boulder Creek near Orodell, Colorado;" and #067303000, "Coal Creek near Plainview, Colorado," as seen in Appendix C, Tables C4-12, C4-13, and C4-14, respectively. The accrual below these gaging stations was assumed negligible. In assessing the native surface water runoff associated with these gaging stations drainage areas, the man-caused

Table 4-11 Flood Characteristics of Middle Boulder Creek at Nederland, Colorado and of South Boulder Creek Near Rollinsville, Colorado (McCain & Jarrett, 1976).

Flood discharges for each gaging station are: (first line) values used in multiple regression analysis, (second line) weighted averages.

Station Number	Station Name	Period of record, in years	Drainage area, in square miles	Gage datum, in feet above mean sea level	Basin slope, in feet per mile	Streambed slope, in feet per mile	Mean annual precipitation in inches	10-Year flood discharge, in cubic ft per second	50-Year flood discharge, in cubic ft per second	100-Year flood discharge, in cubic ft per second	500-Year flood discharge, in cubic ft per second	100-Year flood depth, in feet
0672550	Middle Boulder Creek at Nederland, Colo.	28	36.2	8186	240	100	27	713 695	894 864	967 934	1130 1100	4.9
06729000	South Boulder Creek Near Rollinsville, Colo.	12	42.7	8380	-	69	24	624 594	796 756	872 831	1060 1030	2.3

upstream effects were taken into account. The long term average native surface water runoff of the Boulder Creek sub-basin is estimated to be 122,832 acre-feet per year, based upon computations seen in Table A4-19, Appendix A. This was determined by adjusting the records of gaging station #06729500 for the 1959-1975 period, gaging station #06727000 for the 1917-1960 period, and gaging station #06730300 for the 1960-1975 period.

The native surface water runoff of the Boulder Creek sub-basin for the 1970 water year was estimated to have been 162,914 acre-feet, or 132.6% of the long term average annual; computations are shown in Table A4-20, Appendix A.

The native surface water runoff available to this sub-basin during the 1953-1956 four year drought period was estimated to have averaged 83,824 acre-feet per year, or 68.2% of the long term average. This was determined by adjusting the gaging station records, as seen in Table A4-21, Appendix A.

The surface water outflow of the Boulder Creek sub-basin through Boulder Creek contributes to the surface water supplies of the lower Saint Vrain Creek sub-basin. These flows can be measured at USGS gaging station #7305, "Boulder Creek at mouth, near Longmont, Colorado," whose records are given in Appendix C, Table C4-15. The 1928-1949, and 1952-1955, 26 year average annual recorded discharge of this gaging station was 40,527 acre-feet.

4.3.2 *Existing Development of the Surface Water Runoff* - Figure 4-4 shows the major ditches and reservoirs of the Boulder Creek sub-basin (actually the drawing depicts Irrigation District #6). Figure 4-3 is a perspective view but lacks the detail seen in Figure 4-4.

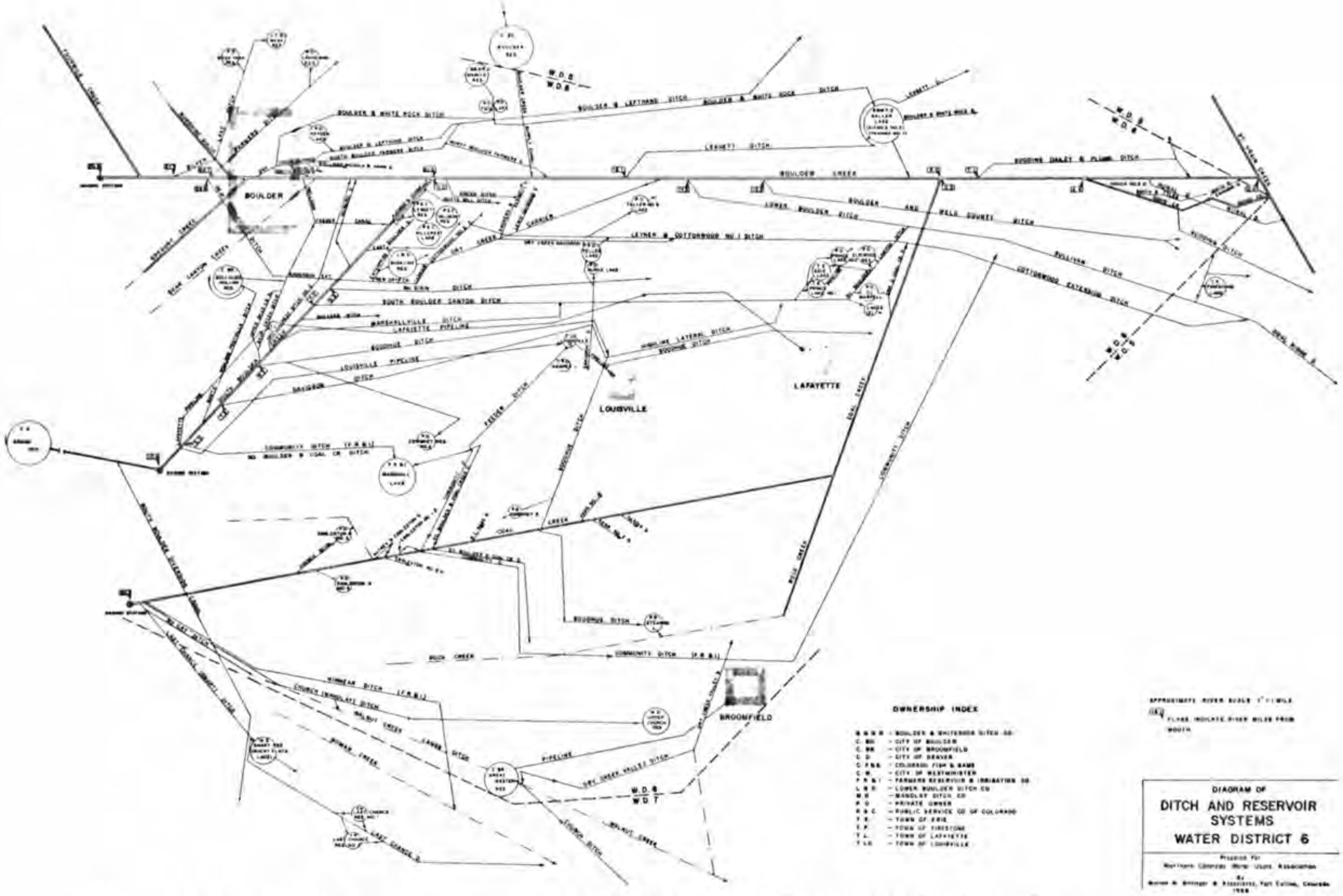


Figure 4-4: The Major Components of the Ditch and Reservoir System of Irrigation District #6 (Countesy of M. W. Bittinger and Associates)

Direct Diversion Structures - In 1959 the United States Department of the Interior reported that there were 90 major direct flow rights decreed for the native surface water runoff of this sub-basin. These appropriations total 5,500 cfs, which is equivalent to approximately 3,982,000 acre-feet per year.

The 1974 revised tabulation of Colorado water rights lists over 300 absolute and conditional direct flow rights decreed to the surface water runoff of the Boulder Creek drainage system. Water from the mainstem of Boulder Creek is decreed to 88 of these rights, while 76 rights are decreed to South Boulder Creek. Coal Creek is appropriated by 24 decreed direct flow rights. The remaining rights are supported by the various other tributaries within the drainage area.

Only one diversion structure, the Moffat Water Tunnel, imports water to the upper reaches of the Boulder Creek sub-basin. This tunnel diverts water from the Colorado River Basin; from the Fraser River Sub-basin and from the Williams Fork River Sub-basin since 1959. The average annual import by the Moffat water tunnel between water years 1960-1974 was 54,322 acre-feet (Appendix B, Table B3-4). Prior to this period and since, the collection system for this tunnel has been in various states of expansion.

Water is also imported to the Boulder Creek drainage area via the Boulder Creek supply canal. This canal delivers CBT project water from the Colorado River Mountains sub-basin Colorado River Basin and occasionally some water from the Big Thompson River sub-basin, South Platte River basin. Besides deliveries to CBT shareholders in the Boulder Creek sub-basin, the imports through this canal include water which is subsequently delivered to CBT shareholders below the Saint Vrain Creek sub-basin, in the South Platte River-Transition sub-basin.

Two major diversion structures exports surface water from the Boulder Creek sub-basin. The South Boulder Diversion Conduit delivers to Ralston Reservoir in the Clear Creek drainage all imports through the Moffat Water Tunnel and the yield from Gross and Ralston Reservoirs storage rights for South Boulder Creek runoff. In addition, this diversion structure has a conditionally decreed direct flow right for 1,250 cfs of native surface water runoff from South Boulder Creek, (Wilkinson, 1974). The appropriation date of this right is January 1, 1930 and its basin rank is 2,371. The South Platte Supply Canal and Diversion works, exports all imports through the Boulder Creek Supply Canal which are intended for CBT shareholders in the South Platte River-Transition sub-basin.

There are about a dozen minor diversion structures which also export the native runoff of this sub-basin. Generally, these exports are used for irrigation. The structures conveying this water include, among others, the Cottonwood Extension, Sullivan, Godding, Rural, Boulder, and Weld Boulder and White Rock and Farmers Ditches (which have turnouts in the Saint Vrain Creek sub-basin) and the Church, Kinnear, McKay, and Last Chance Ditches (which have turnouts in the South Platte River-Transition sub-basin).

Through an analysis performed in section 2.5.4 of "South Platte River Basin Agricultural Water Demands, 1970-2020," (Janonis and Gerlek, 1977), it was estimated that on the average, 4,820 acre-feet per year of the surface water runoff of Boulder Creek is exported through these agricultural ditches. Of this, 3,580 acre-feet is destined to the South

Platte River-Transition sub-basin and 1,240 acre-feet goes to the Saint Vrain Creek sub-basin.

The 1970 State Engineers annual report showed that 62 ditches diverted a total of 92,893 acre-feet of water from the Boulder Creek sub-basin. This represents approximately 57.0% of that water years native surface water runoff of this sub-basin. While this total does not include all diversions, it does represent most of the water diverted in that year. Most of this water was used for irrigation. The total surface diversions includes some return flows from upstream uses. A portion of the diverted water was transported out of this sub-basin for use elsewhere.

The Boulder Creek sub-basin is the site of the most senior direct flow water right in the entire South Platte River basin. Priority number 1 has been decreed to the Lower Boulder Ditch for 25 cfs from Boulder Creek. The appropriation date of this right is October 1, 1859 and its adjudication date was June 2, 1882 (Wilkinson, 1974).

Storage Facilities - In 1959 the United States Bureau of Reclamation reported that there were 31 reservoirs whose rights were dependent on the native surface water runoff of the Boulder Creek drainage. Their decreed storage rights totaled 49,300 acre-feet.

The 1974 revised tabulation of Colorado water rights lists over 150 absolute and conditional storage rights decreed for the surface flows of Boulder Creeks drainage area. Water from the mainstem of Boulder Creek was decreed to 27 of these storage rights, while 58 were decreed to South Boulder Creek. Coal Creek is appropriated by 22 decreed storage rights. The remaining storage rights are supported by the various other tributaries within the sub-basin.

Table 4-12 lists the major reservoirs with absolutely decreed storage rights to the native surface water runoff of the Boulder Creek sub-basin and their storage histories during the 1970 water year. These 45 reservoirs provide most of the existing storage capacity available to capture the runoff of this sub-basin. On May 1, 1970 the total storage amounted to 86,548 acre-feet, or 42,212 acre-feet excluding storage in Gross and Ralston Reservoirs whose major functions are to store imports through the Moffat Water Tunnel.

The reservoirs on this list that have appropriations for water from North Boulder Creek and Middle Boulder Creek are located within the mountainous portion of the Boulder Creek sub-basin. Generally these are on-stream reservoirs and are used for municipal water storage. With the exception of Albion and Gross Reservoirs, which are also located in the mountains, the rest are located in the plains. Most of them are within the Boulder Creek sub-basin boundaries. Generally, these are located in shallow offstream depressions and are used to store irrigation water.

From USGS topographic maps it was found that the Great Western McKay, and Westlake Reservoirs, which have decreed storage rights to the Boulder Creek native surface water runoff, lie outside the Boulder Creek sub-basin. Some of these outlying storage facilities also depend on appropriations of water from other watersheds.

The largest storage facility located outside of this sub-basin which has rights to its runoff is Ralston Reservoir in the Clear Creek sub-basin. It is owned by the City of Denver, and has two absolutely decreed storage rights for South Boulder Creek native flows totaling 12,758 acre-feet. Individually these are for 11,000 and 1,758 acre-feet with appropriation dates of January 1, 1930 and October 31, 1932

Table 4-12 Amounts in Storage During the 1970 Water Year of the Major Reservoirs with Absolutely Decreed Storage Rights to the Native Surface Water Runoff of the Boulder Creek Sub-basin (Division 1 Water Commissioners, 1970).

Name	Source	Amount in Storage (Acre-feet)		
		11-1-69	5-1-70	10-31-70
Marfell Lake No. 1	South Boulder Creek	10	39	79
Marfell Lake No. 2	South Boulder Creek		0	0
McKay	South Boulder Creek	674	1,039	241
Marshall	South Boulder Creek	4,184	8,938	3,998
Prince No. 1	South Boulder Creek		10	40
Prince No. 2	South Boulder Creek		83	47
Elmwood	South Boulder Creek	85	85	85
Erie	South Boulder Creek	96	14	128
Teller Lake No. 1	South Boulder Creek	22	45	11
Teller Lake No. 5	South Boulder Creek	24	8	15
Thomas	South Boulder Creek	67	0	89
West Lake	South Boulder Creek	30	303	350
Waneka	South Boulder Creek	532	355	237
Louisville	South Boulder Creek	125	130	120
Gross Reservoir	South Boulder Creek & the Colorado River Basin via the Moffat Tunnel	36,206	36,462	30,555
Ralston Reservoir	South Boulder Creek and the Colorado River Basin via the Moffat water Tunnel and the South Boulder Diversion Conduits	10,021	7,874	10,343
Subtotal	South Boulder Creek	52,076	55,385	46,333
Glacier Summer	North Boulder Creek		228	228
Green Lake No. 1	North Boulder Creek		197	197
Green Lake No. 2	North Boulder Creek		333	333
Green Lake No. 3	North Boulder Creek		285	285
Green Lake No. 4	North Boulder Creek		88	88
Green Lake No. 5	North Boulder Creek		70	70
Goose Lake	North Boulder Creek	1,036	1,036	1,036
Island	North Boulder Creek	334	334	334
Silver Lake	North Boulder Creek	3,935	1,370	3,987
Subtotal	North Boulder Creek	5,305	3,941	6,558

Table 4-12 Continued.

Name	Source	Amount in Storage (acre-feet)		
		11-1-69	5-1-70	10-31-70
Jasper	Middle Boulder Creek	0	75	0
Lower Boulder Ext.	Middle Boulder Creek	304	108	308
Mesa Park	Middle Boulder Creek	100	126	100
Mesa	Middle Boulder Creek	262	300	250
Barker	Middle Boulder Creek	10,165	197	9,340
Davis No. 1 & 2	Middle Boulder Creek	203	132	159
Panama No. 1	Middle Boulder Creek	785	4,989	3,331
Hayden	Middle Boulder Creek	120	452	413
Sky Scraper	Middle Boulder Creek	146	146	146
Six Mile	Middle Boulder Creek	840	1,088	1,008
Subtotal	Middle Boulder Creek	12,925	7,613	15,055
Leggett	S & M Boulder Creeks	1,502	1,387	1,350
Hillcrest	S. Bldr Ck & M Bldr Ck.	2,075	1,922	1,872
Valmont	S & M Boulder Creeks	7,126	6,772	6,656
Baseline	S & M Boulder Creeks	3,554	4,950	2,592
Subtotal	South and Middle Boulder Creeks	12,857	15,031	12,470
Ballinger Hollow	Not active			
Alvion	Albion Creek	1,111	1,111	1,111
Smart	Coal Creek	589	705	589
Last Chance No. 1	Coal Creek	0	13	0
Great Western	Coal Creek	2,571	2,699	2,699
Subtotal	Other Minor Boulder Creek Tributaries	4,271	4,528	4,399
Grand Total	Entire Boulder Creek Sub-basin	84,434	86,548	84,815

Note: Some of these reservoirs are located outside of Boulder Creeks hydrological drainage area and have absolutely decreed storage appropriations to the surface water runoff of other watersheds. Therefore, their amounts in storage do not necessarily reflect only the yield from their rights to surface water from the Boulder Creek sub-basin. In addition, Gross and Ralston Reservoirs store imports from the Colorado River Basin (delivered through the Moffat water tunnel) as well as runoff from South Boulder Creek.

respectively (Denver Water Board, 1975). Ralston Reservoir also has a conditional storage decree for this water worth 3,210 acre-feet with an appropriation date of October 31, 1932 (Wilkinson, 1974). Ralston Reservoir has no storage rights to the surface water runoff from Clear Creek. The primary function of this reservoir is to provide terminal storage for the water delivered through the Moffat Water Tunnel. This Colorado River Basin water is imported to the head of South Boulder Creek where it flows with that stream to Gross Reservoir for storage and regulation, and then to the South Boulder Diversion intake dam. There this water, along with the yield of Ralston Reservoirs storage rights to the native flows of South Boulder Creek, is transported to the Clear Creek drainage and Ralston Reservoir via a conduit-canal delivery system.

The largest storage facility located within the Boulder Creek subbasin is Gross Reservoir. It is owned by the City of Denver, and is located on the South Boulder Creek. It has a capacity of 43,065 acre-feet (Denver Water Board, 1969). Its primary function is to store and regulate water imports through the Moffat Water Tunnel. However, it also has 152,931 acre-feet worth of absolutely decreed storage appropriations for South Boulder Creek flows. Individually these are for 11,847, 28,006 and 113,078 acre-feet, all with appropriation dates of May 10, 1945, (Wilkinson, 1974). The yield from this right is exported along with the Moffat Tunnel Water to Ralston Reservoir and then to Denver's Moffat water treatment plant.

Between 1959 and 1975 the average annual yield from the Gross and Ralston Reservoirs storage appropriations for South Boulder Creek water was 6,280 acre-feet (Denver Board of Water Commissioners, 1968, 1973, 1975).

The largest reservoir located entirely within the Boulder Creek sub-basin that stores Boulder Creek flows exclusively is Barker Reservoir. This storage facility is located on Middle Boulder Creek and has a capacity of 12,000 acre-feet. It is owned by the Public Service Company of Colorado, and is used for power production. The City of Boulder has an absolutely decreed storage right of 828 acre-feet which is exercised by this facility, which has an adjudiction date of March 4, 1964 (Black and Veatch, 1974).

4.3.3 *Proposed Development*

Gross Reservoir Expansion - Gross Reservoir on South Boulder Creek has a present capacity of 43,065 acre-feet; however, it has 152,931 acre-feet worth of absolutely decreed storage rights for the native surface flows of this sub-basin. The primary purpose of this reservoir is to store Denvers water imports through the Mofat Water Tunnel. Any enlargement would further facilitate this function. It would also allow Denver to better exercise its storage right for South Boulder Creek flows. However, Mr. Fischer of the Denver Water Board (1976) reports that the enlargement of this reservoir would be an extremely expensive project. Comparing the ratio of dollars spent to acre-feet of water realized each year makes the project low priority relative to other alternatives.

Boulders Conditional Storage Decrees - The City of Boulder has conditional decrees for two proposed municipal storage facilities which would be located in the mountains portion of this sub-basin; these are Park and Bradley Ranch Reservoirs. Park Reservoir has a decreed storage right for 6,767 acre-feet with an appropriation date of March 4, 1964. Negotiations are under way with the United States Forest Service to acquire additional lands needed for this project (Black and Veatch, 1974). Bradley Ranch Reservoir has a decreed storage right for 15,062 acre-feet with an appropriation date of March 4, 1964. None of the real property necessary for the dam and reservoir is owned by the City (Black and Veatch, 1974).

The Coal Creek Project - The cities of Lafayette and Louisville have been engated in discussions concerning the development of a proposed Coal Creek project.

Coal Creek is a tributary to Boulder Creek and joins it approximately five miles upstream from its mouth on Saint Vrain Creek. The Coal Creek project involves diverting water from Boulder Creek and Coal Creek to a reservoir for storage. Some of the water this project would utilize will be from irrigation rights that have been purchased by the municipalities involved. Other direct flow and pipeline rights would be used also. A portion of these direct flow rights would be converted to storage appropriations if the reservoir is built. During a 12 year study period beginning in 1959, the additional surface flows that could have been captured by this proposed reservoir would have occurred only during the high spring flows of May 1969. At that time it would have been possible to trap 450 acre-feet of unappropriated water before it left this sub-basin (Hobbs, 1976).

The project would serve primarily to regulate with more effectiveness the existing direct flow rights of these cities. In addition, it would give more flexibility to their overall supply system by providing the option of transferring their waste flows (through exchange) to the reservoir. For the Boulder Creek sub-basin, however, the project would provide very little additional surface water supplies. The amounts of presently unappropriated water which could be captured by the proposed Caol Creek Project would have been equivalent to only 37.5 acre-feet per year during the 1959-1970 period.

The United States Bureau of Reclamation is presently looking at a justification study for this rpoject. Mr. Hobbs, President of the Engineering Firm Consulting on the Coal Creek Project, has stated that these communities will need winter storage in the future and that Coal Creek Reservoir could be a reality in five to ten years.

4.3.4 *Potentially Developable Surface Water Runoff Remaining* - On the average there is very little, if any, unappropriated native surface water runoff in Boulder Creek or its tributaries. In 1959 the United States Bureau of Reclamation reported that the runoff in this sub-basin is overappropriated by rights within the area and by downstream rights along the mainstem of the South Platte River. Because of this, most of the demands for the naturally occurring surface flows, especially from agriculture, have not been fully met. This is evidenced by the aquisition of supplemental water (i.e., CBT project supplies) by the City of Boulder and agricultural interests in the sub-basin.

The proposed Coal Creek Project is a further indication that unappropriated water within this sub-basin is non existent in most years and undependable in the long term. This project involves the consolidation of existing water rights for better management and flexibility. It represents one of the final options available, for water users to "stretch" their existing supplies.

4.4 The Saint Vrain Creek Sub-basin

The Saint Vrain Creek sub-basin is defined here as the drainage area of Saint Vrain Creek about USGS gaging station #06731000, "Saint

Vrain Creek at Mouth, near Platteville, Colorado," excluding the drainage area of its tributary, Boulder Creek above gaging station #7305, "Boulder Creek at Mouth, near Longmont, Colorado." Figure 4-5 is a schematic drawing of the drainage basin. Gaging station #06731000 at the mouth of this sub-basin is located 1.3 miles upstream from the confluence of Saint Vrain Creek, and the South Platte River. The boundaries of the Saint Vrain sub-basin coincide approximately with those of Irrigation District #5.

4.4.1 *Physical Characteristics and Surface Water Runoff* - Saint Vrain Creek begins on the Continental Divide at elevations approaching 14,000 feet. The stream, in its 60 mile journey, flows northeast to the plains where it joins the South Platte at elevation 4,470 feet.

The principal mountain tributaries of Saint Vrain Creek are the North, South, and Middle Saint Vrain Creeks. Lefthand Creek originates in the mountains in the southern portion of the sub-basin and joins the mainstem of Saint Vrain Creek in its plains reach. In addition, outflows from the Boulder Creek sub-basin joins mainstem of the Saint Vrain Creek in its plains reach. This confluence occurs about 12 miles upstream from the confluence of Saint Vrain Creek and on the South Platte River.

The Saint Vrain Creek sub-basin drains 537 square miles. The upper 30% is mountainous, while the lower part is comprised of rolling plains.

Precipitation in the headwaters area of the Saint Vrain Creek sub-basin averages about 40 inches per year, and about 12 inches per year in its lower elevations on the plains (NOAA, United States Department of Commerce, 1974). The water supply of the sub-basin is derived almost entirely from its western mountainous area. About 75 percent of the surface occurs from the melting snowpack during the May-July period.

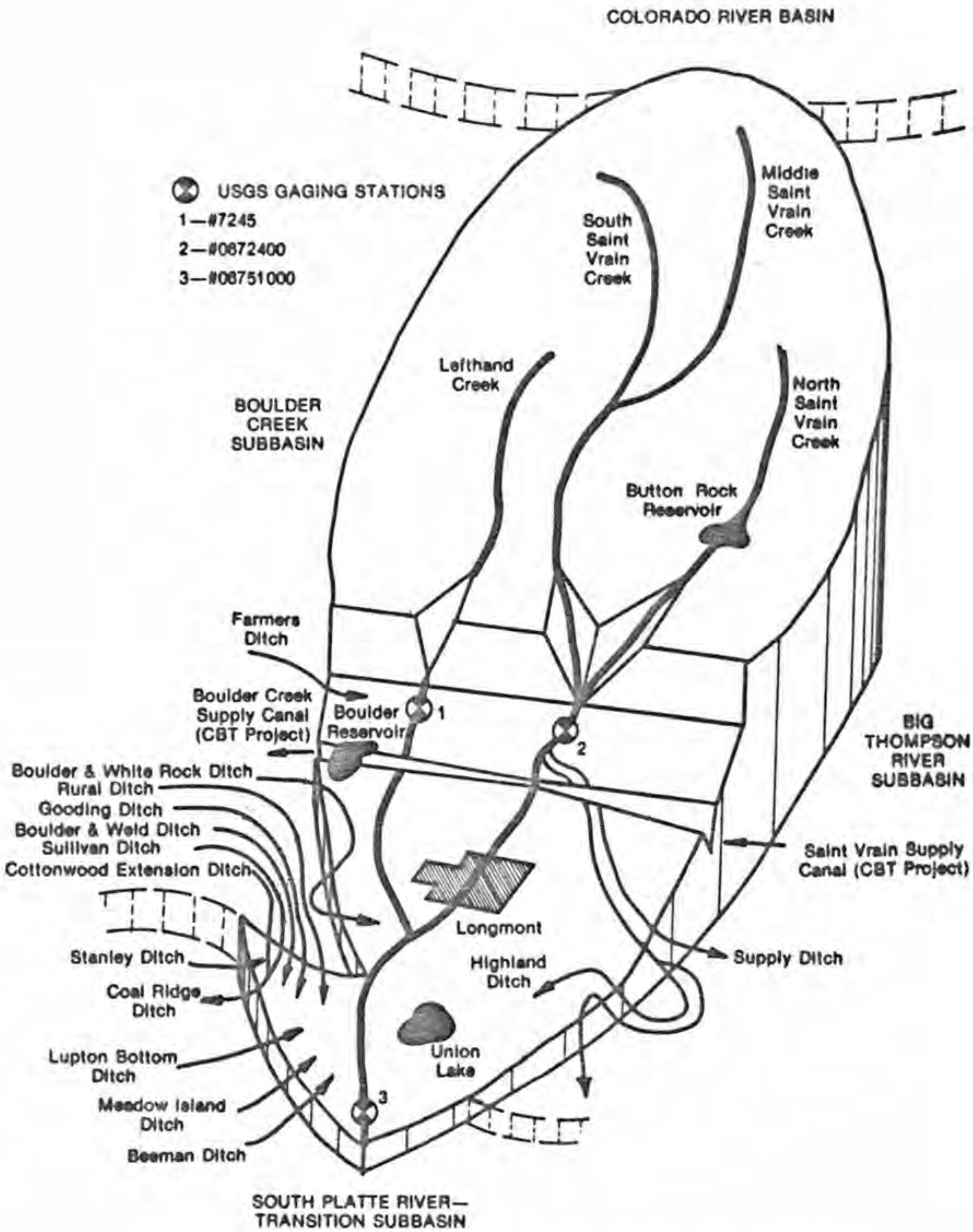


Figure 4-5: Schematic of the Saint Vrain Creek Subbasin

Very little water accrues to the surface flows of the Saint Vrain Creek after the mainstem and tributaries leave their canyons in the foothills.

Table 4-13 shows the average, maximum instantaneous, and minimum daily discharges (in cfs), and the average, maximum and minimum yearly runoffs (in acre-feet), recorded at three key gaging stations within the Saint Vrain Creek sub-basin. The extremes of the records of the gaging stations located in the foothills near the canyon mouths of Saint Vrain Creek and its tributary Lefthand Creek, provide indications of the natural variability of the surface water runoff of this sub-basin. There is very little water resource development above these two gaging stations. However, some of the measured flow in Lefthand Creek is water that has been diverted from South Saint Vrain Creek for irrigation along Lefthand Creek downstream of the gaging station. In addition, the flow records of the Lyons Gaging Station, at the mouth of Saint Vrain Creek Canyon, excludes some native runoff which is exported from its drainage area by a small agricultural ditch diverting just upstream.

The records of the Platteville Gaging Station, in the plains, when compared to these of the Lefthand Creek and Lyons Gaging Stations reflect the effects of diversions, return flows, and inflow from the Boulder Creek.

Table 4-14 shows the probable flood discharges of South Saint Vrain Creek near Ward, Colorado for various frequencies of occurrence. This gaging station is located more than halfway into the mountainous portion of this sub-basin and near the headwaters of South Saint Vrain Creek. This expected runoff data provides a further index to the surface water supply characteristics of this sub-basin.

Table 4-13 Surface Water Runoff Variability within the Saint Vrain Creek Sub-basin as Indicated by the Extremes of the Flow Records of Several Key Gaging Stations.

Gaging Station and Location	Period of Record	Recorded Discharge					Recorded Runoff				
		Average	Maximum instantaneous		Minimum Daily		Average	Maximum		Minimum	
		Cfs	Cfs	Date	Cfs	Date	Acre-Feet	Acre-Feet	Water Year	Acre-Feet	Water Year
#0672400, "Saint Vrain Creek at Lyons, Colorado" (near its canyon mouth)1/	Aug. 1887-Sept 1891, June 1895-Sept. 1975	129.0	10,500	June 22, 1941	0.0	Jan. 19, 20, 1922, Jan. 12, 13, 1950	93,423	166,000	1891	33,480	1954
#7245, "Lefthand Creek near Boulder, Colorado" (near its canyon mouth)2/	Oct. 1949-Dec. 1953, Oct, 1955-Dec. 1957	40.7	1,140	June 4, 1949	1.0	Jan. 4, 1950	26,721	43,290	1957	19,300	1931
#06731000, "Saint Vrain Creek at mouth, near Platteveille"3/	July 1904-Dec. 1906, April-Dec. 1915, March 1927-Sept. 1975	204.0	11,300	Sept. 3, 1938	12.0	April 23, 1935	147,597	343,800	1942	40,100	1954

1/Appendix C, Table C4-16.
2/Appendix C, Table C4-17.
3/Appendix C, Table C4-18.

Table 4-14 Flood Characteristics of South Saint Vrain Creek near Ward, Colorado, (McCain and Jarrett, 1976). [Flood discharges for each gaging station are: (first line) values used in multiple regression analysis, (second line) weighted averages.]

Station Number	Station Name	Period of record, in years	Drainage area, in square miles	Gage datum, in feet above mean sea level	Basin slope, in feet per mile	Streambed slope, in feet per mile	Mean annual precipitation, in inches	10-Year flood discharge, in cubic ft per second	50-Year flood discharge, in cubic ft per second	100-Year flood discharge, in cubic ft per second	500-Year flood discharge, in cubic ft per second	100-Year flood depth, in feet
06722500	South St. Vrain Creek near Ward, Colorado	23	14.4	9372	220	232	33	351 345	453 442	498 484	610 592	2.3

The native surface water runoff of the Saint Vrain Creek sub-basin was estimated from the flow records of the USGS Gaging Stations #06724000, "Saint Vrain Creek at Lyons, Colorado," and #7245, "Lefthand Creek near Boulder, Colorado," which are seen in Tables C4-16 and C4-17, Appendix C, respectively. The surface water runoff below these gaging stations was assumed negligible. In assessing the native surface water runoff of the Saint Vrain drainage area man-caused effects on the flow records of these gaging stations were taken into account.

The long term average native surface water runoff of the Saint Vrain Creek sub-basin is estimated to be 117,600 acre-feet per year; computations are given in Table A4-22, Appendix A. This was determined by adjusting the records of Gaging Station #06724000 for the period of water years 1930-1949, and those of Gaging Station #7245 for 1930-1949.

The 1970 water year native surface water runoff of the Saint Vrain Creek sub-basin was estimated to have been 131,549 acre-feet, or 111.9 percent of the estimated long term average annual runoff; computations are seen in Table A4-23, Appendix A.

The native surface water runoff during the 1953-1956 four year drought period averaged 78,820 acre-feet per year, or 63.6% of the long term average; computations are seen in Table A4-24, Appendix A.

The surface water outflow of this sub-basin through the natural stream channel of Saint Vrain Creek contributes to the surface water supplies of the South Platte River-Transition Sub-basin. These flows are measured at USGS gaging station #06731000, "Saint Vrain Creek at Mouth, near Platteville, Colorado," the annual discharge records are seen in Table C4-18, Appendix C. The 50 year average annual recorded discharge of this gaging station was 147,597 acre-feet. These flows reflect the discharges of Boulder Creek, which enters Saint Vrain Creek about 12 miles upstream from this gaging station. Numerous diversions and substantial return flows occur upstream also.

4.4.2 *Existing Development of Surface Water Runoff* - Figure 4-6 shows the major ditches and reservoirs of this sub-basin in considerable detail. Figure 4-5 is a broader perspective depiction.

Direct Diversion Structures - In 1959 the United States Bureau of Reclamation reported that the native surface water runoff of this sub-basin was used by 45 separate canal systems which had 90 major direct flow rights decreed. These appropriations totaled 3,050 cfs, which is equivalent to approximately 2,200,960 acre-feet per year.

The 1974 revised tabulation of Colorado Water Rights lists over 300 absolute and conditional direct flow rights decreed to the surface water runoff of the Saint Vrain Creek sub-basin. Water from the mainstem of Saint Vrain Creek is decreed to 76 of these rights, while 19 are decreed to North Saint Vrain Creek and 17 are decreed to South Saint Vrain Creek. Lefthand Creek is appropriated by 39 decreed direct flow rights. The remainder of the decrees are supported by the various other tributaries, springs, seepages, and sloughs within this drainage area.

There are no diversion structures which import water directly to the Saint Vrain sub-basin from watershed outside of the South Platte River basin. However, the Saint Vrain Supply Canal imports CBT water to the Saint Vrain sub-basin from the Colorado River, via the Big Thompson River sub-basin. Besides deliveries to CBT shareholders in this sub-basin, the imports through this canal include water which is subsequently exported (via the Boulder Creek Feeder Canal to Boulder

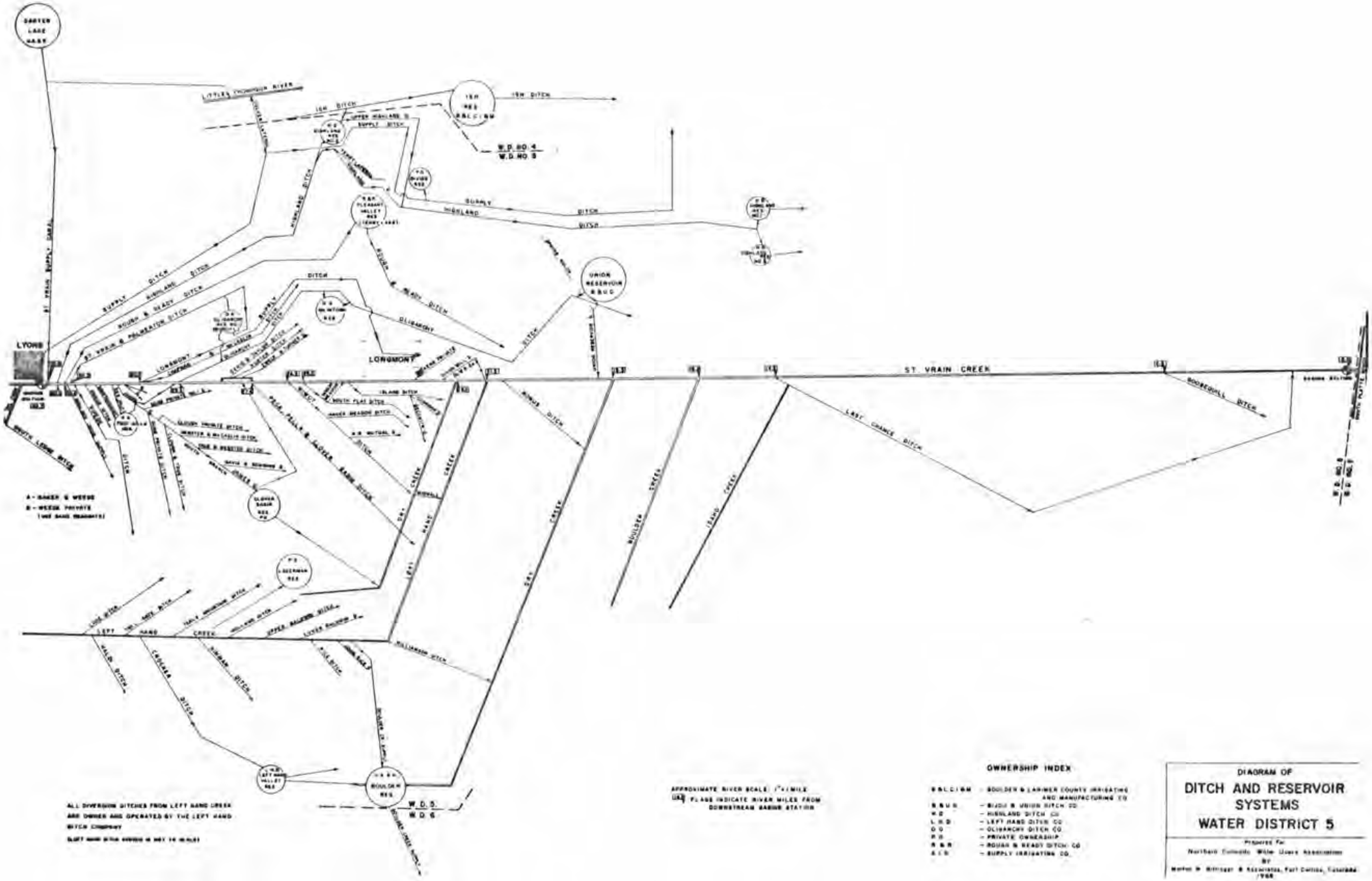


Figure 4-6: The major components of the Ditch and Reservoir System of Irrigation District #5 (Courtesy of M. W. Bittinger and Associates)

Reservoir to the Boulder supply canal) to CBT shareholders in the Boulder Creek and South Platte River-Transition sub-basins.

There are several diversion structures which import water to this sub-basin from other tributary drainage areas of the South Platte. These include, among others the Farmers, Boulder and White Rock, and Boulder and Weld Ditches (from the Boulder Creek sub-basin), and the Stanely, Lupton Bottom, Meadow Island, and Beeman Ditches (from the South Platte River-Transition sub-basin). These ditches are seen in Figure 4-5.

Through an analysis performed in section 2.5.3 and 2.5.4 of "South Platte River Basin Agricultural Water Demands, 1970-2020" (Janonis and Gerlek, 1977), it was estimated that on the average, 1,240 acre-feet per year is imported to this sub-basin through turnouts from ditches originating in the Boulder Creeks sub-basin, and 92,288 acre-feet from those originating in the South Platte River Transition sub-basin. This water is used for irrigation in the Saint Vrain sub-basin.

There are several diversion structures which export the native surface water runoff of this sub-basin to other tributary drainage areas of the South Platte. The major exporters are the Supply Ditch and the Highland Ditches, which divert water from Saint Vrain Creek near its canyon mouth and traverse back and forth along the plains section of the Saint Vrain Creek-Big Thompson River Divide supplying water to tracts of irrigated agriculture on both sides.

Through an analysis performed in section 2.5.2 of "South Platte River Basin Agricultural Water Demands, 1970-2020," (Janonis and Gerlek, 1977), it was estimated that on the average, 37,530 acre-feet per year of the native surface water runoff of this sub-basin is exported to the Big Thompson River sub-basin.

The 1970 State Engineer's annual report showed that 45 ditches had reported diverting a total of 100,808 acre-feet of water from the Saint Vrain Creek sub-basin (Irrigation District #5) in that water year. This represents approximately 76.6% of that water years native surface water runoff of this sub-basin. While this total does not include all diversions, it does represent the bulk of the water diverted in that water year. This water was used primarily for irrigation. Included in this amount is water transported out of the sub-basin for use elsewhere. These ditches also include return flows from prior uses by upstream ditches.

Storage Facilities - In 1959 the United States Bureau of Reclamation reported that there were 55 reservoirs whose rights were dependent on the native surface water runoff of the Saint Vrain Creek drainage area. Their aggregate decreed storage rights were worth 42,200 acre-feet, while their corresponding storage capacity was 35,000 acre-feet. The difference was apparently attributable to conditional decrees associated with future expansions.

The 1974 revised tabulation of Colorado Water Rights lists about 190 absolute and conditional storage rights decreed for the surface water runoff of the Saint Vrain Creek drainage area. Water from the mainstem of Saint Vrain Creek is decreed to 97 of these storage rights, while nine decrees are for water from North Saint Vrain Creek and nine are for water from South Saint Vrain Creek. The remainder were supported by the various other tributaries, springs, seepages, and sloughs within Irrigation District #5.

Table 4-15 lists the major reservoirs with absolutely decreed storage rights to the native surface water runoff of the Saint Vrain Creek sub-basin and their storage history during the 1970 water year. These 63 reservoirs represent the bulk of the existing storage capacity used to capture the runoff within the Saint Vrain sub-basin. The May 1, 1970 total storage was 55,820 acre-feet, which represents about 47.5% of the estimated long term average annual native surface water yield of the Saint Vrain Creek sub-basin.

The reservoirs on this list that have appropriations for South Saint Vrain Creek, Middle Saint Vrain Creek, and North Saint Vrain Creek and the various other minor tributaries of Saint Vrain Creek are all located in the mountains portion of this sub-basin. Moettler Reservoir, however, which obtains water from Walker Gulch, is located on the plains. Generally, the reservoirs in the mountains are onstream and are used for municipal water storage. The reservoirs which store water from the main-stem of Saint Vrain and Lefthand Creeks are located in the plains, except for Lefthand Park and Swede Reservoirs, both of which divert water from Lefthand Creek in the mountains. Generally, the reservoirs in the plains are located off stream in shallow depressions, and they are used to store irrigation water. Most of these reservoirs have capacities less than 1,000 acre-feet, and have high evaporation and seepage losses.

From USGS maps it was found that the Ish, Highland #2, Thomas and Hill Reservoirs, among others, lie outside of its boundaries. While these reservoirs have decreed storage rights to flows within the Saint Vrain sub-basin, some of these outlying storage facilities also depend on appropriations of water from other watersheds.

Table 4-15 Amounts of Water in Storage During the 1970 Water Year in Reservoirs Having Absolutely Decreed Storage Rights to the Native Surface Runoff of the Saint Vrain Creek Sub-basin (Division 1 Water Commissioner, 1970).

		Amount in Storage (acre-feet)		
Name	Source	11-1-69	5-1-70	10-31-70
Mulligan	St. Vrain	50	50	50
Myron Isabell	St. Vrain	60	60	70
Oligarchy No. 1	St. Vrain	1,737	1,737	1,640
Parmalee	St. Vrain	30	30	40
Pleasant Valley	St. Vrain	2,489	2,428	2,428
Sanborn	St. Vrain	150	200	140
Crystal	St. Vrain	100	118	110
Culver	St. Vrain	130	134	130
Divide	St. Vrain	300	300	340
Foothills	St. Vrain	2,103	3,767	2,225
Genevieve	St. Vrain	50	80	50
McKay	St. Vrain	40	40	45
Marie	St. Vrain	150	200	150
Marshall	St. Vrain	24	24	24
Miantenoma	St. Vrain	110	140	100
Minnie	St. Vrain	73	73	70
Thomas	St. Vrain	30	180	230
Union (Calkins Lake)	St. Vrain	11,265	12,715	12,715
Walker	St. Vrain	60	77	50
Zimbeck	St. Vrain	50	62	50
Bellmire	St. Vrain	20	20	20
Calkins Lake	St. Vrain	48	120	44
Clennon	St. Vrain	40	120	45
Clark	St. Vrain	60	72	80
Clover Basin	St. Vrain	450	475	350
Hayden	St. Vrain	44	44	39
Hewitt	St. Vrain	34	34	34
Highland Lake	St. Vrain	500	600	500
Highland No. 1	St. Vrain	313	313	874
Highland No. 2	St. Vrain	2,377	2,377	2,398
Highland No. 3	St. Vrain	389	1,037	1,184
Hill	St. Vrain	104	104	120
Holt	St. Vrain	140	140	150
Ide & Starbird No. 1	St. Vrain	100	100	110
Ide & Starbird No. 2	St. Vrain	50	50	50
Independent	St. Vrain	100	164	120
McCall	St. Vrain	500	500	500
Little Gem	St. Vrain	70	70	80
Logan	St. Vrain	28	28	28
Akers & Tarr	St. Vrain	550	700	550
Kistler & Holliday	St. Vrain	5	5	5
Knouth	St. Vrain	138	138	138
McCaslin	St. Vrain	100	100	110

Table 4-15 Continued

Name	Source	Amount in Storage (acre-feet)		
		11-1-69	5-1-70	10-31-70
McIntosh Ballinger Baxter	St. Vrain St. Vrain St. Vrain	2,202 6 60	2,459 9 160	2,202 6 60
Subtotal	St. Vrain	27,429	32,354	30,454
Isabelle	S. St. Vrain	N.A.	N.A.	N.A.
Subtotal	S. St. Vrain	-	-	-
Hartford Green Lake	M. St. Vrain M. St. Vrain	87 120	87 120	60 120
Subtotal	M. St. Vrain	207	207	180
Arbucle No. 2 Arbucle No. 4 Copeland Button Rock	M. Fk. N. St. Vrain S. Fk. N. St. Vrain N. St. Vrain N. St. Vrain	410 420 50 14,201	490 420 50 13,398	944 420 50 13,398
Subtotal	N. St. Vrain	15,081	14,358	14,812
Allen Lake Left Hand Valley Left Hand Park Left Hand Lagerman Gold Lake Swede	Left Hand Left Hand Left Hand Left Hand Left Hand Left Hand Left Hand	700 3,783 1,548 180 200 300 170	700 3,783 1,548 180 240 350 170	700 3,783 1,496 184 240 280 180
Subtotal	Left Hand Creek	6,881	6,971	6,863
Supply No. 1 Moeller Beaver Park	Big Cascade Walker Gulch Beaver Creek	120 50 1,935	160 50 1,720	296 50 2,046
Subtotal	Other Minor St. Vrain Creek Tribs.	2,105	1,930	2,392

Table 4-15 Continued

Name	Source	Amount in Storage (acre-feet)		
		11-1-69	5-1-70	10-31-70
Grand Total	Entire St. Vrain Creek Sub-basin	51,703	55,820	54,701

Note: Some of these reservoirs are located outside of the Saint Vrain Creek drainage area and have absolutely decreed storage appropriations to the surface water runoff of other watersheds. Therefore, their respective amounts in storage are not necessarily from the Saint Vrain Creek Sub-basin alone.

The largest storage facility within the sub-basin is Button Rock Reservoir. It is owned by the City of Longmont, and is located on North Saint Vrain Creek. The reservoir has a storage capacity of 16,085 acre-feet and maximum surface area of 221.8 acres (McCall, Ellingson, 1969). Therefore, the avearage depth of this reservoir when full is about 73 feet. Preliminary investigations concerning the location of a storage facility for Longmont at this site were initiated in the 1920's. However, the active pursuit of this project did not begin until the 1960's. Construction began in the spring of 1967 and the Button Rock Dam was completed two years later. There are three absolutely decreed storage rights associated with this reservoir that total 17,962.2 acre-feet. Individually they are for 1765.0, 2866.5 and 13330.7 acre-feet with appropriation dates of February 18, 1910, July 3, 1926, and May 27, 1967 respectively (Cinea, November 4, 1976). On May 1, 1970 this reservoir had 13,398 acre-feet in storage, which represented one fourth of the runoff of Saint Vrain Creek that was in storage at that time.

Longmont also owns two conditional storage decrees for Button Rock Reservoir. They are for 32551.1 and 1515.8 acre-feet with appropriation dates of May 27, 1967 and November 13, 1964 respectively (Cinea, November 4, 1976). While Longmont is showing due diligence in accordance with the law to keep these decrees viable, plans for the future expansion of Button Rock Reservoir are still in the preliminary stages (Cinea, November 17, 1976).

The second largeststorage reservoir which has rights to surface water of the Saint Vrain system is Union Reservoir (which is sometimes called Calkins Lake). It is also located within the sub-basin, but in the plains. The reservoir is owned by the Bijou and Union Ditch Company, and is used to store irrigation water. It has a capacity of 12,739 acre-feet (Anderson, 1961) and maximum surface area of 746 acres (USGS, 1973c). The average depth of this lake when full is about 17 feet. The Oligarchy Ditch delivers water to this reservoir from the mainstem of the Saint Vrain Creek. Information on the storage rights of this reservoir to Saint Vrain Creek were not available.

Union Reservoir also has an absolutely decreed storage right to Spring Creek, a minor intermittant plains tributary of Saint Vrain Creek who's drainage area this reservoir is located in. This right is for 138 acre-feet and its appropriation date is June 1, 1879 (Wilkinson, 1974). On May 1, 1970 this reservoir had 12,715 acre-feet in storage. This represents about one fifth of the native surface water runoff of the Saint Vrain sub-basin that was in storage at that time.

The Boulder Reservoir, located in the Saint Vrain sub-basin, primarily stores water imported from other watersheds. It receives CBT project water, transported into the Saint Vrain sub-basin by the Saint Vrain Supply Canal; the stored water is subsequently exported by the Boulder Feeder Canal. This 12,800 acre-feet reservoir also has an absolutely decreed storage right and a conditionally decreed storage right to water from the mainstem of Saint Vrain Creek. Their amounts are for 10,591 and 2,679 acre-feet respectively. Both have appropriation dates of April 19, 1954 (Wilkinson, 1974). The yield from the absolutely decreed right is delivered to this reservoir, along with its CBT water, through the Boulder Supply Canal.

4.4.3 *Proposed Development*

The Coffintop Reservoir Project - The Coffintop Reservoir Project is currently being studied for feasibility by the Saint Vrain and

Lefthand Water Conservancy District. The United States Army Corps of Engineers is conducting studies relative to its utility for flood control.

The dam would be an earthfill type located on South Saint Vrain Creek just above its confluence with the North Saint Vrain Creek near the mouth of the Saint Vrain Canyon. Three reservoir sizings are under construction; these are for 42,000 acre-feet, 58,000 acre-feet, and 84,000 acre-feet, respectively. A tunnel would aacompany the largest sized proposal diverting water from the North Saint Vrain Creek (Brand, 1976).

The Coffintop Reservoir project would be a multipurpose endeavor by municipal, industrial, and agricultural interests and would involve the transferring of some existing water rights to it for storage. In addition, an application for a storage right has been filed with the courts so that this project may capture excess surface flows.

It has been estimated that the high spring runoff in this sub-basin has unappropriated water equivalent to an annual average of 3,200 acre-feet on the South Saint Vrain Creek and 4,800 acre-feet on the North Saint Vrain Creek (Brand, 1976). In its largest size envisioned, the proposed Coffintop Reservoir would divert both of these amounts and thus make available to the sub-basin an additional 8,000 acre-feet of surface water supplies. The proposal for the two smaller projects would capture only the excess on South Saint Vrain Creek or 3,200 acre-feet per year (Brand, 1976).

An economic analysis performed by the Saint Vrain and Lefthand Water Conservancy District showed that the Coffintop Reservoir Project will not be financially feasible until 1983-1990. However, a series of dry years could make earlier construction a possibility (Sigg, 1976).

The Geer Canyon Reservoir Project - The Geer Canyon Reservoir Project is also being investigated for feasibility by the Saint Vrain and Lefthand Water Conservancy District. It would involve an earth fill dam located on the Lefthand Creek about 14 miles upstream from its confluence with the mainstem of the Saint Vrain Creek. An application for a storage right for this reservoir has been filed with the courts. Because of the lack of data concerning the surface flows of Lefthand Creek, correlation studies using the historical flows of the South Platte are being made (Brand, 1976). Preliminary estimates of storage capacities for the project are at 25,000 acre-feet for agricultural use and 25,000 acre-feet for flood control. Potential yields from the storage appropriations will be assessed and the total storage capacity will be adjusted accordingly after correlation studies concerning flow variations of Lefthand Creek are complete.

4.4.4 *Potentially Developable Surface Water Runoff Remaining* - In 1959, the United States Bureau of Reclamation reported that on the average, existing rights utilize most of the runoff naturally accruing to the Saint Vrain Creek. However, irrigators in this sub-basin have experienced shortages in drought years and are presently relying on supplemental water supplies from outside the sub-basin (i.e., CBT project water).

It has been estimated that the surface water runoff of Saint Vrain Creek at its canyon mouth presently carries an equivalent of 8,000 acre-feet or unalpropriated water each spring. While these flows are presently wasted, they have been conditionally decreed to water users within this sub-basin.

It appears that if and when Button Rock Reservoir is expanded and the Geer and Coffintop Reservoirs are built, the runoff of this sub-basin will be appropriated to the point where any additional development will not be feasible. The conditional water rights and filings associated with these projects would increase the storage capacity available to the runoff of the Saint Vrain sub-basin by more than 100%.

4.5 The Big Thompson River Sub-basin

The Big Thompson River sub-basin encompasses the drainage area of the Big Thompson River above USGS gaging station #06744000, "Big Thompson River at Mouth, near La Salle, Colorado." Figure 4-7 is a schematic drawing of the sub-basin. The La Salle Gaging Station is located 1.6 miles upstream from the confluence of the Big Thompson River and the South Platte River. The boundaries of the sub-basin coincide approximately with those of Irrigation District #4.

4.5.1 *Physical Characteristics and Surface Water Runoff* - The Big Thompson River, the third largest tributary of the South Platte River, originates on the Continental Divide at elevations ranging to 14,000 feet. It flows about 65 miles due east to the plains and its confluence with the South Platte River. This juncture occurs about three miles south of the town of La Salle at an elevation of 4,675.

The principal mountain tributaries of the Big Thompson are: the North Fork, Fall River, and Glacier Creek. Buckhorn Creek and the Little Thompson River originate in the mountains also but join the mainstem in the plains.

The Big Thompson River sub-basin drains 828 square miles. The upper 65% is mountainous, while the lower portion is rolling plains.

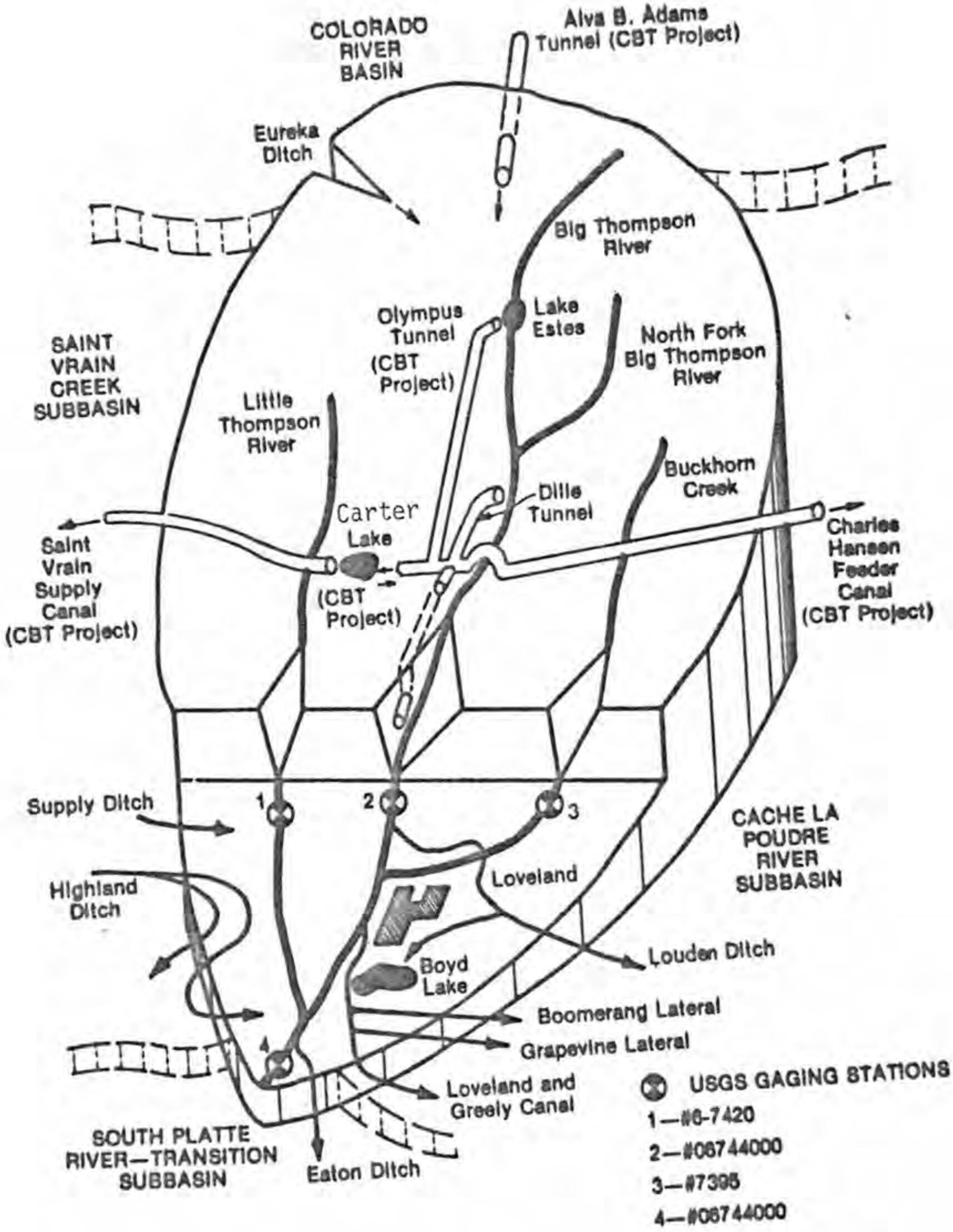


Figure 4-7: Schematic of the Big Thompson River Subbasin

Most of the diversions and consumptive uses of its surface water supplies occur in the plains.

Precipitation in the headwaters of the Big Thompson River averages about 40 inches per year, and about 14 inches per year in the lower elevations (NOAA, United States Department of Commerce, 1974). About 70 percent of the stream flows occur between May and July from melting snow pack in the higher elevations. Very little water accrues to the surface flows of the Big Thompson sub-basin after its mainstem and tributaries leave their canyons in the foothills.

The stream is subject to flash floods. One of the most tragic floods in the history of Colorado resulted from a torrential storm which dropped 12 inches of rain on this sub-basin on the night of July 31, 1976 (USGS, 1976). The subsequent flash flood started in the mainstem of the Big Thompson River at Estes Park, and funneled through the narrow Big Thompson canyon. The flood dissipated rapidly in the plains as the discharge was reduced by valley storage. While the flood lasted only a few hours, it left more than 140 dead and caused 16.5 million dollars worth of damage (USGS, 1976). The discharge at the mouth of the Big Thompson canyon was estimated to peak at 31,200 cfs or about 120 times the average flow (USGS, 1976).

Table 4-16 shows the average, maximum instantaneous and minimum daily discharges (in cfs), and the average, maximum and minimum yearly runoffs (in acre-feet), recorded at four key gaging stations within the Big Thompson River sub-basin. The extremes of the records shown are indicative of the natural variability of the surface water runoff of this sub-basin. There is very little water resource development above these three gaging stations except for use of the mainstem of the Big

Table 4-16 Surface Water Runoff Variability within the Big Thompson River Sub-basin as Indicated by the Extremes of the Flow Records of Several Key Gaging Stations.

Gaging Station Location	Period of Record	Recorded Discharge: Average	Recorded Discharge: Maximum instantaneous		Recorded Discharge: Minimum Daily		Recorded Runoff: Average	Recorded Runoff: Maximum		Recorded Runoff: Minimum	
		Cfs	Cfs	Date	Cfs	Date	Acre-Feet	Acre-Feet	Water Year	Acre-Feet	Water Year
#6-7420, "Little Thompson River near Berthoud, Colorado" (near its canyon mouth)1/	May 1929-Sept. 1930, April 1947-Sept. 1961	19.6	4,000	May 9, 1957	0.0	at times in 1948-49 1951, 1953-55	14,177	33,220	1957	3,020	1950
#06738000, "Big Thompson River at mouth of Canyon, near Drake, Colorado"2/	Aug. 1887-Sept. 1892, May 1895-Sept. 1903, Oct. 1926-Sept. 1933, April 1938-Sept. 1949, March 1951-Sept. 1975.	128.9	31,200	July 31, 1976	0.2	Dec.10-12, 1969	93,293	189,900	1947	46,690	1964
#7395, "Buckhorn Creek near Masonville, Colorado" (near its canyon mouth)3/	April 1947-Sept. 1955	14.7	14,000	Aug. 3, 1951	0.1	Sept. 22, 1948	10,659	32,380	1949	1,000	1954
#06744000, "Big Thompson River at Mouth, near La Salle, Colorado"4/	April 1914-Oct. 1915, March 1927-Sept. 1975	70.7	6,100	Aug. 4, 1951	0.0	At times in 1934-35, 1948	51,191	145,600	1958	12,560	1940

1/Appendix C, Table C4-19
2/Appendix C, Table C4-20
3/Appendix C, Table C4-21
4/Appendix C, Table C4-22

Thompson River as a part of the Colorado Big Thompson project. It's operation has a significant effect on flows of the mainstem, and consequently on the recorded flows at the Loveland Gaging Station. Also flows at the Loveland Gaging Station are affected by several medium sized reservoirs and also diversions above. A comparison of the records of the La Salle Gaging Station at the mouth of the Big Thompson River with those of the three gaging stations upstream indicate the effect of diversions and return flows in between.

The native surface water runoff of the Big Thompson River sub-basin was estimated from the records of the USGS gaging stations #06738000, "Big Thompson River at Mouth of Canyon, near Drake, Colorado;" "6-7420, "Little Thompson River near Berthoud, Colorado;" and #7395, "Buckhorn Creek near Masonville, Colorado." These records are given in Tables C4-20, C4-19, and C4-21, respectively, in Appendix C. Below these gaging stations from the canyon mouths of the Big Thompson River, the Little Thompson River, and Buckhorn Creek, the surface water runoff was assumed negligible. In assessing the native surface water runoff above these gaging stations, man-caused upstream effects on their flow records were taken into account. Some of these were noted above. From these adjustments, the long term average native surface water runoff of the Big Thompson River sub-basin is estimated to be 147,600 acre-feet per year; computations are seen in Table A4-25, Appendix A. This was determined by adjusting the records of the Drake Gaging Station #06738000 for the period of water years 1930 to 1949, the Little Thompson Gaging Station #6-7420 for the period 1930 to 1949, and the Buckhorn Creek Gaging Station #7395 for the period 1930 to 1949.

The 1970 water year native surface water runoff of the Big Thompson River sub-basin was estimated to be 177,006 acre-feet or 119.9% of the long term average annual; computations are seen in Table A4-26, Appendix A. The native surface water runoff available to this sub-basin during the 1953-1956 four year drought period averaged 93,903 acre-feet per year, or 63.6% of the long term average; computations are seen in Table A4-27, Appendix A. This was determined by adjusting the records of these gaging stations for the 1953-1956 period.

The surface water outflow of this sub-basin through the natural stream channel of the Big Thompson River contributes to the surface water supplies of the South Platte River-Transition sub-basin. These flows can be measured at USGS gaging station #06744000, "Big Thompson River at Mouth, near La Salle, Colorado," whose annual records are seen in Appendix C, Table C4-22. The 1915, 1928-1975 49 year average annual discharge recorded by this gaging station was 51,191 acre-feet.

4.5.2 *Existing Development of the Surface Water Runoff* - Figure 4-8 shows the major ditches and reservoirs of the Big Thompson sub-basin (Irrigation District #4). Figure 4-7 is a perspective drawing of the sub-basin.

Direct Diversion Structures - In 1959 the United States Bureau of Reclamation reported that there were 30 major canal systems and 75 major decreed direct flow rights for the native surface water runoff of this sub-basin. These appropriations totaled 2,730 cfs which is equivalent to approximately 1,976,520 acre-feet per year.

The 1974 revised tabulation of Colorado water rights lists about 265 absolute and conditional direct flow rights decreed to the surface water runoff of the Big Thompson Rivers hydrological drainage area. Water from

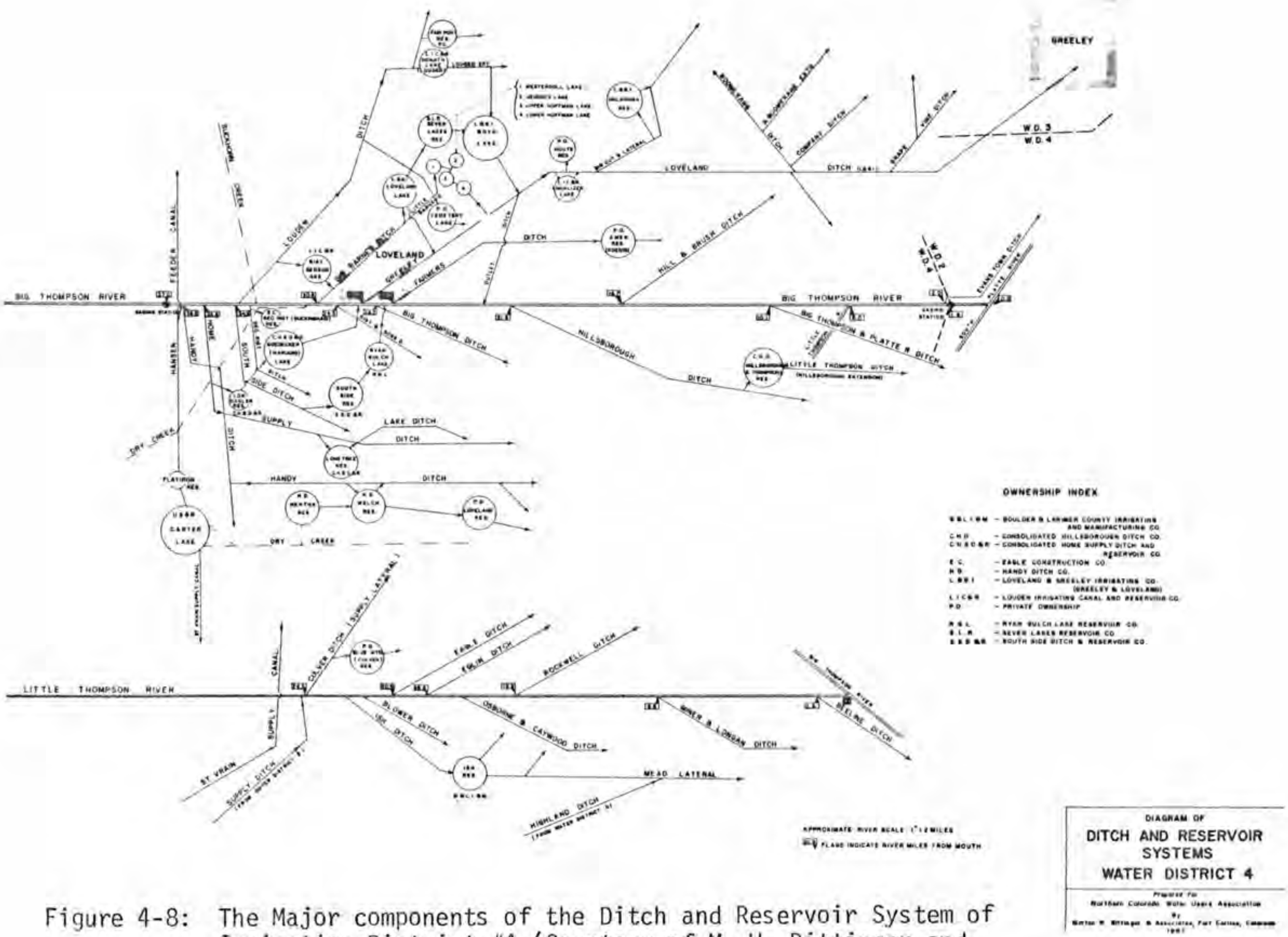


Figure 4-8: The Major components of the Ditch and Reservoir System of Irrigation District #4 (Courtesy of M. W. Bittinger and Associates)

the mainstem of the Big Thompson River is decreed to 157 of these rights, with 20 to the Little Thompson River. Buckhorn Creek is appropriated by 12 decreed flow rights. The remainder are supported by the various other tributaries, springs, seepages, and sloughs within this drainage area.

There are two diversion structures which import water directly to the Big Thompson River sub-basin from watersheds outside of the South Platte River Basin; these are the Alva B. Adams Tunnel and the Eureka Ditch. Their imports presently average 277,626 and 82 acre-feet per year from Tables B3-3 and B3-2, respectively. While all of the imports through the Eureka ditch are used within this sub-basin, a large part of those through the Alva B. Adams tunnel (which is the importation facility of the CBT project) are subsequently exported for uses elsewhere in the South Platte River Basin.

There are several diversion structures that import water to this sub-basin from other watersheds of the South Platte River basin. The largest of these are the Supply Ditch and the Highland Ditch, which deliver water from the Saint Vrain Creek sub-basin. Through an analysis performed in section 2.5.2 of "South Platte River Basin Agricultural Water Demands, 1970-2020" (Janonis and Gerlek, 1977), it was estimated that on the average; 37,530 acre-feet per year is imported to this sub-basin through turnouts from ditches originating in the Saint Vrain Creek sub-basin.

There are about six diversion structures which export water from the Big Thompson sub-basin. In terms of volume, the largest are the Charles Hansen Feeder Canal and the Saint Vrain Supply Canal. These structures are components of the distribution system for the CBT project, which uses water from the Colorado River. The Charles Hansen Feeder Canal also has an absolutely decreed ditch right for 450 cfs of native runoff from the mainstem of the Big Thompson River. The priority date of this appropriation is September 14, 1933 (Wilkinson, 1974). In addition, the Dille Tunnel, which can be interconnected with this canal, has direct flow rights to the mainstem of the Big Thompson River. One is conditionally decreed for 385 cfs and the other is absolutely decreed for 208 cfs. The appropriation dates of both of these are September 14, 1933 (Wilkinson, 1974). The yield from these rights, along with the imported Colorado River Basin water, are exported through the Charles Hansen Feeder Canal to Horsetooth Reservoir in the Cache La Poudre River sub-basin, and then to CBT sharefholders in that sub-basin. The Saint Vrain Supply Canal, originating at Carter Lake, exports water from this sub-basin to CBT shareholders in the Saint Vrain Creek, Boulder Creek, and South Platte River-Transition sub-basins. The Carter Lake Supply Canal has a conditionally decreed ditch right for 300 cfs from the mainstem of the Big Thompson River. The priority date of this appropriation is also September 14, 1933 (Wilkinson, 1974). The stream channel of the Big Thompson River is used also to export some of the CBT project water to users downstream along the South Platte.

There are several other diversion structures which also export the native surface water runoff of this sub-basin. These include, among others, the Grapevine and Boomerang laterals, and the Louden Ditch (which export water to the Cache La Poudre Sub-basin), and the Evans Town Ditch (which exports water to the South Platte River-Transition sub-basin). Through an analysis performed in section 2.5.2 of "South Platte River Basin Agricultural Water Demands 1970-2020," (Janonis and Gerlek, 1977) it was estimated that on the average, 31,344 acre-feet per year is exported through ditch turnouts to the Cache La Poudre

Sub-basin, and 7,000 acre-feet per year is exported to the South Platte River Transition sub-basin.

The 1970 State Engineer's report showed that 37 ditches had reported diverting a total of 153,970 acre-feet of water from the Big Thompson River in that water year. This represents approximately 87.0% of the native surface water runoff that occurred in this sub-basin during the 1970 water year. While this total does not include all diversions, it does represent the bulk of the water diverted in that water year. This water was primarily used for irrigation. The diversions also include some return flows from prior uses. In addition, this total diverted amount includes some water that was transported out of the Big Thompson River sub-basin for use elsewhere. Table 4-17 is a listing of the major diverters of surface water runoff from the Big Thompson River sub-basin and their 1973 diversions.

Storage Facilities - In 1959 the United States Bureau of Reclamation reported that there were 14 reservoirs whose rights were dependent on the native surface water runoff in the Big Thompson River sub-basin. Their decreed storage rights were worth 101,000 acre-feet.

The 1974 revised tabulation of Colorado Water Rights lists about 80 absolute and conditional storage rights decreed for the native surface water runoff of this sub-basin water. Some 49 decrees are for water from the mainstem of the Big Thompson and five are for water from the Little Thompson River. Runoff from Buckhorn Creek supports two decreed storage appropriations, while the remainder are for water from the various other tributaries, springs, seepages, and sloughs within this sub-basin.

Table 4-17 The Major Direct Diversion Structures in the Big Thompson River Sub-basin and their 1973 Diversions (Toups, 1975).

Structure Name	Stream Source (Diversion Point)	1973 Diversion (acre-feet)
Evanstown Ditch	Big Thompson River	N.A.
Thomas and Platte Ditch	Big Thompson River	N.A.
Hillsboro Ditch	Big Thompson River	15,500
Farmers Ditch	Big Thompson River	5,000
Big Thompson Ditch No. 2	Big Thompson River	10,770
Big Barnes Ditch	Big Thompson River	N.A.
Loveland and Greeley Canal	Big Thompson River	21,500
Louden Ditch	Big Thompson River	12,700
Home Supply Ditch	Big Thompson River	14,000
Handy Ditch	Big Thompson River	12,300
Total	-	91,770

Note: Some of these ditches also have direct flow rights to the various tributaries of the Big Thompson River that they intercept on their way to outlying agricultural acreages. In addition, some of the diverted water was put to storage and some was applied to lands lying outside of the Big Thompson River Sub-basin.

Table 4-18 lists the major reservoirs with absolutely decreed storage rights to the native surface water runoff of the Big Thompson River sub-basin and their amounts in storage during the 1970 water year. The list does not include Carter or Horsetooth Reservoirs. Although the main purpose of the two reservoirs is to store CBT project water, they also have absolutely decreed storage rights to the surface water from this sub-basin. Information on the yield of these rights during the 1970 water year was not available. The total amount in storage on May 1, 1970 of the 19 reservoirs listed in Table 4-18 which excludes Carter and Horsetooth Reservoirs, represents about 65.7% of the estimated long term average annual native surface water yield of this sub-basin.

With the exception of Lawn Lake Reservoir, which lies in the mountains, all of the reservoirs in Table 4-18 are located in the plains portion of the Big Thompson River sub-basin. Generally, these are shallow off stream depressions and are used for the storage of irrigation water.

Some of the storage facilities in this sub-basin, which includes among others the Ish Reservoir, also store water imported from other sub-basins of the South Platte River basin. Carter Lake is the only major reservoir located within this sub-basin that is used to store water imported from outside of the South Platte River basin. It has a live storage capacity of 108,924 acre-feet, a maximum surface area of 1,144 acres, and is located in the foothills west of Berthoud between two hogbacks. Carter Lake is one of the key east slope storage facilities of the CBT Project, storing water imported from the Colorado River basin. Occasionally, however, it is used to store the native surface flows of this sub-basin. It has an absolutely decreed storage right for

Table 4-18 Amounts in Storage During the 1970 Water Year of the Major Reservoirs with Absolutely Decreed Storage Rights to the Native Surface Water Runoff of the Big Thompson River Sub-basin (Division I Water Commissioners, 1970).

Name	Source	Amount in Storage (acre-feet)		
		11-1-69	5-1-70	10-31-70
Lone Tree	Big Thompson	8,525	7,854	7,254
Lon Hagler	Big Thompson	4,701	4,663	1,262
Mariano	Big Thompson	2,853	5,493	5,182
Lake Loveland	Big Thompson	12,492	10,411	12,153
Boyd Lake	Big Thompson	29,372	42,498	43,960
Horseshoe	Big Thompson	7,170	5,877	6,274
Welsh	Big Thompson	6,013	6,468	6,514
Rist Benson	Big Thompson	456	372	450
Geo. Rist (Buckingham)	Big Thompson	284	231	371
Fairport	Big Thompson	269	269	308
Cemetary	Big Thompson	379	379	364
South Side	Big Thompson	299	334	339
Donath	Big Thompson	373	346	351
Oklahoma	Big Thompson	392	384	434
Loveland Lake	Big Thompson	1,375	1,764	1,545
Subtotal	Big Thompson	74,953	87,343	86,761
Boulder-Larimer (Ish)	Little Thompson	4,110	6,693	3,264
Subtotal	Little Thompson	4,110	6,693	3,264
Hertha	Dry Creek	1,063	1,307	764
Lawn Lake	Roaring Fork	817	817	817
Ryan Gulch	Ryan Gulch	582	812	828
Subtotal	Other minor Tributaries	2,462	2,936	2,409
Grand Total	Entire Big Thompson River sub-basin	81,525	96,972	92,434

Note: Some of these reservoirs also store imported water as they have absolutely decreed rights to the surface water runoff of other South Platte Sub-basins as well. Therefore, their amounts in storage do not necessarily reflect only the yield from their rights to water from this sub-basin. In addition, some are located outside of sub-basin. This list does not include Horsetooth or Carter Reservoirs. Although these storage facilities prime function is to store CBT project water imported from the Colorado River Basin, they do have absolutely decreed storage rights to the surface water from this sub-basin. Information on the yield of these rights which are known to be minor or nothing in most years were not available.

112,830 acre-feet of water from the mainstem of the Big Thompson River with an appropriation date of August 1, 1935 (Wilkinson, 1974). When this water is available, it is delivered through the Carter Lake pressure tunnel and conduit, a component of the CBT Project.

Of the other reservoirs located within this sub-basin, Boyd Lake is the largest. This reservoir is located in the plains in an off stream depression just north and east of Loveland. It is owned by the Loveland and Greeley Irrigation Company and has an absolutely decreed storage right for 48,564 acre-feet of water from the mainstem of the Big Thompson. The priority date of this appropriation is April 28, 1902 and the basin rank is 1,386 (Wilkinson, 1974). The yield from this right is delivered by a turnout from the Louden Extension Ditch and the Big Barnes Ditch via Horseshoe Lake and Lake Loveland. On May 1, 1970 this reservoir had 42,498 acre-feet in storage. This represents about 43% of the total amount of the sub-basins native surface water runoff in storage at that time.

Horsetooth reservoir is the only major reservoir located outside of the Big Thompson sub-basin that has an absolutely decreed storage right to its native water runoff. It is located in the Cache La Poudre River sub-basin, has a live storage capacity of 143,486 acre-feet, and a maximum surface area of 1,873 acres (USBR, 1968). Horsetooth is the other key east slope storage facility for the CBT Project which stores imports from the Colorado River basin. Occasionally, however, it is also used to store the native surface water runoff of the Big Thompson River sub-basin. It has an absolutely decreed storage right for water from the mainstem of the Big Thompson River in the amount of 153,252 acre-feet with a priority date of August 1, 1935 (Wilkinson, 1974). When this water is available, it is delivered by the Charles Hansen Feeder Canal, a component of the CBT Project.

4.5.3 *Potentially Developable Surface Water Runoff Remaining* - In 1959 the United States Bureau of Reclamation judged that the principal tributaries of the Big Thompson River, the Little Thompson River and Buckhorn Creek, were fully appropriated and could not support further development. Furthermore, they reported that the mainstem of the Big Thompson River appeared to be over appropriated as the irrigated agriculture it serves has experienced severe shortages in the past. This situation has been considerably alleviated by the dependable supply of supplemental irrigation water brought from the west slope by the CBT Project.

As is the case with all of the South Platte Front Range tributaries, existing absolutely decreed water rights can absorb above average flows if they appear coincidental with demands. This however, does not always happen and occasionally some water is lost to this sub-basin. In addition, as with all the Front Range tributaries, hydrological events of an extreme nature do occur periodically. In August, 1976, intensive rainfall on this sub-basin caused exceptionally high surface flows (more than 100 times of average) on the mainstem of the Big Thompson River. However, the creation of a storage facility in this sub-basin to capture these rare flows of unappropriated water, which may occur once in every several hundred years, is not feasible. A more appropriate strategy might be to build a reservoir on the South Platte in the plains, below the Front Range tributaries to capture such flows from all of the tributaries.

4.6 The Cache La Poudre River Sub-basin

The Cache La Poudre River sub-basin encompasses the drainage area of the Cache La Poudre River above USGS gaging station #06752500, "Cache La Poudre River near Greeley, Colorado." This gaging station is located 3.0 miles upstream from the confluence of the Cache La Poudre River with the South Platte River. The boundaries of the sub-basin coincide approximately with those of Irrigation District #3. Figure 4-9 is a schematic drawing of the sub-basin.

4.6.1 *Physical Characteristics and Surface Water Runoff* - The Cache La Poudre River is the largest tributary of the South Platte River. It originates on the Continental Divide and on the divide between the North and South Platte River basins; elevations exceed 13,000 feet. From its headwaters, the Cache La Poudre River flows about 50 miles in a northeast direction to its canyon mouth. From this point it flows southeast over the open plains for about 35 miles until it meets the South Platte just east of Greeley, at an elevation of 4,610 feet.

The principal mountain tributaries of the Cache La Poudre River are the North Fork, the South Fork, and Elkhorn Creek. Boxelder Creek and Fossil Creek originate in the foothills and join the Cache La Poudre in the plains below Fort Collins.

The Cache La Poudre Sub-basin drains 1,877 square miles; about half of this area is mountainous. The lower elevation portion is rolling plains. Most of the diversions, uses, and return flows are in the plains. A small portion of the sub-basin, about 160 square miles, is in Wyoming.

Precipitation in the headwaters of this sub-basin average from 20 to 40 inches per year; in the lower elevations, in the plains, it is

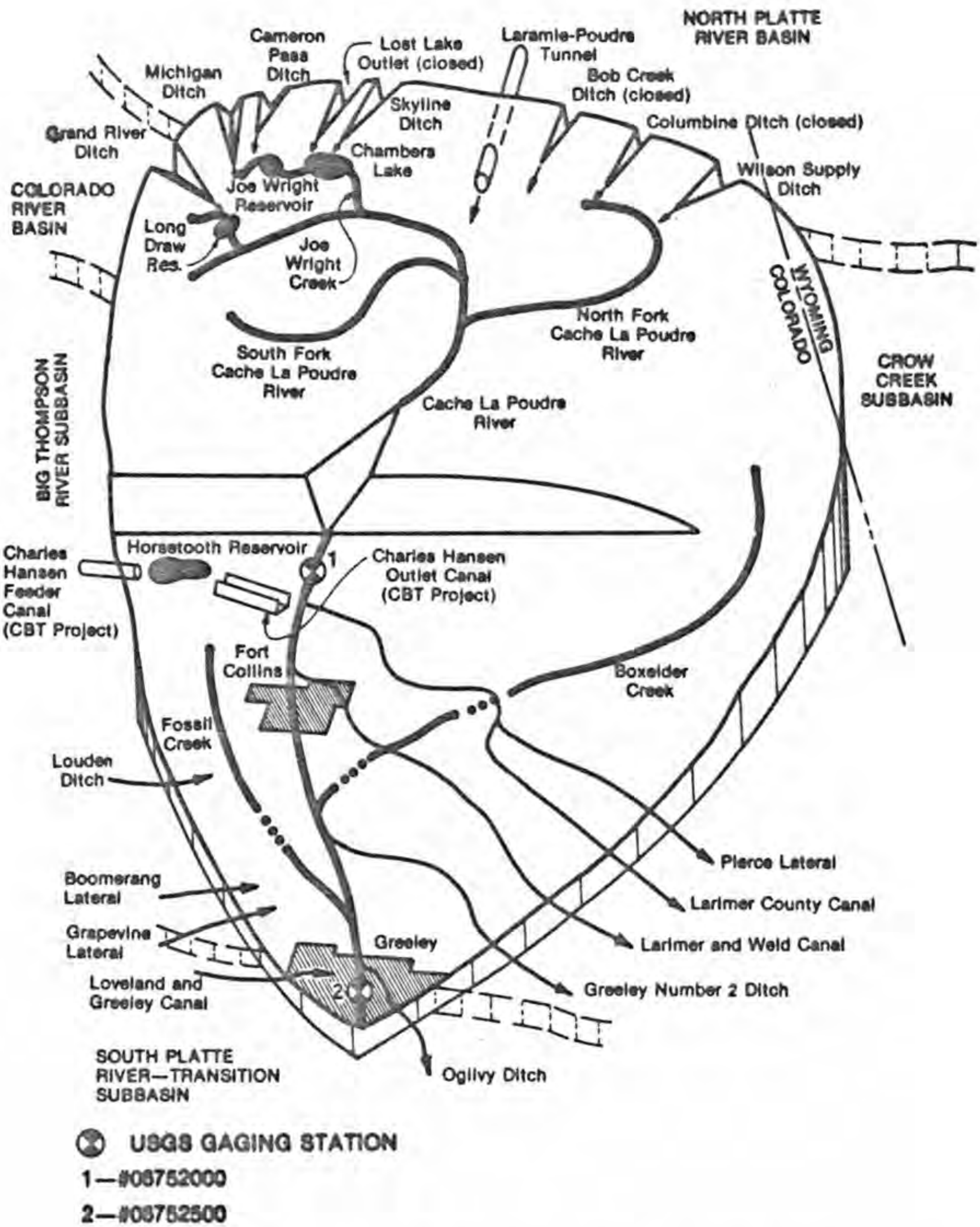


Figure 4-9: Schematic of the Cache La Poudre River Subbasin

about 12 inches per year (NOAA, United States Department of Commerce, 1974). Nearly all of the surface water supply of this sub-basin is derived from melting snow pack in the mountains. Very little virgin water accrues to the surface flow of the Cache La Poudre River after it leaves its canyon. Boxelder Creek and Fossil Creek drain the low plains area as depicted in Figure 4-9. These streams are intermittent and contribute very little surface flow to the Cache La Poudre River.

Table 4-19 shows the average, maximum instantaneous, and minimum daily discharges (in cfs), and the average, maximum, and minimum yearly runoffs (in acre-feet) of the mainstem Cache La Poudre River from records at the Fort Collins and Greeley Gaging Stations. The differences in flows between the two stations are indicative of the water use activity between Fort Collins and Greeley. The extremes of the records of the Fort Collins Gaging Station gives some indication of the natural variability of the surface water runoff of this river. However, there is rather substantial water resource development above this gaging station. Its flow records include imports from other river basins and exclude some native runoff which is held back in reservoirs and which bypasses the gaging station through ditches, canals and pipelines. In fact, the maximum instantaneous discharge of the Cache La Poudre River at this point was caused by the failure of Chambers Lake Dam and minimum daily discharge was caused by diversions of the Poudre Valley Canal half a mile upstream.

Table 4-20 shows the porbable flood discharges of the South Fork of the Cache La Poudre River near Rustic, Colorado for various frequencies of occurrence. This gaging station is located 5.7 miles upstream from the confluence of the South Fork and the mainstem of the Cache La Poudre.

Table 4-19 Surface Water Runoff Variability Within the Cache La Poudre River Subbasin as Indicated by the Extremes of the Flow Records of Several Key Gaging Stations.

Gaging Station and Location	Period of Record	Recorded Discharge					Recorded Runoff				
		Average	Maximum instantaneous		Minimum Daily		Average	Maximum		Minimum	
		Cfs	Cfs	Date	Cfs	Date	Acre-Feet	Acre-Feet	Water Year	Acre-Feet	Water Year
#06752000, "Cache La Poudre River at mouth of Canyon, near Fort Collins, Colorado"[1/]	June-Aug. 1881 May-July 1883 Oct. 1883-Sept. 1975	382.8	21,000[3/]	June 9, 1891	1.6[4/]	Nov. 20, 28 1948	277,159	675,000	1884	98,290	1966
#067525000, "Cache La Poudre River near Greeley, Colorado" (near its mouth)[2/]	March-Oct. 1903 Aug.-Nov. 1904 Jan. 1914, Dec. 1919 June 1904-Sept. 1975	105.2	(maximum daily) 4,200	June 24, 26, 1917	0.8	Oct. 3, 1946	76,167	286,000	1917	21,410	1941

1/Appendix C, Table C4-23
2/Appendix C, Table C4-24
3/Caused by failure of Chambers Lake Dam.
4/Caused by diversion of Poudre Valley Canal 0.5 miles upstream.

Table 4-20 Flood Characteristics of the South Fork of the Cache La Poudre River near Rustic, Colorado (McCain & Jarrett, 1976).

Flood discharges are: (first line) values used in multiple regression analysis, (second line) weighed averages.

Station Number	Station Name	Period of record, in years	Drainage area, in square miles	Gage datum, in feet above mean sea level	Basin slope, in feet per mile	Streambed slope, in feet per mile	Mean annual precipitation, in inches	10-year flood discharge, in cubic ft per second	50-year flood discharge, in cubic ft per second	100-year flood discharge, in cubic ft per second	500-year flood discharge, in cubic ft per second	100-year flood depth, in feet
06748600	South Fork Cache La Poudre River near Rustic, Colo.	17	90.3	7597	220	74	24	924 857	1400 1290	1630 1490	2250 2020	4.5

Its drainage area includes about nine percent of the mountainous portion of this sub-basin. These data help to further characterize the surface water runoff of this sub-basin.

The native surface water runoff of the Cache La Poudre River sub-basin was estimated from the records of the USGS gaging station #06752000, "Cache La Poudre River at Mouth of Canyon, near Fort Collins, Colorado." The surface water runoff below this gaging station was assumed negligible. The flows gaged were adjusted for man-caused effects upstream (i.e., storage, reservoir evaporation, diversions, etc.). Using this method, the long term average annual native surface water runoff of the Cache La Poudre River sub-basin was estimated to be 234,833 acre-feet per year; computations are seen in Table A4-28, Appendix A. The 1970 native surface water runoff was determined to be 321,200 acre-feet or 136.8% of the estimated long term average; computations are given in Table A-29, Appendix A.

The native surface water runoff of this sub-basin during the 1953-1956 four year drough period averaged 158,066 acre-feet per year or 67.3% of the long term average; computations, are seen in Table A4-30, Appendix A.

The surface water outflow of this sub-basin through the natural stream channel of the Cache La Poudre River contributes to the surface water supplies of the South Platte River-Transition sub-basin. These flows are measured at the USGS Gaging Station #06752500 near Greeley and are seen in Table C4-24, Appendix C. The 1915-1919, 1924-1975, 56 year average annual discharge recorded by this gaging station was 76,167 acre-feet.

4.6.2 *Existing Development of the Surface Water Runoff* - Figure 4-10 shows the major ditches and reservoirs in the Cache La Poudre sub-basin (which coincides with Irrigation District #3). The Cache La Poudre sub-basin, of all the sub-basins in the South Platte River basin, is perhaps the most intricately developed with regards to "exchanges" by water users. In the search for more water, an extensive and complex system of exchanges has been developed. This system relies upon accounting of water rather than upon strict application of priorities. It is an ingenious system and a splendid example of cooperation. All of the canals and most of the reservoirs are tied together in a complex network of ditches and pipelines that can permit the exchange of water between any two parties that may wish to do so. Therefore, the diversions of water in this sub-basin can be somewhat deceiving at first glance. In many instances, the water flowing in a ditch or being held in a reservoir is not necessarily the yield of that sturctures water right. For example, Fort Collins may transfer some of its CBT water in Horsetooth Reservoir "up to" its storage facility in the mountains, Joe Wright Reservoir. Or, an irrigation company may divert out of priority to upstream lands by replacing it with stored water at lower elevations to satisfy the senior appropriator who is calling the river. In both cases, of course, compensation for carriage losses over the distance of the exchange is made so as not to injure a third party.

Direct Diversion Structures - In 1959 the United States Bureau of Reclamation reported that there were 32 separate canal systems and 70 major decreed direct flow rights for the native surface water runoff of this sub-basin. These appropriations totaled 6,200 cfs which is equivalent to approximately 4,488,800 acre-feet per year.

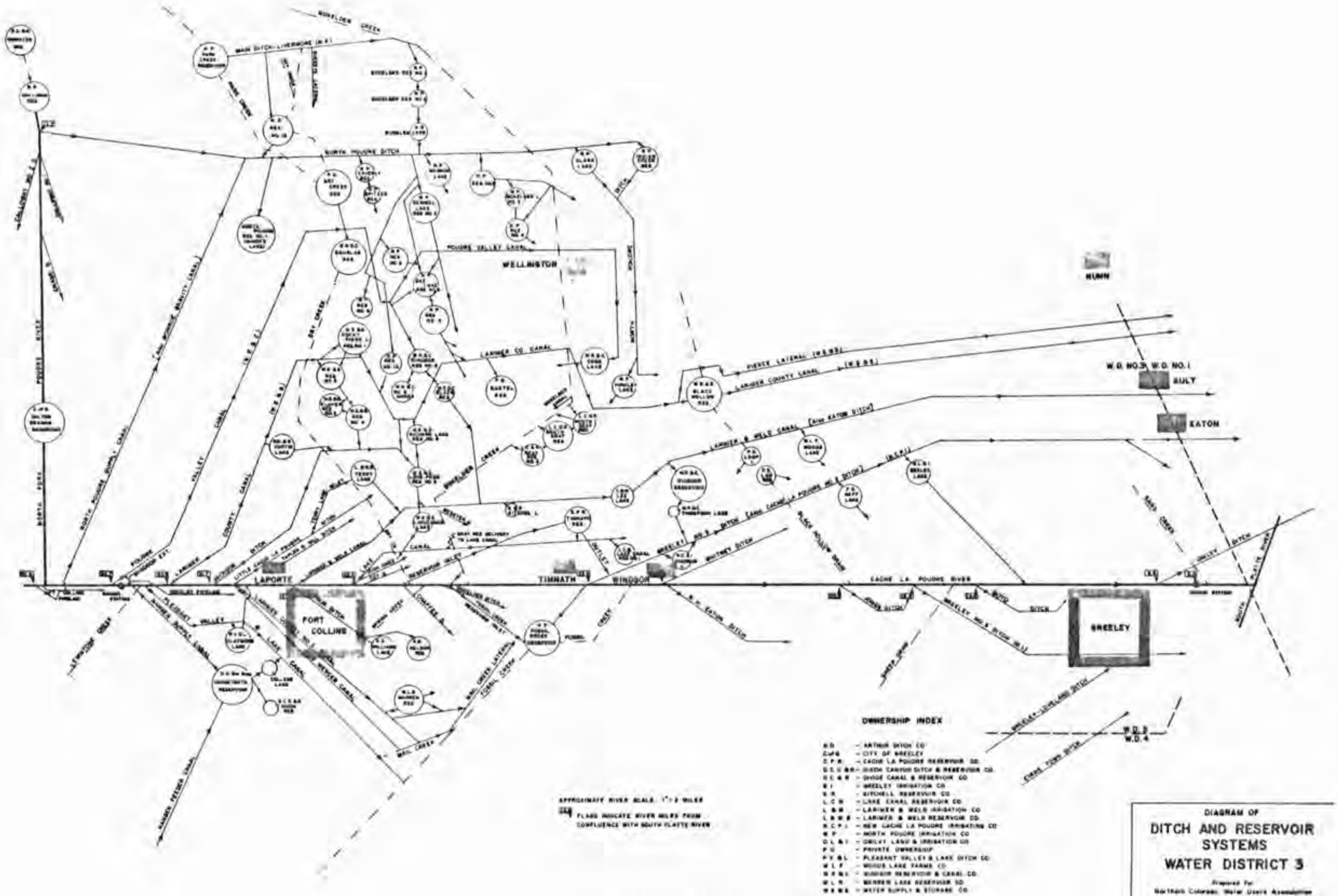


Figure 4-10: The major components of the Ditch and Reservoir System of Irrigation District #3 (Courtesy of M. W. Bittinger and Associates)

The 1974 revised tabulation of Colorado Water Rights lists nearly 370 absolute and conditional direct flow rights decreed to the surface water runoff of the Cache La Poudre's drainage area. Direct flow rights are granted to ditches, pipelines, and surface pumps which in addition to surface flows, may also divert water from seeps and springs. There are approximately 330 absolutely and conditionally decreed ditch rights held in the Cache La Poudre River Sbu-basin. Water from the mainstem of the Cache La Poudre River is decreed to 144 ditch rights and 13 pipeline rights, while 31 ditch rights are decreed to waters of the North Fork. Boxelder Creek is appropriated by 14 decreed ditch rights. The remaining rights are supported by the various other tributaries, springs, seepages, and sloughs within this drainage area.

Nine diversion structures have been built to import water directly to this sub-basin from watersheds outside of the South Platte River basin; these are listed in Table 4-21. More information on these diversion structures can be found in Part III of this report. There is one indirect importation of foreign water, which involves the Charles Hansen Feeder Canal, a component of the CBT Project. This canal directs imports from the Colorado River Basin which have been brought through the Alva B. Adams Tunnel to the Big Thompson River. Occasionally, the Charles Hansen Feeder Canal imports some of the native surface water runoff of the Big Thompson as well. The water is brought into the Cache La Poudre sub-basin and delivered to Horsetooth Reservoir (another CBT Project component) for terminal storage.

Table 4-21 Diversion Structures Directly Importing Water to the Cache La Poudre River Subbasin from Water Sheds Outside the South Platte River Basin.

Diversion Structure	Source	Destination	Years of Operation	Imports (acre-feet)	
				Average Annual	1970
Wilson Supply[1/] Ditch	North Platte River Basin, Laramie River Sub-basin	Sheep Creek, tributary to North Fork Cache La Poudre River	1902-present	2,383	2,880
Columbine[2/] Ditch	North Platte River Basin, Laramie River Sub-basin	North Fork Cache La Poudre River	1921-57	121	-
Bob Creek[3/] Ditch	North Platte River Basin Laramie River Sub-basin	Roaring Fork, tributary to Cache La Poudre River	1920-57	358	-
Laramie-Poudre Tunnel[4/]	North Platte River Basin, Laramie River Sub-basin	Cache La Poudre River	1914-present	15,630	14,990
Skyline[5/] Ditch	North Platte River Basin, Laramie River Basin	Chambers Lake on the Cache La Poudre River	1895-present	1,707	1,550
The Lost Lake Outlet[6/]	North Platte River Basin, Laramie River Basin	Chambers Lake on the Cache La Poudre River	1899-1950	215	-
Cameron Pass Ditch[7/]	North Platte River Basin, North Platte River-Mountains-Sub-basin	Joe Wright Creek, tributary to Cache La Poudre River	1913-present	107	0
Michigan[8/] Ditch	North Platte River Basin, North Platte River-Mountains-Sub-basin	Joe Wright Creek, tributary to Cache La Poudre River	1905-present	1,190	0
Grand River Ditch[9/]	Colorado River Basin, Colorado River-Mountains Sub-basin	Long Draw, tributary to Cache La Poudre River	1896-present	17,523	12,830
Total				39,234	32,250

1/Appendix B, Table B1-1, Annual Average is since 1957 and the enactment of the Laramie River Agreement.
2/Appendix B, Table B1-2, The Columbine Ditch was shut down by court order in 1957.
3/Appendix B, Table B1-3, The Bob Creek Ditch was shut down by court order in 1957.
4/Appendix B, Table B1-4, Annual Average is since 1957 and the enactment of the Laramie River Decree.
5/Appendix B, Table B1-5, Annual Average is since 1957 and the enactment of the Laramie River Decree.
6/Appendix B, Table B1-6, The Lost Lake outlet was closed by the Colorado State Engineer in 1950.
7/Appendix B, Table B1-7, Annual Average is since 1945 and the Enactment of the North Platte River Decree.
8/Appendix B, Table B1-8, Annual Average is since 1945 and the Enactment of the North Platte River Decree.
9/Appendix B, Table B3-1, Annual Average is between 1935-74 when no expansion of this ditches collection system was underway.

There are several ditches which import the native surface water runoff of other sub-basins of the South Platte River Basin. These include, among others, the Grapevine and Boomerang Laterals, and the Louden Ditch, which bring water in from the Big Thompson River sub-basin. It has been estimated that on the average, 31,344 acre-feet per year is imported to the Cache La Poudre River sub-basin through turnouts from these ditches (Janonis and Gerlek, 1977).

Several diversion structures export water from the Cache La Poudre sub-basin, to other sub-basins of the South Platte. These include, among others, the Larimer County Canal, the Larimer and Weld Canal (also called the Eaton Ditch), the Greeley #2 Ditch (also called the Cache La Poudre #2 Ditch), and the Pierce Lateral; all of these export water to the Crow Creek sub-basin. Th- Ogilvy Ditch exports water to the South Platte River-Transition and the South Platte River-Plains sub-basins.

It has been estimated that in an average year, 66,405 acre-feet of water is exported from this sub-basin to the Crow Creek sub-basin, while 4,413 acre-feet is exposed to the South Platte River-Transition sub-basin with the same amount going also to the South Platte River-Plains sub-basin (Janonis and Gerlek, 1977).

The 1970 State Engineer's report showed that 28 ditches diverted a total of 276,839 acre-feet of water from the Cache La Poudre River sub-basin in that water year. This represents approximately 86.2% of the native surface water that occurred in this sub-basin during the 1970 water year. While this total does not include all diversions, it does represent the bulk of the water diverted in that water year. This water was primarily used for irrigation. Because there is considerable returns from irrigation applications and from the City of Fort Collins, the total surface diversions includes return flows. Also, some of this diverted water was transported out of the Cache La Poudre sub-basin for use elsewhere. Table 4-22 is a listing of the major diverters of surface water runoff from the Cache La Poudre River sub-basin and their 1973 diversions.

Storage Facilities - In 1959 the United States Bureau of Reclamation reported that there were about 75 reservoirs whose rights were dependent on the native surface water runoff of the Cache La Poudre sub-basin. Their decrees ranged from 90 to over 22,000 acre-feet; the total storage decrees amounted to about 200,000 acre-feet.

The 1974 revised tabulation of Colorado Water Rights lists over 200 absolute and conditional storage rights decreed for the native surface water runoff of this sub-basin. Water from the mainstem of the Cache La Poudre River is decreed to 55 of these storage rights, while North Fork water is decreed to 40 storage rights. Runoff from Boxelder Creek supports 19 decreed storage appropriations.

Table 4-22 The Major Direct Diversion Structures in the Cache La Poudre River Sub-basin and their 1973 Diversions (Toups, (1975).

Structure Name	Stream Source (Diversion Point)	1973 Diversion (acre-feet)
Ogilvy Ditch	Cache La Poudre River	13,500
Greeley No. 3 Ditch	Cache La Poudre River	17,700
B. H. Eaton Ditch	Cache La Poudre River	5,800
Whitney Ditch	Cache La Poudre River	11,200
New Cache La Poudre Canal	Cache La Poudre River	43,300
Boxelder Ditch	Cache La Poudre River	6,800
Lake Canal	Cache La Poudre River	14,000
Larimer & Weld Canal	Cache La Poudre River	83,100
Arthur Ditch	Cache La Poudre River	5,300
Larimer County No. 2 Canal	Cache La Poudre River	N.A.
New Mercer Canal	Cache La Poudre River	7,300
Jackson Ditch	Cache La Poudre River	6,100
Larimer County Canal	Cache La Poudre River	64,200
Pleasant Valley & Lake Canal	Cache La Poudre River	18,100
North Poudre Supply Canal	Cahce La Poudre River	26,700
Subtotal	-	323,100

Note: Some of these ditches also have direct flow rights to the various tributaries of the Cache La Poudre River that they intercept on their way to outlying agricultural land. In addition, some of the diverted water was applied to lands lying outside of the Cache La Poudre River Sub-basin.

The remainder are for water from various other tributaries, springs, seepages, and sloughs within this sub-basin.

There are no major reservoirs located outside of the Cache La Poudre River sub-basin that have storage rights to its native surface water runoff. However, there are several minor ones located in the Crow Creek sub-basin which store some of the water transported there by agricultural ditches and canals. These include, among others, Saxton Lake (which is fed by Greeley #2 ditch) and Briscoe and Faber Reservoirs (which are fed by the Eaton Ditch). Therefore, the bulk of the existing storage capacity available to the native surface water runoff of the Cache La Poudre River sub-basin is located within the sub-basin.

Twenty-two reservoirs with a combined capacity of 50,511 acre-feet are located in the mountains of the Cache La Poudre sub-basin. These range in size from 69 acre-feet Bellaires Lakes to the 10,128 acre-feet Halligan Reservoir (United States Bureau of Reclamation, 1966); capacities given are the amounts associated with the storage rights. Most are owned by irrigation companies but six are owned by the City of Greeley (Evans, 1971). However, the difficulties and expense of operation and maintenance of these high mountain storage facilities has led to the near abandonment of some, especially the smaller ones (United States Bureau of Reclamation, 1966).

There are numerous depressions scattered throughout the plains drainage area of this sub-basin which are a result of natural phenomena. The depressions are five to fifty feet deep, and were caused by wind scour. Some of these depressions collected rain water and formed watering holes and "buffalo wallows." These same basins now provide facilities for storing water at a relatively low expense. The discovery was made at an early date that these natural depressions could have their holding capacity increased greatly by building an embankment across a saccle in a rim and joining it to higher ground. Nearly all of the present "basin" reservoirs in the Cache La Poudre River sub-basin were completed prior to 1920 (USBR, 1966). Very few feasible sites for potential offstream reservoirs of this type remain in the sub-basin today.

Excluding Horsetooth Reservoir whose function is to store imported CBT water, there are over 90 reservoirs in the plains portion of this sub-basin. Some 56 have a total decreed capacity of 161,300 acre-feet; they range in size from less than 100 acre-feet to the 22,300 acre-feet Cob Reservoir (USBR, 1966). Many of these reservoirs have been operating at less than decreed capacity due to sediment buildup, phreatophytic growth, and deterioration of the facilities (Evans, 1971). The total decreed storage capacity within the entire Cache La Poudre River sub-basin is approximately 211,811 acre-feet. This represents about 90.2% of the estimated long term average annual native surface water run-off of this sub-basin.

Table 4-23 lists the major reservoirs which store the native surface water runoff of the Cache La Poudre River sub-basin, along with their respective capacities. Table 4-24 lists some of the minor reservoirs which store the native surface water runoff of this sub-basin. Very little information is available for most of these reservoirs.

The reservoirs in this sub-basin are usually filled during periods of high runoff caused by melting snows, generally April to June. However, some plains reservoirs also take water during the fall and winter when direct diversion users do not require these flows.

A tabulation of the historical contents of the plains reservoirs in the Cache La Poudre sub-basin for the 1930-1949 period was performed by the USBR (1966). They found the maximum and minimum agreegate storage to be 133,800 and 5,100 acre-feet respectively. An estimated operation of these reservoirs, considered as a group, was also performed fro the 1947-1960 period. They found the average annual yield to be 60,000 acre-feet ranging from a minimum of 22,000 in 1957 to 90,000 in 1947. Table 4-25 lists the major reservoirs which absolutely decreed storage rights to the native surface water runoff of the Cache La Poudre River sub-basin and their amounts in storage during the 1970 water year. All of the reservoirs on this list are located within the sub-basin. However, some also store water that had been imported from the west slope.

Based on the length of feeder canals and other studies, canal losses were estimated by the USBR (1966) to be 20% of the diversions made from the river to storage in the plains. In addition, they estimated that the net surface loss was 1.78 acre-feet per acre for the plains reservoirs which they reported as having a total surface area of

Table 4-23 The Major Reservoirs which Store the Native Surface Water Runoff of the Cache La Poudre River Sub-basin (Evans, 1971).

Name	Cap (AF)	Ownership
Black Hollow	7,485	Water Supply & Storage Co.
Timnath (Cache La Poudre	10,070	Cache La Poudre Res. Co. (Greeley No. 2)
Claymore	883	Pleasant Valley & Lake Canal
Cobb Lake	22,300	Windsor Res. & Canal Co.
Curtis	1,525	Water Supply & Storage Co.
Douglas Res.	8,834	Windsor Res. & Canal Co.
Fossil Creek Res.	11,508	North Poudre
Indian Creek Res.	1,908	North Poudre
Luna Pond (Res. No. 5)	4,082	Water Supply & Storage Co.
Kluver Res.	1,503	Water Supply & Storage Co.
Demmel (Res. No. 2)	3,910	North Poudre
Hackel (Res. No. 3)	3,441	North Poudre
Res. No. 4	1,674	North Poudre
Bee Lake (Res. No. 5)	8,413	North Poudre
Res. No. 6	9,986	North Poudre
Clarks Lake	871	North Poudre
Res. No. 15	5,526	North Poudre
Res. No. 8	10,524	Windsor Res. & Canal Co.
Res. No. 8 Annex	3,607	Windsor Res. & Canal Co.
Richards Res. (Res. No. 6)	960	Water Supply & Storage Co.
Rocky Ridge	4,492	Water Supply & Storage Co.
Terry Lake	8,145	Larimer & Weld Res. Co.
Warren Lake	2,354	Warren Lake Res. Co.
Water Supply & Storage No. 3	4,750	Water Supply & Storage Co.
Water Supply & Storage No. 4	1,012	Water Supply & Storage Co.
Windsor Lake	1,275	New Cache La Poudre Irrigation Co.
Windsor Res.	17,689	Windsor Res. & Canal Co.
Woods Lake Res.	2,687	Woods Lake Farms Co.
Park Creek	7,155	North Poudre
Barnes Meadow	898	City of Greeley
Big Beaver (Hourglass) Res.	1,693	City of Greeley
Chambers Lake	8,824	Water Supply & Storage Co.
Comanche Res.	2,629	City of Greeley
Dowdy Res.	1,619	Colorado Dept. of Game, Fish & Parks
Italligan Res.	6,428	North Poudre
Joe Wright Res.	800	North Poudre
Long Draw Res.	10,800	Water Supply & Storage Co.
Peterson Res.	892	City of Greeley
Seaman Res.	5,008	City of Greeley
Eaton (Worster) Res.	3,749	Divide Canal & Res. Co. (Larimer & Weld)
Total	211,809	-

Note: All of these reservoirs are located within this sub-basin. However some are also used to store imported foreign water.

Table 4-24 The Minor Reservoirs Which Store the Native Surface Water Runoff of the Cache La Poudre River Sub-basin (Evans, 1971).

Plains Reservoirs

Drake Reservoir	Brewer Lake
Neff Lake	Howards Lake
Seeley Lake	Briscoe Lake
Lee Lake	Lindies Lake
N. Gray Reservoir	Darling Reservoir
S. Gray Reservoir	Neuman Reservoir
Gray No. 3 Reservoir	Watson Lake
College Lake	Cole Reservoir
Dixon Reservoir	Mason Reservoir
Donath Reservoir	Rowe Bros. Reservoir
Gress Reservoir	McGrew Reservoir
Kitchell Reservoir	Thomas Lake Reservoir
Deadman Lake	Oklahoma Reservoir
Nelson Reservoir	Bubbles Lake
Benson Lake	Caverly Reservoir
Williams Reservoir	Crom Lake
Mahood Reservoir	Hinkley Lake
James Reservoir	Morris Reservoir
Angel Lake	Duck Lake
Saxton Lake	Mud Lake
Packard Reservoir	Loop Lake
Owl Creek Reservoir	Law Reservoir
Antelope Reservoir	Franklin Lake
	Swanson Lake

Mountain Reservoirs

Trap Lake
Twin Lake
Zimmerman Lake
Cameron Pass Reservoir
Timberline Lake
Bellaires Lake

Note: Not all of these reservoirs are located inside of this sub-basin. In addition, some are also used to store water foreign to the Cache La Poudre Sub-basin.

Table 4-25 Amounts in Storage During the 1970 Water Year of the Major Reservoirs with Absolutely Decreed Storage Rights to the Native Surface Water Runoff of the Cache La Poudre River Sub-basin (Division I Water Commissioners, 1970).

Name	Source	Amount in Storage (acre-feet)		
		11-1-69	5-1-70	10-31-70
Long Pond	Cache La Poudre	2,433	2,398	2,720
Richards	Cache La Poudre	292	489	670
Rocky Ridge	Cache La Poudre	3,203	3,363	3,124
WS & S No. 3	Cache La Poudre	3,552	3,920	3,488
WS & S No. 4	Cache La Poudre	407	485	584
Cobb	Cache La Poudre	16,330	18,504	22,220
Douglas	Cache La Poudre	5,710	6,726	6,680
Res. No. 8	Cache La Poudre	5,629	7,377	7,764
Res. No. 8 Annex	Cache La Poudre	1,842	2,524	2,734
Windsor Res.	Cache La Poudre	7,211	14,439	0
Curtis	Cache La Poudre	862	838	876
Kluver	Cache La Poudre	853	801	844
Lindenmeir	Cache La Poudre	150	150	348
N. Poudre No. 5	Cache La Poudre	4,364	4,436	6,622
N. Poudre No. 6	Cache La Poudre	3,065	5,557	4,898
Claymore	Cache La Poudre	767	886	482
Warren Lake	Cache La Poudre	738	718	1,652
Woods Lake	Cache La Poudre	1,770	2,295	2,064
Fossil Creek	Cache La Poudre	5,399	10,294	8,282
Cache La Poudre	Cache La Poudre	6,935	9,399	7,790
Windsor Lake	Cache La Poudre	781	986	1,058
Larimer & Weld	Cache La Poudre	0	6,050	6,184
Black Hollow	Cache La Poudre	2,626	4,130	3,972
Subtotal	Cache La Poudre R.	74,919	106,765	95,056
N. Poudre No. 2	N. Fk. Cache La Poudre	2,131	1,744	2,586
N. Poudre No. 3	N. Fk. Cache La Poudre	597	1,827	1,275
N. Poudre No. 4	N. Fk. Cache La Poudre	442	442	810
Seaman	N. Fk. Cache La Poudre	3,045	3,185	1,986
Clarks Lake	N. Fk. Cache La Poudre	465	465	690
N. Poudre No. 15	N. Fk. Cache La Poudre	2,557	5,517	4,082
Park Creek	N. Fk. Cache La Poudre		3,042	2,524
Halligan	N. Fk. Cache La Poudre	1,153	3,351	0

Table 4-25 Continued

Name	Source	Amount in Storage (acre-feet)		
		11-1-69	5-1-70	10-31-70
Indian Creek	N. Fk. Cache La Poudre	1,309	1,309	1,556
Subtotal	North Fork Cache La Poudre River	11,699	20,882	15,509
N. Gray	Boxelder Creek	248	240	144
South Gray	Boxelder Creek	104	700	470
Gray No. 3	Boxelder Creek	6	126	10
Subtotal	Boxelder Creek	358	1,066	624
Chambers	Wright, Trap & Fall Cks	1,169	3,465	2,216
Peterson	Unnamed Creek	0	0	0
Dowdy	Pine Creek	907	854	906
Twin Lake	Trib. of Pennock Creek	0	0	0
Portner	Fossil Creek	166	45	44
Barnes Meadow	Barnes Meadow	0	0	0
Joe Wright	Joe Wright Creek	0	0	0
Long Draw	Long Draw	41	290 est.	206 est
Worster	Sheep Creek	25	515	110
Big Beaver	Big Beaver Creek	0	0	0
Comanche	Big Beaver Creek	319	319	272
Subtotal	Other Minor Tribs.	2,627	5,488	3,754
Grand Total	Entire Cache La Poudre sub-basin	89,603	134,168	114,943

Note: All of the reservoirs on this list are located within the Cache La Poudre River Sub-basin. However, some also store water that had been imported from the west slope.

10,000 acres. There are several reservoirs located inside of the Cache La Poudre River sub-basin that store water imported from another sub-basin of the South Platte River basin and/or another river basin. Duck Lake and Okalahoma Reservoir are located in the plains section of this sub-basin and they store water imported from the Big Thompson River sub-basin. Chambers Lake, Joe Wright, and Long Draw Reservoirs are located in the mountains and store water imported from the North Platte and Colorado River Basins. Although some of these reservoirs do not have storage rights to the native surface water runoff of this sub-basin, they may contain this water through exchanges. However, by far the most important reservoir within this sub-basin that receives water foreign to its watershed is Horsetooth Reservoir. It has a live storage capacity of 143,486 acre-feet, a maximum surface area of 1,873 acres and is located between two hogbacks in the foothills immediately west of Fort Collins (USBR, 1968). Its primary purpose is to store CBT water imported from the Colorado River Basin and delivered to this sub-basin by the Charles Hansen Feeder Canal.

Horsetooth Reservoir has no absolutely decreed storage rights for the surface flows of the Cache La Poudre River sub-basin. It does however, have a conditional storage appropriation for 96,000 acre-feet of water from Soldier Creek. The appropriation date of the right is October 15, 1935 (Wilkinson, 1974).

4.6.3 *Potentially Developable Surface Water Runoff Remaining* - In 1959 the USBR reported that the natural surface water runoff of the Cache La Poudre River had long been overappropriated. However, in some years, water in excess of demands pass out of this sub-basin unused. This is the case specifically whenever the plains reservoirs are filled and water in excess of the needs of direct flow appropriators occur. W. G. Wilkinson, former Water Commissioner for Irrigation District #3, determined these surplus flows during the 1947-1960 period from the daily operations on the river and consideration of downstream rights. He estimated that they were equivalent to 24,500 acre-feet per year during that 14 year period (USBR, 1966).

The USBR has studied the Cache La Poudre River sub-basin since 1928 when investigations were made in cooperation with the Poudre Valley Water Conservation Association. In a 1963 Reconnaissance Report they presented a comprehensive plan for further development for this sub-basin. It included a proposed project, which was later modified, and several alternative plans that would among other things, capture this unused water. None of these have come to fruitation and none are actively pursued today. A brief history of their plan of development and the reason it never got off the ground, is given below.

The 1963 Reconnaissance Report of the United States Bureau of Reclamation proposed the creation within this sub-basin of two storage facilities, the Idylwilde and Livermore Reservoirs, two hydro-electric power plants, one power forebay, one power afterbay, one diversion dam, and various conduits, transmission lines, and substations. The proposed 148,500 acre-feet Idylwilde Reservoir was to be located on the mainstem of the Cache La Poudre 33 miles northwest of Fort Collins. The proposed 394,500 acre-foot Livermore Reservoir was to be located on the North Fork of the Cache La Poudre River, 15 miles northwest of Fort Collins. About 80 percent of the cost of this project was to be allocated to commercial power with the remainder to the associated functions of municipal and industrial water supply, supplemental irrigation water supply, flood control, fish and wildlife and recreation. In a preliminary analysis, the USBR estimated that this project would have regulated for beneficial use 4,900 acre-feet of unappropriated water that could not otherwise have been stored within this sub-basin. The 1963 Reconnaissance Report also presented a complex plan which included the combination of storage rights of Greeley's mountain reservoirs, regulating through exchange of this sub-basins municipal allotments from the CBT project, abandonment of some plains irrigation reservoirs, and transfer of such plains storage rights upstream to existing reservoirs and the proposed ones. Enhancement of the available irrigation water supply by these means would accrue through reduction of seepage losses from intake canals, addition to storage by provision of replacement capacity lost through sedimentation, and savings of water by reduction of evaporation.

Although the reconnaissance plan appeared to hold promise of economic justification and financial feasibility, serious questions were raised concerning the market for the developed peaking power within the confines of reclamation law and policy. Accordingly, approval for subsequent feasibility investigations was limited to a possible first-stage development consisting of the Idylwilde Dam and Reservoir only, with minimum provisions to permit the possible future inclusion of power.

In their 1966 concluding report, the USBR presented estimates which showed that a new storage right in this sub-basin could capture 24,500 acre-feet of unappropriated water each year on the average. However, it was concluded that the total irrigated area in the Cache La Poudre basin had facilities and water supplies (including CBT project water) ample to meet an average of 95 percent of their theoretical requirements.

They reported the limited need for supplemental irrigation water probably could be met almost entirely by conservation measures and cooperative efforts of local interests.

During this study, questions arose concerning: (1) whether supplemental irrigation water was urgently needed, and could be justified, and (2) the practicability of plains reservoir consolidation-transfer and the willingness of their owners to participate. Numerous other problems were also encountered in attempting to devise procedures for practical application of the plains reservoir consolidation-transfer plans.

Further analysis was also made of the municipal and industrial water supplies and requirements of Fort Collins and Greeley. The analysis was based upon the population projections by the cities, a per capita requirement of 250 gallons of water daily, the full exercise of all presently owned water rights, and the new water rights accruing from these cities annexation policies. That analysis indicated that both cities would have adequate water until at least the year 2010 if the preceding basic assumptions are met.

With the probability of elimination of most, if not all, of the irrigation function from the reservoir, most of the cost would necessarily have to be allocated to municipal and industrial water supply. The only other participating functions would be recreation and fish and wildlife enhancement.

Assuming a yield of 20,000 acre-feet per year from a new storage right exercised by the proposed Idylwilde Reservoir, an economic analysis indicated the cost of this water would be $30.57 per acre-foot annually. At that time, CBT water was available to these cities at a price equivalent to about $11.25 per acre-foot of water annually at Horsetooth Reservoir. The two factors: (a) lack of a ready market for possibly 30 years, and (b) an available alternative at almost one-third of the projected cost of Idylwilde water, led to the decision in the fall of 1965 to terminate the investigations.

4.7 The South Platte River-Transition Sub-basin

The South Platte River-Transition sub-basin is the designation used in this study for that drainage area of the South Platte River between its mountainous and plains reaches, exclusive of the drainage area of its major tributaries within this reach, i.e., Plum Creek, Cherry Creek, Bear Creek, Clear Creek, Saint Vrain Creek, the Big Thompson River and the Cache La Poudre Rivers, and the Lone Tree Creek drainage of the Crow Creek sub-basin. Figure 4-11 is a schematic drawing which outlines the sub-basin as defined above. The gaging stations shown in Figure 4-11 delineate the sub-basin in more explicit terms. Thus the sub-basin as defined has boundaries which are at the canyon mouths at the South part but are at the river mouths at the northern part. This sub-basin encompasses most of Irrigation District #2 as well as parts of Irrigation Districts #7, 8, and 9.

4.7.1 *Physical Characteristics and Surface Water Runoff* - The reach of the South Platte River encompassed by this sub-basin begins at an elevation of 5484.43 feet at USGS gaging station #06708000, "South Platte at Watertown, Colorado." It ends approximately 100 miles downstream, after a loss of 908.66 vertical feet, at USGS gaging station #06754000, "South Platte near Kersey, Colorado."

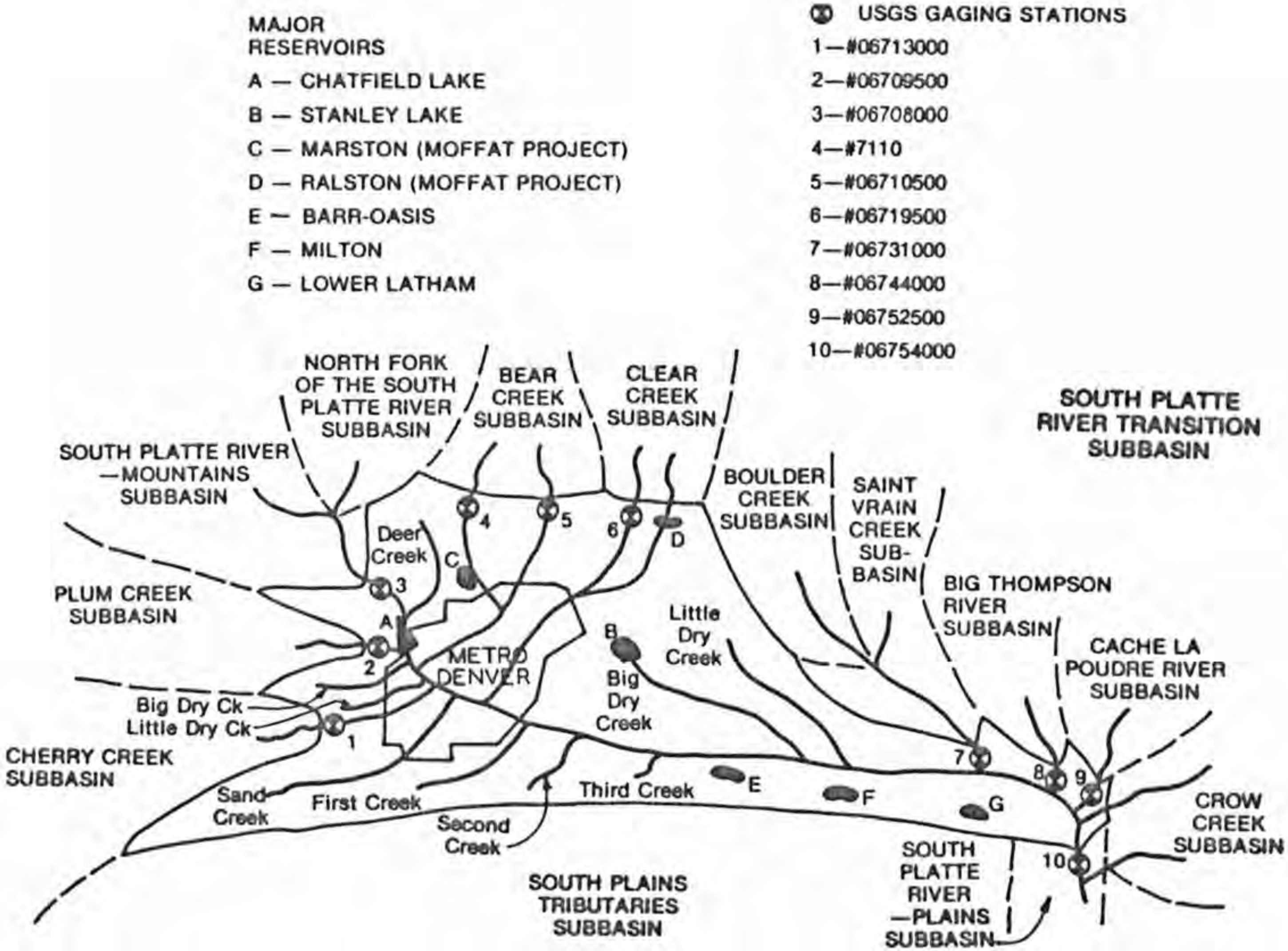


Figure 4-11: Schematic of the South Platte River-Transition Subbasin

The drainage area of this sub-basin encompasses 1,477 square miles of high plains type terrain. The tributaries of the South Platte River located entirely within this sub-basin are generally intermittant and include Deer Creek, Sand Creek, First Creek, Second Creek, and Third Creek. Also located within this sub-basin are two creeks called Big Dry Creek and two called Little Dry Creek. In addition, the South Platte River-Transition Sub-basin includes the lower drainage area of Cherry Creek below Cherry Creek Lake Dam and the lower drainage areas of Bear and Clear Creeks below where they and their tributaries issue out of the foothills.

Near Watertown the South Platte River flows through an area where the precipitation averages about 16 inches per year. As the South Platte continues through this sub-basin, the average annual precipitation gradually decreases to approximately 12 inches per year near Kersey. About 75% of the average annual precipitation in the sub-basin occurs in the summer months as short duration high intensity down-pours. The resulting runoff is usually low volume flash floods.

The surface water runoff within this sub-basin was estimated in part from USGS gaging station records and in part from the yield of absolutely decreed storage appropriations within its boundaries.

The long term average native surface water runoff of this sub-basin was estimated to be 12,341 acre-feet per year; computations are seen in Table A4-31, Appendix A. The 1970 water year native surface runoff of this sub-basin was estimated to have been 9,074 acre-feet, or 73.5% of the long term computations are seen in Table A4-32, Appendix A. The native surface water runoff of this sub-basin during the 1953-1956 four year drought period averaged 5,133 acre-feet per year, or 41.6%

of the long term average; computations are seen in Table A4-33, Appendix A.

The primary source of surface water in the sub-basin is inflow from its surrounding tributary sub-basins and from the mainstem of the South Platte as it flows into its transition reach from the mountains. The transition reach functions then as a collector stream vis a vis as a water supply source. It also functions to distribute water to adjacent agricultural lands.

The total inflow through natural stream channels to the drainage area of this sub-basin averages 639,779 acre-feet per year. Table 4-26 shows the distribution of tributary inflows. These inflows are highly variable and may range through an order of magnitude. For example, in 1940 a flow of 41,530 acre-feet came to this sub-basin from the South Platte River mountains; the anual flow in 1942 was 513,900 acre-feet.

These tributary inflows are comprised of return flows from the various uses within the surrounding sub-basins, of the native runoff of these sub-basins that was not used because of senior water rights here and further downstream on the mainstem, and of the unappropriated surface flows which occasionally occur in these sub-basins and which flow through this sub-basin subsequently. In addition, there may be some imported water, i.e., from the CBT Project, destined for lower lands which use the stream channels for conveyance. In some cases, this west slope water, diverted through tunnels at higher elevations, is specifically bound for this sub-basin. The natural stream channels of the sub-basin tributaries are used also as canals to deliver this water. In other cases, the imported water that flows into this sub-basin is return

Table 4-26 Average Annual Inflow to the South Platte River-Transition Sub-basin from its Surrounding Sub-basins.

Sub-basin	Drainage Area (Sq. miles)	Average Annual in flow (acre-feet)
South Platte River-Mountains1/	2,621	127,302
Cherry Creek2/	385	3,756
Plum Creek3/	302	20,589
Bear Creek4/	214	42,011
Clear Creek5/	448	171,166
Saint Vrain Creek6/	976	147,597
Big Thompson River7/	828	51,191
Cache La Poudre River8/	1,877	76,167
Crow Creek9/	500	0
Total	8,151	639,779

1/Appendix C, Table C4-3, this includes the inflows from the North Fork of the South Platte River sub-basin which join the flows of the mainstem of the South Platte just above the mouth of the South Platte River-Mountains sub-basin.
2/Appendix C, Table C4-8.
3/Appendix C, Table C4-7.
4/Appendix C, Table C4-6.
5/Appendis C, Table C4-11.
6/Appendix C, Table C4-18, this includes the inflows from the Boulder Creek sub-basin which join the flows of the mainstem of Saint Vrain Creek just above the mouth of the Saint Vrain Creek sub-basin.
7/Appendix C, Table C4-22.
8/Appendix C, Table C4-24.
9/Appendix C, Talbe C4-32, this includes only the inflows from the Lone Tree Creek drainage area of the Crow Creek sub-basin. Surface water runoff from the rest of this sub-basins drainage area flows into the South Platte River-Plains sub-basin.

flow, having been used once as twice before upstream in the surrounding sub-basins.

The surface water outlfow of this sub-basin through the natural stream channel of the South Platte River contributes to the surface water supplies of the South Platte River-Plains sub-basin. These flows are measured at USGS gaging station #06754000, "South Platte near Kersey, Colorado." The 1902-1903, 1906-1975 72 year average annual discharge recorded by this gaging station for the periods 1902-1903 and 1906-1975 was 561,342 acre-feet; the records are seen in Table C4-27, Appendix C. These outflows are highly variable also. The maximum instantaneous discharge measured by this gaging station was 31,500 cfs on May 8, 1973. The minimum daily discharge of the South Platte River at this point was on April 30, 1955 when 28 cfs was recorded.

Flood flows are a major concern in the sub-basin, too, along with the water supply. Since 1844, 20 floods are known to have occurred on the South Platte River at Denver as a result of tributary inflows (United States Army Corps of Engineers, 1975). The most severe occurred in 1884, 1864, 1867, 1894, 1921, 1933, and 1965, (U.S. Dept. of Int., 1974). The flood of June 16, 1965 was one of the most destructive in the history of Colorado. Torrential rains accumulating up to 12 inches fell on the Plum and Cherry Creek sub-basin. As the resulting runoff swept into the South Platte River-Transition sub-basin, Denver suffered damage to, or the destruction of 2,033 homes, 167 house trailers, 6 apartment houses, and 617 business establishments for an estimated total loss of 324 million dollars.

4.7.2 *Existing Development of the Surface Water Supply* - Figure 4-12 shows the major ditches and reservoirs in the sub-basin. Its

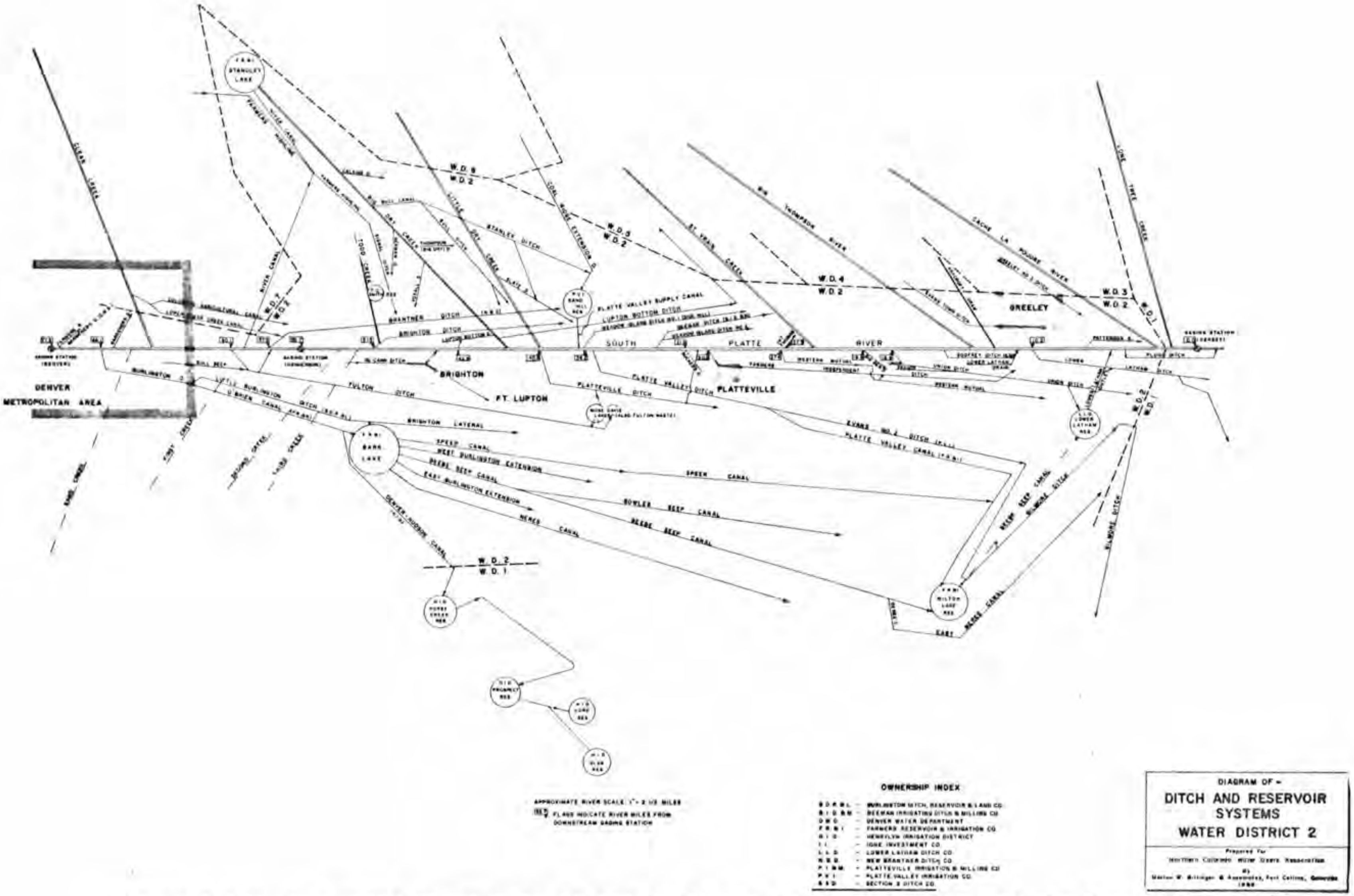


Figure 4-12: The major components of the Ditch and Reservoir System of the South Platte River-Transition Reach (Courtesy of M. W. Bittinger and Associates)

function in both collecting inflows and distributing water via ditches diverted from it is evident in the configuration shown. Irrigation districts are indicated also.

Direct Diversion Structures - In 1959 the USBR reported that there were 65 major decreed direct flow rights for water from the reach of the mainstem of the South Platte River within this sub-basin. These appropriations totaled 6,340 cfs which is equivalent to approximately 4,590,160 acre-feet per year. The 1974 tabulation of Colorado water rights lists 126 absolute and conditional ditch rights decreed to water from the reach of the mainstem of the South Platte River within this sub-basin (Wilkinson, 1974). The minor intermittent plans tributaries of the South Platte whose drainage areas are completely located within this sub-basin are appropriated by about 75 absolute and conditional ditch rights (Wilkinson, 1974). In 1959, the USBR reported that the small tributaries from the right bank of the South Platte supported 28 major decreed direct flow rights worth 510 cfs.

In addition, the South Platte River-Transition sub-basin has been defined to include the lower portions of the Cherry Creek, Clear Creek, and Bear Creek drainages. Information on the water rights to these creeks appear in the sections of this report describing their sub-basin.

Table 4-27 shows the 1947-1961 average annual diversions by the major diversion structures in this sub-basin for direct irrigation from the South Platte River, and the amount diverted for storage, to be used subsequently for irrigation. The "nine-year range" in the table shows the minimum and maximum amounts of surface water diverted during nine of the 15 years, omitting the three low years and the three high years.

Table 4-27 1947-61 Average Annual Sruface Water Diversions by the Major Ditches which Divert from the Main Stem of the South Platte River within the South Platte River-Transition Sub-basin (Bittinger, 1968).

Ditch Name	15 Yr. Range Min. to Max. (100 acre-feet)	9 Yr. Range Min. to Max. (100 acre-feet)	15 Yr. Average
Prospect Valley	32 to 270	66 to 220	144
Lower Barr Lake	93 to 448	211 to 351	274
Fulton	183 to 325	209 to 291	254
Brantner	107 to 192	130 to 164	149
Brighton	65 to 105	73 to 96	85
Lupton Bottom	171 to 280	184 to 236	213
Platteville	114 to 186	143 to 185	164
Meadow Island No. 1	26 to 67	46 to 54	50
Evans No. 2	33 to 353	247 to 332	271
Gilmore	0 to 187	86 to 155	109
Meadow Island No. 2	27 to 138	88 to 123	103
Farmers Independent	157 to 290	182 to 242	218
Western Mutual	42 to 259	163 to 237	195
Union	279 to 447	313 to 413	365
Lower Latham	183 to 407	304 to 385	335
Patterson	39 to 66	43 to 58	51
Highland (Plumb)	29 to 58	39 to 49	44
		TOTAL	3,021

Note: Diversions include releases from storage. Some of these ditches serve agricultural acreages which lie outside of this sub-basin. The "9-year Range" excludes the 3 lowest and 3 highest years of diversion. Some of these ditches also have direct flow rights to various seepage areas that they intercept on their way to outlying agricultural acreages.

Table 4-28 shows the estimated 1947-1961 average annual amount of canal losses by the major diversion structures in this sub-basin. These estimates were made monthly, based upon the amount of water and number of days it was carried by each ditch. By comparison of data presented in Table 4-27 and 4-28 it can be summarized that, on the average, 28% of all direct diversions in this sub-basin are lost to evapoaration and seepage.

Three of the most important direct diversion structures within this sub-basin are the Fulton Ditch, the Farmer's Independent Ditch, and Union Ditch. The operational characteristics of each of these ditches are summarized in the following sections to provide a better understanding of the nature of the water delivery system. The information was obtained from Bittinger (1968).

The Fulton Ditch - The Fulton Ditch irrigates an estimated 12,013 acres of land lying east of the South Platte River from a point about six miles upstream from Henderson to about three miles southeast of Platteville. The water commissioner for Water District 2 reported 11,500 acres under irrigation during the 1961 and 1966. Part of the irrigated area is river bottom land and part is located on terrance land.

The Fulton Ditch holds direct-flow water rights as follows:

Number	Priority Date	Amount (cubic feet/second)
8	May 1, 1865	79.70
43	July 8, 1876	74.25
51	Nov. 5, 1879	50.23
	Total Decreed Rights	204.18

Historical River Diversions - During the 15-year period of 1947 to 1961, inclusive, the monthly and yearly diversion records show the following:

Table 4-28 1947-61 Average Annual Seepage and Evaporation Losses of the Major Ditches which Divert from the Main Stem of the South Platte River within the South Platte River-Transition Sub-basin (Bittinger, 1968).

Name	15 Year Average Annual Loss (acre-feet)
Prospect Valley	3,200
Lower Barr Lake	7,200
Fulton Ditch	7,900
Brantner Ditch	4,300
Brighton Ditch	2,500
Lupton Bottom Ditch	5,900
Platteville Ditch	4,800
Meadow Island Ditch No. 1	1,400
Evans No. 2 Ditch	6,800
Gilmore Ditch	2,600
Meadow Island Ditch No. 2	2,900
Farmers Independent	6,800
Western Mutual Ditch	5,700
Union Ditch	10,400
Lower Latham Ditch	9,700
Patterson Ditch	1,300
Highland (Plumb) Ditch	1,300
Total	84,700

Acre-Feet Diverted

	April	May	June	July	Aug.	Sept.	Oct.	Yearly
Maximum	1,400	6,200	9,300	9,200	9,000	5,500	3,600	32,500
Minimum	0	500	3,000	2,300	2,500	200	0	18,300
Average	413	3,147	5,553	5,927	5,100	3,587	1,660	25,870

During 9 of the 15 years (where the three lowest and three highest years were eliminate) between 23,000 and 29,100 acre-feet was diverted losses for the 15-year period.

Canal Losses (acre-feet)

	April	May	June	July	Aug.	Sept.	Oct.	Yearly
Maximum	300	1,600	2,000	1,600	1,100	900	800	8,300
Minimum	0	500	2,000	1,600	1,100	200	0	6,900
Average	160	1,500	2,000	1,600	1,100	840	673	7,873

Percent Lost

	April	May	June	July	Aug.	Sept.	Oct.	Yearly
Maximum	100	100	67	70	44	100	100	43
Minimum	21	26	22	17	12	16	22	25
Average	78	59	40	31	23	34	59	32

Farm Delivery (acre-feet)

	April	May	June	July	Aug.	Sept.	Oct.	Yearly
Maximum	1,100	4,600	7,300	7,600	7,900	4,600	2,800	24,400
Minimum	0	0	1,000	700	1,400	0	0	10,400
Average	253	1,647	3,553	4,327	4,000	2,747	987	17,510

During 9 of the 15 years the estimated delivery of surface water to the farm headgate ranged from 16,100 to 21,000 acre-feet annually.

Farmers Independent Ditch - The Farmers Independent Ditch diverts water to land east of the South Platte River and the Western Mutual Ditch and west of Highway 85 between Platteville and La Salle. According to the Farm Water Utilization Study made for the Narrows Project the

Ditch irrigates an estimated 6,194 acres. Mr. William Grant, attorney and secretary for the Consolidated Ditches Association reported 7,500 acres of irrigated land the water commissioner reported 9,000 acres for 1961 and 1966.

Potatoes are a major crop under the Farmers Independent Ditch and are harvested relatively early, i.e., in August and September. Usually the potatoes are irrigated very frequently, often every two or three days from the time the first irrigation is applied until shortly before harvest. The potato producers feel this is necessary to produce a high quality product and some leading producers believe the frequent irrigation is needed to reduce soil temperature for the production of good quality potatoes.

The Farmers Independent Ditch has two direct-flow water rights:

1. Priority number 10, dated November 20, 1965 for 61.60 cfs and
2. Priority number 45, dated November 20, 1876 for 85.40 cfs for

   Total in 147.000 cubic feet per second.

<u>The Historical Water Diversion</u> - Records compiled by the Bureau of Reclamation includes water diverted and used directly for irrigation plus any water released from storage reservoirs. The record does not include diversion to storage. A summary of diversion records for the 15-year period is shown in the following table:

	April	May	June	July	Aug. (acre-feet)	Sept.	Oct.	Yearly
Maximum	1,900	4,800	7,000	8,500	7,000	4,400	2,800	29,000
Minimum	0	700	2,500	2,400	2,500	1,100	0	15,700
Average	480	2,840	4,920	4,733	4,107	3,207	1,507	21,800

When three extreme low and three extreme high years are eliminated the range of diversions for 9 of the 15 years was from 18,200 to 24,200 acre-feet.

The estimated canal losses and farm headgate delivery of surface water is seen in the following table.

Canal Losses (acre-feet)

	April	May	June	July	Aug.	Sept.	Oct.	Yearly
Maximum	300	1,400	1,700	1,300	900	800	700	7,100
Minimum	0	700	1,700	1,300	900	800	0	6,100
Average	167	1,353	1,700	1,300	900	800	593	6,813

Percent Lost

	April	May	June	July	Aug.	Sept.	Oct.	Yearly
Maximum	100	100	68	54	36	73	100	41
Minimum	16	29	24	15	13	18	25	24
Average	73	54	38	31	23	18	53	68

Farm Delivery (acre-feet)

	April	May	June	July	Aug.	Sept.	Oct.	Yearly
Maximum	1,600	3,400	5,300	7,200	6,100	3,600	2,100	22,100
Minimum	0	0	800	1,100	1,600	300	0	9,300
Average	313	1,487	3,220	3,433	3,207	2,407	913	15,000

During 60 percent of the time, or 9 years out of the 15-year period the farm delivery ranged from 11,700 to 17,200 acre-feet.

Union Ditch - According to the Farm Utilization Study made by the Bureau of Reclamation, the Union Ditch irrigates 5,245 acres. The water commissioner for Water District 2 reported 7,000 irrigated acres for 1961 and 1966, and Mr. William Gaunt, attorney and secretary for the Consolidated Ditches Association reported 5,863 irrigated acres for the Union Ditch. The canal starts at a point about three miles northwest of

Gilcrest and ends about four miles northeast of Evans. Enroute the canal passes just south of La Salle. Most of the irrigated land is river bottom land along the east and south of the South Platte River; also some of the Kersey Terrace is served by the lower end of the ditch.

The Union Ditch Company holds direct-flow water rights from the South Platte River as follows:

1.	Priority number 32 dated Sept. 26, 1873	for	4.00	cu. ft. per sec.
2.	Priority number 36 dated Nov. 5, 1874	for	100.00	cu. ft. per sec.
3.	Priority number 54 dated Nov. 2, 1881	for	84.03	cu. ft. per sec.
		Total	188.03	cu. ft. per sec.

The Union Ditch also has a right for seepage wastewater from a drainage feeder to the canal for 20 cfs dated July 15, 1893. Because of its location the ditch probably obtains significant amounts of bank seepage water from the irrigation of land and canals lying above the elevation of the Union Canal. In the data for this canal no estimate has been made for any seepage water accruing to the canal flow. Consequently, the amount of water delivered to the farm headgates may be somewhat greater than reported. The ditch company owns stock in the Union Reservoir in Water District 5, from which it generally receives 2,000 to 3,000 acre-feet of water per year.

The Historical Water Diversion - During the 15-year period from 1947 to 1961, inclusive, the historical water diversions are given in terms of monthly and yearly diversion records in the following table, compiled by the Bureau of Reclamation.

Total Water Diverted (acre-feet)

	April	May	June	July	Aug.	Sept.	Oct.	Yearly
Maximum	400	1,900	2,200	2,200	1,800	1,400	1,000	10,000
Minimum	0	300	2,200	2,200	1,800	1,400	0	900
Average	220	1,793	2,200	2,200	1,800	1,400	813	10,427

Percent Canal Loss

	April	May	June	July	Aug.	Sept.	Oct.	Yearly
Maximum	100	100	71	39	34	58	100	36
Minimum	11	31	23	21	16	19	22	23
Average	66	49	40	27	22	25	51	29

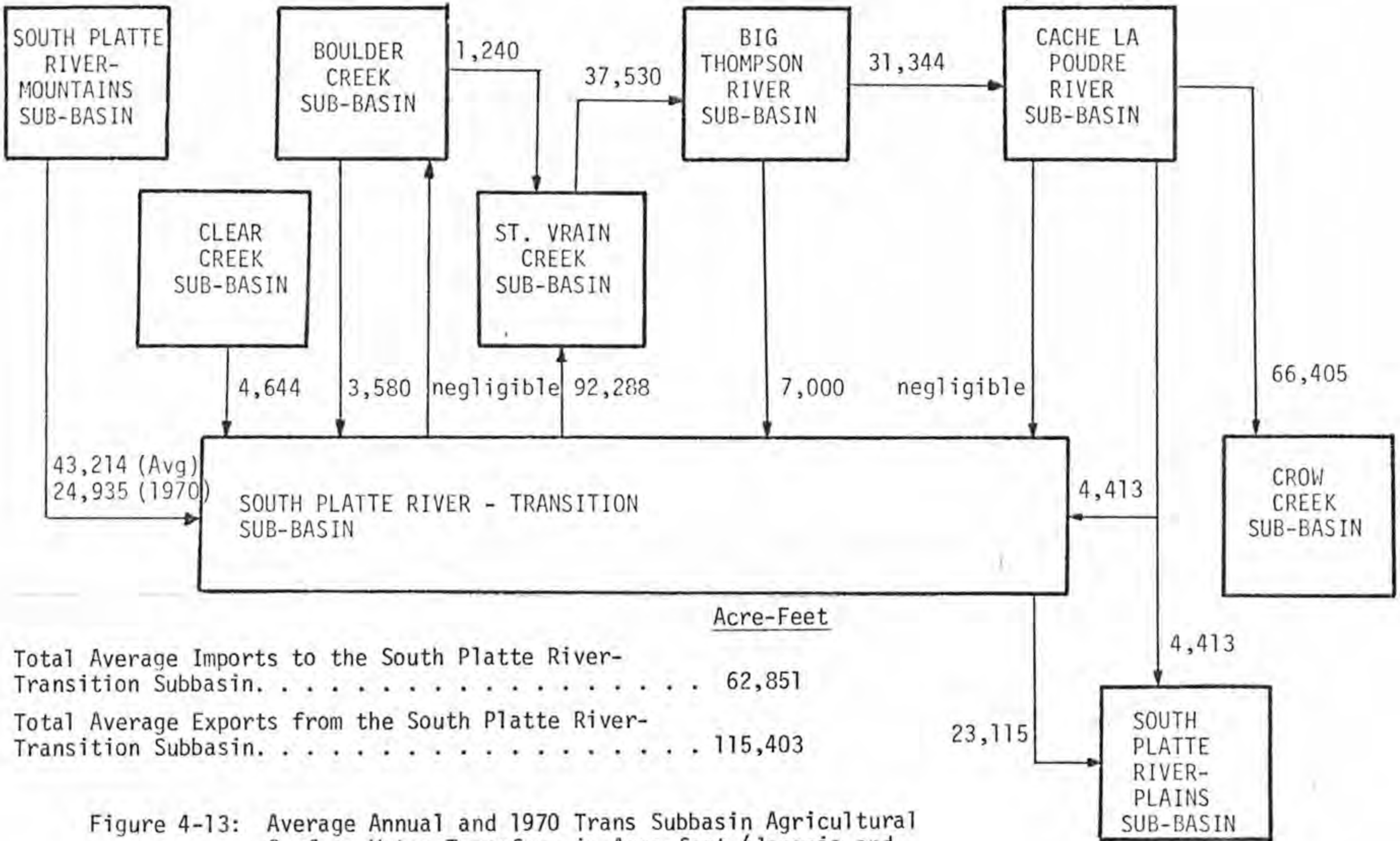
Farm Delivery (acre-feet)

	April	May	June	July	Aug.	Sept.	Oct.	Yearly
Maximum	3,100	4,300	7,200	8,300	9,200	6,100	3,600	33,800
Minimum	0	0	900	3,400	3,500	1,000	0	18,300
Average	593	2,387	3,953	6,293	6,613	4,593	1,627	26,060

During 9 of the 15 years from 21,600 to 31,000 acre-feet of water was delivered to the farm headgate annually.

Numerous ditches and canals carry water both in and out of this sub-basin. Figure 4-13 summarizes these surface water transfers, which are used primarily for irrigation. There are several other important diversion structures which import water to this sub-basin for municipal and industrial use. These are the Aurora-Ramparts Tunnel and the Denver Municipal Aqueduct (which originate in the South Platte River-Mountains sub-basin) and the South Boulder Diversion Conduit (which originates in the Boulder Creek sub-basin). Information on these diversion structures, which also import water from the west slope, can be found in the section on the sub-basin where they originate.

Storage Facilities - In 1959, the Bureau of Reclamation reported that 39 reservoirs were in this sub-basin which had storage rights to water from the mainstem of the South Platte and its small tributaries from the right bank (Irrigation District #2). In aggregate, their decreed capacity totaled 138,000 acre-feet. Bittinger (1968) reports the maximum total physical storage capacity of these reservoirs to be



	Acre-Feet
Total Average Imports to the South Platte River-Transition Subbasin.	62,851
Total Average Exports from the South Platte River-Transition Subbasin.	115,403

Figure 4-13: Average Annual and 1970 Trans Subbasin Agricultural Surface Water Transfers in Acre-feet (Janonis and Gerlek, 1977)

70,000 to 80,000 acre-feet. The 1974 tabulation of Colorado water rights lists 35 absolute and conditional storage rights decreed for water from the reach of the South Platte River within this sub-basin (Wilkinson, 1974).

The minor intermittent plains tributaries of the South Platte whose drainage areas are located wholly within this sub-basin are appropriated by about 30 absolute and conditional storage rights (Wilkinson, 1974).

In addition, the South Platte River-Transition sub-basin has been defined to include the lower portions of the Cherry Creek, Clear Creek, and Bear Creek drainages. Information on the water rights to these creeks appear in the sections describing their sub-basins. The largest storage facility located within this sub-basin is Chatfield Lake, a flood control reservoir. It is located on the mainstem of the South Platte about eight miles upstream from Denver and just below the confluence of Plum Creek. The dam is an earth fill, about 150 feet high and 12,900 feet long. Chatfield Lake has a maximum storage capacity of 385,000 acre-feet, with a maximum surface area of 5,120 acres. This includes a 215,000 acre-feet for flood control and 20,000 acre-feet for sediment control; the latter is the estimated 100 year sediment accumulation (United States Army Corps of Engineers, 1975).

The normal operation of Chatfield Lake will be to allow incoming water to pass through the lake, up to a maximum of 5,000 cfs. This will be adjusted from time to time to insure a more or less steady flow, and to insure that the rights of downstream water users are not violated. In the event of flooding conditions downstream from the dam, releases will be curtailed until sufficient channel capacity is available to allow releases. Likewise, during flooding conditions upstream from the dam, releases may be curtailed if inflow is too great to allow it all to be released downstream without causing damages.

A contract exists between the State of Colorado and the Denver Water Board to provide for the initial filling of a multipurpose pool and also to replace water lost by evaporation. Briefly, the Denver Water Board will be responsible for maintaining the multipurpose pool at 20,000 to 24,000 acre-feet. At times it may be allowed to fluctuate as low as 18,000 acre-feet. During extended drought periods, the State shall give its consent in writing to some lesser storage for a prescribed period of time. This permanent pool will have a maximum area of about 1,300 acres, maximum shoreline of about 7.5 miles and maximum initial depth of about 48 feet.

The Chatfield Lake or multipurpose pool, will have a "V" configuration - its arms lying in the valleys of the South Platte River and one in its tributaries, Plum Creek. The South Platte River arm of the lake will extend about two miles upstream from the dam while the shorter Plum Creek arm will be about 0.5 mile in length. Construction began on this projects in August of 1967 and is now virtually complete.

Besides Chatfield Lake, there are six major reservoirs located within this sub-basin. Table 4-29 presents information on their ownership, capacities, surface areas, and amounts in storage during the 1970 water year. Four of these reservoirs store water diverted from the mainstem of the South Platte. Three of them are located offstream in shallow depressions to the east of the South Platte; they are Barr, Milton, and Lower Latham Reservoirs. These reservoirs are fed by rather long ditches which have points of diversion higher upstream; they are used for the storage of irrigation water. The fourth is Marston Reservoir.

Table 4-29 The Major Reservoirs in the South Platte River-Transition Sub-basin and Relevant Statistical Information.

Reservoir	Source	Owner[1/]	Capacity (acre-feet)	Surface[3/] area (acres)	Amounts in Storage (acre-feet)[4/]		
					11-1-69	5-1-70	10-31-70
Stanley	Clear Creek	Farmers Reservoir and Irrigation Company, City of Westminister	50,000[1/]	1,212	27,778	37,893	30,480
Barr-Oasis	South Platte	Farmers Reservoir and Irrigation Company	33,010[1/]	1,749	22,403	27,686	25,144
Milton	South Platte	Farmers Reservoir and Irrigation Company	26,770[1/]	852	11,116	16,923	13,410
Lower Latham	South Platte	Lower Latham Reservoir Co.	5,740[1/]	714	5,740	5,740	5,315
Marston	South Platte and Exogenous Imports from the Blue River in the Colorado River Basin	Denver	17,213[2/]	622	16,421	16,519	15,221
Ralston	South Boulder Creek and Exogenous Imports from the Fraser and Williams Fork Rivers in the Colorado River Basin	Denver	11,272[2/]	150	10,021	7,874	10,343
Total	-	-	144,005	5,299	93,479	112,635	99,913

1/Paul Neehl, 1977 (Water Commissioner for Irrigation District #2). Reservoir capacities are the absolutely decreed capacities of their storage rights.
2/Denver Water Board, 1969.
3/USGS, 1973c.
4/Division #1 Water Commissioners, 1970.

It too is located offstream, but to the west of the South Platte and on the edge of the Bear Creek drainage area. It is fed by the Denver Municipal Aqueduct, which diverts water from the South Platte near its canyon mouth, outside of this sub-basin. The water stored in Marston Reservoir is used for municipal and industrial purposes.

The two other major storage facilities located within this sub-basin are Ralston Reservoir and Stanley Lake. Ralston Reservoir is located in the Clear Creek drainage at the edge of the foothills on Ralston Creek. It is owned by Denver and is used to store and regulate imports to this sub-basin from South Boulder Creek and from the Fraser and Williams Fork Rivers in the Colorado River Basin. Stanely Lake is located on Big Dry Creek, a minor intermittant plains tributary of the South Platte to the west whose drainage area is entirely encompassed by this sub-basin. Its principal source of water is from Clear Creek.

The 1936-1966 year average amount of water stored in Barr, Milton, Latham and Stanely Reservoirs, the largest reservoirs in this sub-basin that do not store water imported from the west slope, was 35,900 acre-feet (Bittinger, 1968). Table 4-30 shows the monthly distribution of this average.

Besides the six reservoirs mentioned above, there are approximately 120 others located within this sub-basin. Two of these, the Platte Canyon and the Aurora Ramparts Reservoirs, store water imported to the sub-basin from the South Platte River-Mountains sub-basin.

Also, there are 3 major reservoirs located outside of this sub-basin which store water exported from it. These are the Horse Creek, Prospect and Lord Reservoirs which are located in Boxelder Creek drainage of the South Plains tributaries sub-basin. The 1936-1966 31 year average

Table 4-30 1936-66 31 Year Average Monthly Contents in Barr, Milton, Latham, and Stanley Reservoirs, (Bittinger, 1968).

Month	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	For the entire year
Average total contents (acre-feet x 1000)	33	39	44	48	54	53	48	33	20	14	18	27	35.9

Table 4-31 1936-66 31 Year Average Monthly Contents in Horse Creek, Prospect, and Lord Reservoirs (Bittinger, 1908).

Month	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	For the entire year
Average total contents (acre-feet x 1000)	7	9	11	13	14	14	12	9	5	3	4	5	9.3

annual contents of these reservoirs were 9,300 acre-feet (Bittinger, 1968). Table 4-31 shows the monthly distribution of this average.

Table 4-32 shows the 41 major reservoirs (excluding Barr-Oasis, Milton and Lower Latham Reservoirs which are included in Table 4-30) with absolutely decreed storage rights to the reach of the South Platte River within, and to its main tributaries who's drainage areas are entirely within, this sub-basin. Their storage history during the 1970 water year is shown also.

The reservoirs shown in the preceeding Tables 4-4 and 4-9 show the major reservoirs with absolutely decreed storage rights to the portions of the Bear and Clear Creek drainages respectively which are located within this sub-basin and their amounts in storage during the 1970 water year.

4.7.3 *Potentially Developable Surface Water Supply Remaining* - The South Platte River-Transition sub-basin serves as a strategic link between the Front Range tributary areas and downstream plains areas of the South Platte River basin. Because of this location, water users in this sub-basin are largely dependent upon water from several sources. Thus, they experience water supply situations which are quite variable.

In 1974 the USDI reported that the storable excess flow of the upper South Platte River and tributaries above Denver varies considerably from year to year and within any one year ranging from zero to about 60,000 acre-feet per month. Approximately 80% of the annual volume is available in the four months April through July, with about 40% occurring during June. The proposed construction of Two Forks Reservoir and the recent completion of the Chatfield Lake Project and the Bear Creek Lake Project combined with the existing regulation facilities on

Table 4-32 Amounts in Storage During the 1970 Water Year of the Major Reservoirs with Absolutely Decreed Storage Rights to the Reach of the South Platte within and to its Minor Tributaries whose Drainage Areas are Entirely within the South Platte River-Transition Sub-basin, (Division I Water Commissioners, 1970)1/

Name	Source	Amount - A.F.		
		11-1-69	5-1-70	10-31-70
Behrns	South Platte	70	52	30
Beulah	South Platte	45	45	1
Bowles No. 1	South Platte	500	200	500
Bowles No. 2	South Platte	475	475	475
H. A. Smith	South Platte	10	10	10
Henry	South Platte	0	2	0
Horse Creek	South Platte	3,655	14,052	10,405
Ireland No. 1	South Platte	54	54	54
Ireland No. 5	South Platte	73	73	73
Loloff	South Platte	145	45	100
Lord	South Platte	136	847	113
Meek No. 1	South Platte	45	15	45
Meek No. 2	South Platte	65	25	65
Olds	South Platte	0	N.A.	0
Prospect	South Platte	2,485	6,146	1,125
Mc Lellen	South Platte	4,370	4,370	5,254
Carlin	South Platte	0	0	0
Fultonwaste	South Platte	525	525	367
Tule No. 1 (Upper)	South Platte	45	84	80
Tule No. 2 (Lower)	South Platte	75	90	90
Subtotal	South Platte	12,773	27,110	18,787
Marshall	Brantner Gulch	28	25	27
Brantner No. 2	Brantner Gulch	11	11	11
Church Lower Lake	Dry Creek	100	100	100
Coal Ridge (Sandhill)	Little Dry Creek	696	486	603
German No. 2	Big Dry Creek	46	30	45
German No. 3	Big Dry Creek	6	3	8
German No. 4	Big Dry Creek	7	6	25
German No. 6	Big Dry Creek	21	18	20
German No. 8	Big Dry Creek	54	46	20
German No. 9	Big Dry Creek	18	14	5
German No. 12	Big Dry Creek	92	92	92
North Star	Big Dry Creek	65	55	65
Parson-Holmes	Second Creek	9	9	18
Maul	First Creek	33	33	33
J. B. Smith	Todd Creek	105	110	130
L. A. Dore	Seepage	203	203	203
Mann	Deer Creek	Feeder washed in 1969		

Table 4-32 Continued.

Name	Source	Amount - A.F.		
		11-1-69	5-1-70	10-31-70
Fairview	Deer Creek	Not used		
Fairview No. 2	Deer Creek	Not used		
Husted	Willow Creek	Stock water only		
Wakeman	Willow Creek	Stock water only this year		
Subtotal	South Platte Tributaries	1,494	1,241	1,405
Totals		14,267	28,351	20,192

Note: Some of these reservoirs are located outside of the South Platte River-Transition Sub-basin.

1/Excludes Barr, Milton, and Lower Latham Reservoirs, which are included in Table 4-29. Also excluded are the reservoirs located in this sub-basin with decreed storage rights to the plains reach of Bear and Clear Creeks. These can be seen in the preceeding Tables 4-4 and 4-9 respectively.

the other tributaries will make this reach of the South Platte River less subject to such excess flows. The releases from the various tributaries and from the mainstem will be only enough to satisfy downstream rights. Also the rapid urbanization within this sub-basin is encroaching significantly on irrigated agriculture.

One consequence is that Denver and surrounding communities are importing more water from the West Slope. This has provided irrigators with a rather dependable supply of return flows. In addition, the return flows from CBT project water usage in the Saint Vrain Creek, Boulder Creek, Big Thompson River, and Cache La Poudre River sub-basin accrue here.

As a result, Bittinger (1968) reports that the Union and Godfrey Ditches, diverting from the east side of the South Platte between the confluences of Saint Vrain Creek and the Big Thompson River, are currently enjoying a 5,000 to 7,000 acre-feet per year increase in their water rights yield, compared to yields prior to 1950. He also reports that since 1959 there has been a significant increase in the amount of water stored by the major reservoirs within this sub-basin. In addition, Bittinger states that there has been an increasing amount of water remaining in surface storage reservoirs at the end of the irrigation season compared to earlier years.

CHAPTER 5

PLUM CREEK AND CHERRY CREEK

Two distinctive tributaries of the South Platte River are Plum Creek and Cherry Creek. They are located at the south end of the basin. The area of the two sub-basins is 687 square miles and their native water supply averages 33,864 acre-feet per year. The two streams are perennial, but their flows may be very erratic. They are also subject to flash floods which occur mostly in the summer due to cloud bursts. One of the most destructive of these floods was on June 16, 1965 which was caused by a twelve inch torrential rain.

5.1 The Plum Creek Sub-basin

The Plum Creek sub-basin encompasses the drainage area of Plum Creek above USGS gaging station #06709500, "Plum Creek Near Louvers." This gaging station is located approximately 7.5 miles upstream the confluence of Plum Creek with the South Platte River. Figure 5-1 is a schematic representation of this sub-basin.

5.1.1 *Physical Characteristics and Surface Water Runoff* - Plum Creek starts at elevations of 9,000 feet on the divide separating the South Platte and Arkansas River Basins. The stream flows northwest about 40 miles to its confluence with the South Platte, approximately ten miles south to Denver, at an elevation of 5,385 feet. Its major tributaries are the West Plum Creek and East Plum Creek. The drainage area of the Plum Creek sub-basin includes about 302 square miles of high plains type terrain with a narrow ridge of foothills in the western edge.

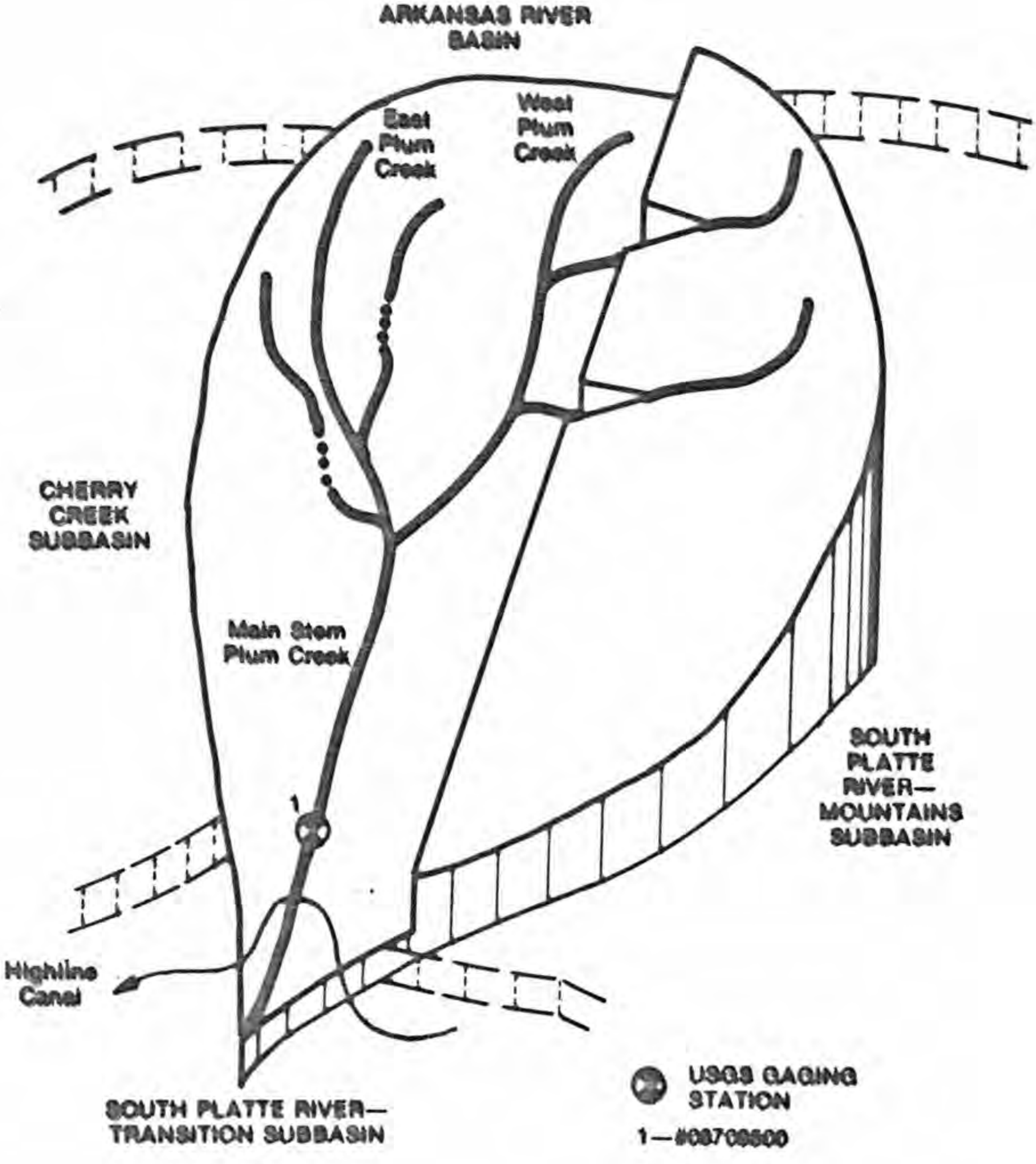


Figure 5-1: Schematic of the Plum Creek Subbasin

The precipitation in the headwaters average about 20 inches per year and about 14 inches per year in the lower elevations (National Oceanic and Atmospheric and Atmospheric Administration, (United States Department of Commerce, 1974).

About two thirds of the mean annual precipitation occurs during the April through September period as high intensity rainfalls - which produce flood flows in Plum Creek (McCain and Jarrett, 1976). Occasionally, winter snow accumulates in the upper drainage of Plum Creek to produce sustained flows during April and May (USBR, 1959).

Generally, the eastern tributaries of Plum Creek are ephemeral. They respond quickly to intense rainfall, resulting in short duration, small-volume floods, which for the most part infiltrate quickly.

Plum Creek proper, and its western tributaries which drain the foothills, are generally perennial. While the base flow of Plum Creek is several cubic feet per second, its surface water runoff is highly erratic from month to month, or even from day to day.

At times during the 1952, 1956-1960 and 1964 water years, the lower reach of Plum Creek was completely dry. During the flood on June 16, 1965, the flow of this creek nears its mouth was estimated to peak at 154,000 cfs, which is equivalent to about 308,000 acre-feet per day (USGS, 1975).

The native surface water runoff of the Plum Creek Sub-basin was estimated from the flows recorded at the United States Geological Survey gaging station at its mouth, #06709500, "Plum Creek near Louviers, Colorado;" these records are given in Table C4-7, Appendix C. However, in assessing the native surface water supply of the drainage area, man-caused upstream effects must be taken into account. From such adjustments, seen in Table A4-10, Appendix A, the long term average native surface water supply was estimated to be 22,789 acre-feet per year. This computation was based on the 1948-1975 period of record. The 1970 native surface water supply of this sub-basin is estimated to have been 31,440 acre-feet, or 137.96% of average; computations are seen in Table A4-11, Appendix A.

The native surface water supply available to this sub-basin during the 1953-1956 four year drought period averaged 7,142 acre-feet per year or 31.3% of average; computations are seen in Table A4-12, Appendix A.

The outflow from this sub-basin, the unused portion of its native surface water runoff, contributes to the surface water supplies of the South Platte River-Transition Sub-basin. This is measured directly by the USGS gaging station #06709500, "Plum Creek near Louviers." The outflow was averaged 20,589 acre-feet per year since the 1948 water year as seen in Table C4-7, Appendix C.

5.1.2 *Existing Development of the Surface Water Runoff* - The October 10, 1974 revised tabulation of Colorado water rights lists 17, 14 and 15 ditch rights and 0, 4, and 5 storage rights absolutely and conditionally decreed for the surface flows of Plum Creek (the mainstem), West Plum Creek, and East Plum Creek, respectively. It also lists about 50 other decreed ditch and storage appropriations that are supported by the native surface flows of the minor tributaries of Plum Creek, (Wilkinson, 1974).

Direct Diversion Structures - There are no diversion structures importing water to the Plum Creek sub-basin from other river basins or other sub-basins of the South Platte River basin. There is one diversion structure, the Highline Canal, which imports water to the Plum Creek drainage below the gaging station marking the mouth of the Plum Creek sub-basin. This canal brings water from the mainstem of the South Platte River in the South Platte River-Mountains Sub-basin to outlying valley lands in the South Platte River-Transition Sub-basin. Turnouts from this canal have supplied irrigation water to approximately 400 acres within the lower Plum Creek drainage (United States Bureau of Reclamation, 1959). However, all of this acreage appears to have been inundated or encroached upon by the Chatfield Lake Project. There are no diversion structures exporting the native surface flows of the Plum Creek or its tributaries to uses outside of their sub-basin.

Diversions of surface water from Plum Creeks hydrological drainage therefore, are used exclusively within the sub-basin, primarily for agriculture. The decreed water rights for the majority of these diversion structures are for less than 10 cfs (Wilkinson, 1974).

Storage Facilities - There are few reservoirs in the Plum Creek sub-basin and without exception they are extremely small. The majority have decreed capacities of less than 25 acre-feet (Wilkinson, 1974).

5.1.3 *Potentially Developable Surface Water Runoff Remaining* - Virtually all of the native flows arising in the Plum Creek sub-basin have long been appropriated by users within the sub-basin and by users downstream on the South Platte dependent on its tributary flows. Unappropriated water occasionally appears in the sub-basin, in the form of flash floods in the spring. However, the irrigated land in the sub-basin does not receive an adequate supply of water, and generally experience shortages in the later summer, due to the undependability of the surface flows and lack of sufficient storage (United States Department of the Interior, 1959).

Unappropriated water, if it does appear, is presently lost to the sub-basin. It flows unregulated down Plum Creek and is intercepted just below its mouth of the South Platte River by Chatfield Lake, a flood controlling structure. There are no proposed projects in the Plum Creek sub-basin to significantly increase the storage capacity in order to capture native surface flows.

5.2 The Cherry Creek Sub-basin

The Cherry Creek sub-basin is defined in this study as the Cherry Creek drainage above the Cherry Creek Lake Dam. The dam is on the main-stem of Cherry Creek about 11 miles upstream from its confluence with the South Platte River. The portion of the Cherry Creek drainage below the dam, about five percent of the total, is included in the South Platte River-Transition sub-basin, but it will be discussed in this section. Figure 5-2 is a schematic representation of Cherry Creeks entire hydrological drainage area.

5.2.1 *Physical Characteristics and Surface Water Runoff* - Cherry Creek rises in a cloudburst area south of Denver, on the South Platte-Arkansas River Basin boundary, around elevations of 7,000 feet. The creek flows northward about 55 miles to its junction with the South Platte River, at an elevation of 5,184 feet, within the city limits of Denver. The upper 44 miles of Cherry Creek, above elevations of 5,490 feet are included in the Cherry Creek sub-basin.

The portion of the Cherry Creek drainage within the South Platte River-Transition sub-basin is highly urbanized. It lies within the metropolitan Denver area and the watershed is covered with parking lots, streets, and buildings. As a result, very little precipitation finds

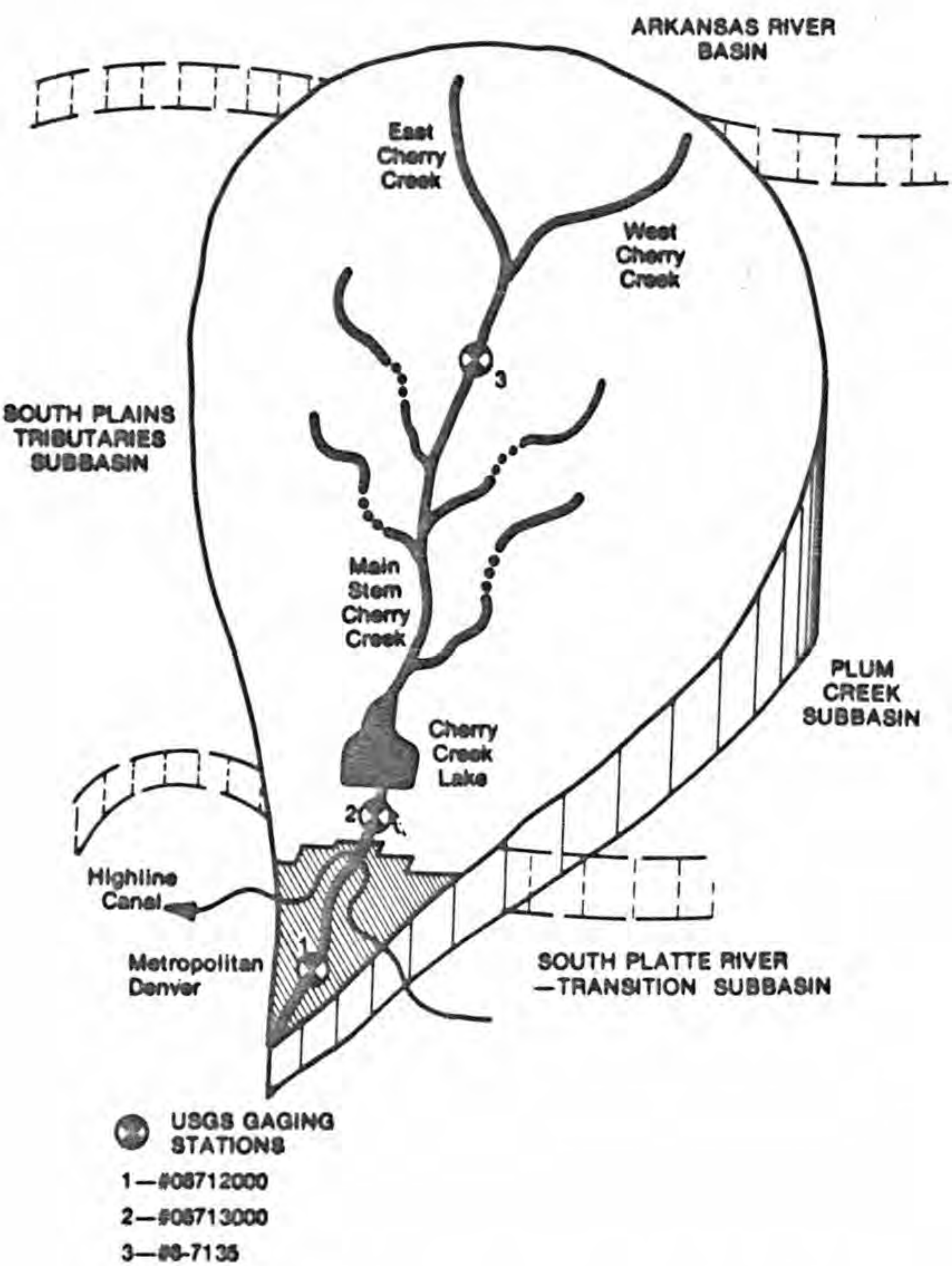


Figure 5-2: Schematic of Cherry Creeks Hydrological Drainage Area

its way into the groun and a greater percentage is converted into surface runoff.

Cherry Creeks major tributaries are all located within the Cherry Creek sub-basin boundaries. These are the East and West Cherry Creeks in the upper reaches and about half a dozen ephemeral gulches in its lower reaches.

Cherry Creek drains an area of 409 square miles of rolling plains type terrain. The upper 95%, or 385 square miles, are located in the Cherry Creek sub-basin. Demarkated by the Cherry Creek Lake Dam, the other 24 square miles Cherry Creeks hydrological drainage are located in the South Platte River-Transition sub-basin.

The precipitation in the headwaters of the Cherry Creek drainage averages about 16 inches per year, and about 14 inches per year in its lower elevations around Denver (National Oceanic and Atmospheric Administration, United States Department of Commerce, 1974).

About two-thirds of the mean annual precipitation occurs as flood producing rainfalls during the period April through September (McCain and Jarrett, 1976). Occasionally, snow accumulates in the upper drainage areas to produce sustained flows during April or May (USBR, 1959).

Cherry Creek is perennial, its base flow is a few cubic feet per second. However, its surface water runoff is very erratic. On June 16-18, 1948 the flow of this creek at Denver was recorded to be 0.4 cfs (USGS, 1958). During the flood on June 16, 1965 the flow of Cherry Creek was estimated to peak at 58,000 cfs which is equivalent to 116,000 acre-feet per day (United States Army Corps of Engineers, 1975). Fortunately for Denver, this runoff was impounded in Cherry Creek Lake.

Table 5-1 shows Cherry Creeks probable flood discharges at two locations for various frequencies of occurrence. This provides an index to the surface water supply characteristics of this sub-basin.

The tributaries of Cherry Creek are ephemeral. They respond quickly to the intense rainfalls to produce the floods noted above. The native surface water runoff of the Cherry Creeks drainage was estimated from the flows recorded at the various gaging stations that are, or have been, located on Cherry Creek, as seen in Appendix C, Tables C4-8 and C4-9. However, in assessing the native surface water supply of a gaging stations drainage area, man-caused effects upstream which effect its flow records must be taken into account.

Table 5-2 shows the 1934-1956 long term average annual, the 1970, and the 1953-1956 drought period average annual estimated native surface water runoff of the Cherry Creek drainage.

The outflow from the Cherry Creek sub-basin contributes to the surface water supplies of the South Platte River Transition sub-basin. Since permanent storage began behind Cherry Creek Dam, this has averaged 3,756 acre-feet per year (Supporting Appendix C, Table C4-9).

5.2.2 *Existing Development of the Surface Water Runoff* - The October 10, 1974 revised tabulation of Colorado water rights lists 50, 1, and 6 ditch rights and 5, 0, and 0 storage rights absolutely and conditionally decreed for the surface flows of the Cherry Creek mainstem, West Cherry Creek, and East Cherry Creeks, respectively. It also lists about 50 other decreed ditch and storage appropriations that are supported by the native surface flows of the minor tributaries of Cherry Creek (Wilkinson, 1974).

Table 5-1 Flood Characteristics of Cherry Creek at Selected Gaging Station Sites (McCain and Jarrett, 1976). [Flood discharges for each gaging station are (first line) values used in multiple regression analysis, (second line) weighed averages]

Station Number	Station name	Period of record, in years	Drainage area, in square miles	Gage datum, in feet above mean sea level	Basin slope in feet per mile	Streambed slope, in feet per mile	Mean annual precipitation, in inches	10-year flood discharge, in cubic ft per second	50-year flood discharge, in cubic ft per second	100-year flood discharge, in cubic ft per second	500-year flood discharge, in cubic ft per second	100-year flood depth, in feet
06712000	Cherry Creek Near Franktown, Colo.	34	169	6,150	32	26	16	4,530 5,070	11,700 13,100	16,300 18,400	31,000 36,000	10.7
06712500	Cherry Creek Near Melvin, Colo.	29	336	5,626	34	17	16	11,800 11,400	29,700 28,600	41,100 39,600	78,700 76,800	13.2

Table 5-2 The Native Surface Water Runoff of the Cherry Creek Drainage

Drainage Area	Average Annual Native Surface Water Runoff (acre-feet/year)				
		1970 Water Year 2/		1953-56 Drought Period Ave. 3/	
	1943-56 Long Term Average 1/	Annual Flow	% of Long Term Average	Annual Flow	% of Long Term Average
The Cherry Creek sub-basin	11,075	6,119	55.25	4,606	41.59
The portion of Cherry Creek drainage within the South Platte-Transition sub-basin	7,301	4,034	55.25	3,036	41.59
The entire Cherry Creek drainage	18,376	10,153	55.25	7,642	41.59

1/ Appendix A, Table A4-7.

2/ Appendix A, Table A4-8.

3/ Appendix A, Table A4-9.

Direct Diversion Structures - There are no diversion structures importing water from other river basins to the Cherry Creek drainage. However, the Highline Canal traverses the lower portion of the Cherry Creek drainage on its way to the South Platte River-Transition sub-basin from the South Platte River-Mountains sub-basin. Turnouts from this ditch are minor and occur only in the portion of Cherry Creek drainage within the South Platte River-Transition sub-basin. Also there are no diversion structures exporting the native surface flows of Cherry Creek or its tributaries to uses outside of their drainage areas. Diversions of surface water from Cherry Creek and its tributaries are used exclusively within Cherry Creeks hydrological drainage. The decreed water rights for the majority of these direct diversion structures are for less than five cfs (Wilkinson, 1974).

Irrigation ditch development started in the Cherry Creek drainage in 1862 and was concentrated in the valley between Franktown and Denver. At the turn of the century, the 30 mile long Arapahoe Canal was built. This was the largest diversion structure ever to be constructed in the Cherry Creek drainage. It delivered water from Castlewood Dam above Franktown to an irrigation development of about 3,000 acres in the lower Cherry Creek drainage. The Arapahoe Canal has not been used since 1933 when the Castlewood Dam failed (United States Department of the Interior, 1959).

Storage Facilities - In 1890 the Castlewood Dam was built about two miles upstream from Franktown. Until 1950 it was the largest storage facility to be built in Cherry Creeks hydrological drainage. The stored water was used for irrigation and was delivered by the Arapahoe Canal. On August 3, 1933 the Castlewood Dam failed, creating one of the largest floods recorded in the sub-basin. The native surface water supply at the dam site is too limited to justify rehabilitation (United States Department of the Interior, 1959), and its storage rights have since been abandoned (Wilkinson, 1974).

With one exception, Cherry Creek Lake, the existing reservoirs on Cherry Creek and its tributaries are extremely small. The majority have decreed storage capacities of less than 25 acre-feet (Wilkinson, 1974).

Cherry Creek Dam was constructed by the United States Army Corps of Engineers in 1946-1953, about 11 miles above Denver, to protect the metropolitan area from floods. This earth fill dam is 140 feet above the streambed 14,300 feet long, and creates a total storage capacity of 96,000 acre-feet (United States Army Corps of Engineers, 1975). In 1964 the USGS published the capacity of Cherry Creek Lake as 247,500 acre-feet. While this was revised in 1970 to the correct capacity, 96,000 acre-feet, it points out the discrepancies that are sometimes found when collecting water resource data of the South Platte River basin.

The mean annual evaporation minus the mean annual precipitation rates in and around the Denver Metro area is approximately 30 inches per year (Meyer, 1942). While the surface area of Cherry Creek Lake fluctuates with the impoundable runoff, according to the United States Soil Conservation Service, Outdoor Recreation Potential in Colorado, 1973, it averages 1,207 acres. However, according to the United States Geological Survey, Lakes in the Front Range Urban Corridor, Colorado, 1973c its surface area is 890 acres. Based on the interpretation of United States Soil Conservation Service Land Use Maps and United States Geological Survey Topographic Maps, the surface area of Cherry Creek

Lake was estimated to be around 1,100 acre-feet on the average. If this is the case, then the average evaporation from Cherry Creek Lake, 2,750 acre-feet per year, is almost 25% of the average annual native surface water runoff of the drainage area above it.

Beginning in June of 1950, Cherry Creek Lake was originally operated as a dry reservoir. Several years later, however, the Governor of Colorado requested that 10,000 acre-feet be impounded for conservation purposes. Permanent storage began on May 15, 1957 (USGS, 1973a). Later this was increased to 15,000 acre-feet for recreation which leaves an effective flood control capacity of 81,000 acre-feet.

This dam was built to replace and supplement the limited protection afforded by the Castelwood Dam, located about 25 miles further upstream, which failed in 1933, and the Sullifan Barrier (Kenwood Dam) which was removed during construction of Cherry Creek Dam (United States Department of the Interior, 1959). There are two absolutely decreed storage rights associated with Cherry Creek Lake. These are for 10,000 acre-feet and 5,580 acre-feet of water from the mainstem of Cherry Creek. They both have adjudication dates of May 18, 1972 and their appropriation dates are May 5, 1958 and March 22, 1960, respectively. Both of these rights have previous adjudication dates of June 16, 1930 (Wilkinson, 1974).

5.2.3 *Potentially Developable Surface Water Runoff Remaining* - Since the 1920's all the surface water arising in Cherry Creek on the average, and in most high runoff years, has been used within its drainage and by downstream appropriators on the South Platte who have rights dependent on this water (United States Department of the Interior, 1959).

Additional surface water supplies from Cherry Creek are extremely undependable but they are of substantial magnitude when they do occur.

These unappropriated flows usually are a result of intensive rainfall in the spring. The storage facilities above Cherry Creek Lake do not have the capacity to capture this water for use later in the irrigation season. Because of the flood control function of Cherry Creek Lake, it will not be available to the major appropriators in the Cherry Creek drainage during times of low flow. However, the downstream appropriators along the mainstem of the South Platte may benefit, if they capture the regulated releases to the Cherry Creek Dam before they leave the South Platte River basin at large. At any rate, since permanent storage began in 1957, and in particular since 1967, no water has been released from Cherry Creek Lake except for small amounts during April or May. There are no proposed projects in the Cherry Creek drainage to futher increase the storage capacity available for its native surface flows.

CHAPTER 6

THE SOUTH PLATTE RIVER PLAINS AND ITS EPHEMERAL TRIBUTARIES

Beyond Greeley the South Platte River has the characteristics of a plains stream system. As a natural stream it carried the Front Range Mountains spring snowmelt discharge and then, later in the season, it may have become dry as the low flows were lost by seepage from the streambed. Its tributaries in this reach are generally ephemeral with most of the annual discharge consisting of the flood flows from spring and summer cloud-bursts. The more important tributaries are Crow Creek and Lodgepole Creek.

The development of irrigation along the Front Range tributaries and in the plains adjacent to the South Platte River has changed the basic character of the stream. The irrigation of large tracts of land adjacent to the river has, over the decades, raised the water table enough that the river flow is sustained by return flows. This same situation has developed in the lower reaches of the Front Range tributaries as well. As the return flows accrue with distance, diversions cause the stream to be dry again. This pattern repeats itself as the South Platte flows towards its confluence with the Platte River in Nebraska.

A portion of the basins plains drainage is in Wyoming and it also extends into Nebraska where the South Platte flows parallel to the North Platte River for a number of miles.

Table 6-1 summarizes the drainage areas and estimated surface water runoff of the sub-basins in this grouping.

Table 6-1 Surface Water Runoff Characteristics of the South Platte River-Plains and its Ephemeral Tributaries.

Sub-basin	Drainage Area (Square Miles)	Surface Water Runoff (acre-feet/year)				
			1970 Water Year3/		1953-56 Drought Period Average4/	
		Long-Term Average	Annual Flow	% of Long Term Average	Annual Flow	% of Long Term Average
Crow Creek	1,824	60,000	60,000	100.0	36,540	60.9
North Plains Tributaries	2,400	1,090	1,090	100.0	664	60.9
Lodgepole Creek	1,946	43,023	43,023	100.0	26,201	60.9
South Plains Tributaries	4,276	50,000	50,000	100.0	30,450	60.9
South Platte River-Plains	1,956	0	0	-	0	-
Sub Area Total	12,402	154,113	154,113	100.0	93,855	60.9

1/ Includes only that portion of Lodgepole Creek within the study area (Wyoming and Colorado).

2/ The assumptions and judgment involved in determining the long-term average annual native surface water runoff can be found in the individual sections of this chapter which describe these sub-basins. Because of the Plains nature of this grouping of sub-basins much of the surface water runoff quickly infiltrates to the groundwater reservoir or evaporates; very little ever reaches the main stem of the South Platte.

3/ Assumed to be the same as the long-term average annual. The 1970 pecipitation in this part of the South Platte Basin departed from normal only +.11 in.(U.S. Dept. of Commerce, Environmental Data Service, 1970).

4/ In aggregate, the 1953-56 average annual native surface water runoff of sub-basin groupings 1,2, and 3 was 60.9% of the long-term average annual. It was assumed that the sub-basins of this sub-basin grouping (number 4) were likewise affected during this 4-year drought period.

6.1 The Crow Creek Sub-basin

The Crow Creek sub-basin encompasses the drainage area of Crow Creek above the site of former gaging station #7565, "Crow Creek near Barnesville, Colorado." In addition, it includes the hydrological drainage of Lone Tree Creek above a point approximately two miles upstream from its mouth. The lower eight miles of Crow Creek below Barnesville and their drainage area are included in the South Platte River-Plains sub-basin. The lower two miles of Lone Tree Creek and their drainage area are included in the South Platte River-Transition sub-basin. Figure 6-1 is a schematic drawing of the sub-basin.

6.1.1 *Physical Characteristics and Surface Water Runoff* - Crow Creek starts in the Laramie Mountains, between Laramie and Cheyenne, Wyoming, at elevations ranging to 8,500 feet. The stream flows east for about 35 miles to Cheyenne, and traverses the city at an elevation of about 5,940 feet. It then veers southeast for approximately 30 miles and enters Colorado. Here it flows due south for 55 miles where it joins the main stem of the South Platte, at an elevation of 4,570 feet; this point is about 11 miles downstream of Greeley.

The drainage area of Crow Creek above Barnesville, Colorado, which is located almost eight miles upstream from its confluence with the South Platte, is about 1,324 square miles.

The major tributaries of Crow Creek are the North Fork, Middle Fork, and the South Fork; these are all mountain streams. About six minor intermittent creeks are tributary to Crow Creek in its plains reach in both Wyoming and Colorado.

Lonetree Creek also rises in the Laramie Mountains. The watershed is similar to the headwaters of Crow Creek; it is a rugged woodsbrush

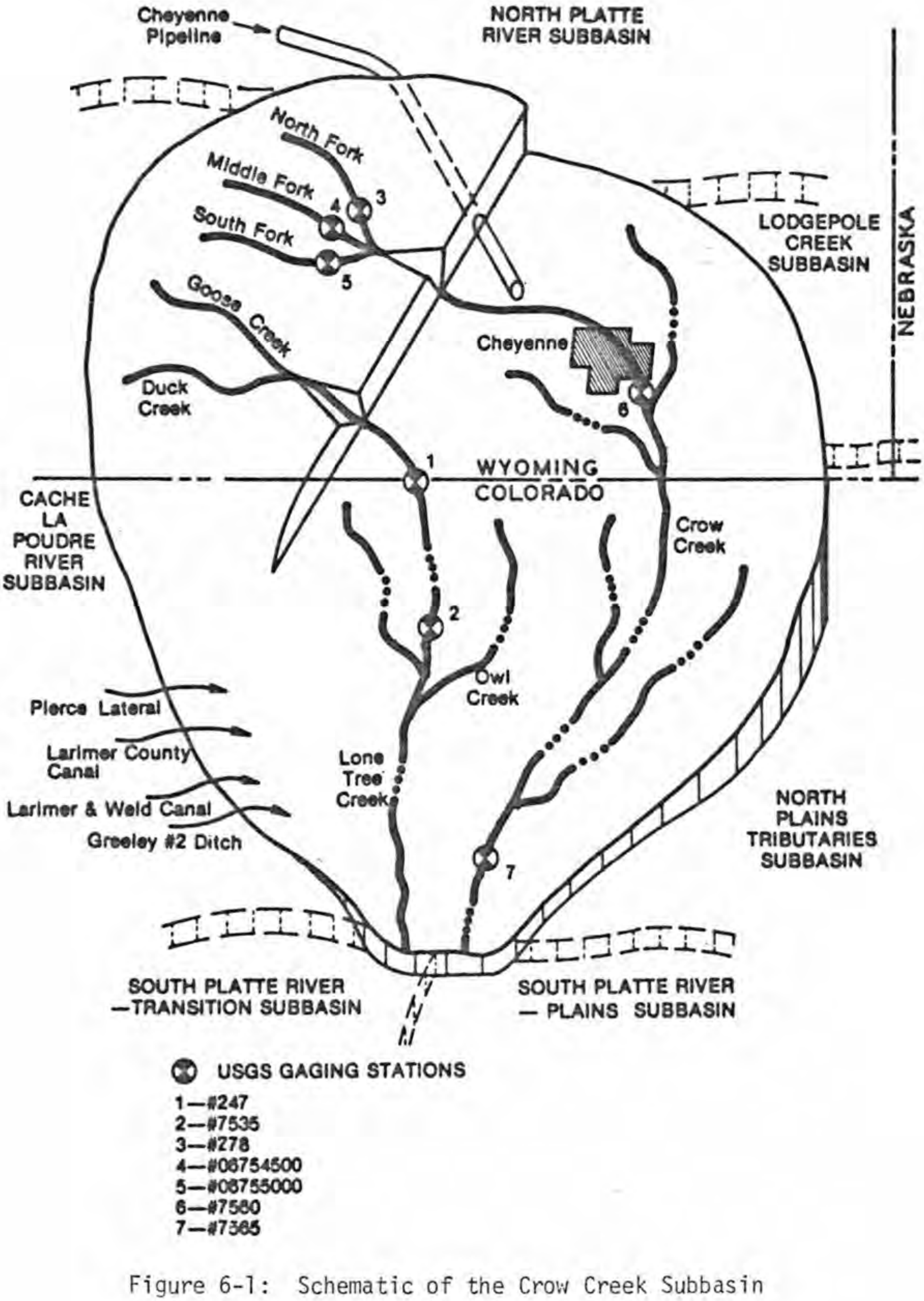


Figure 6-1: Schematic of the Crow Creek Subbasin

land type terrain. From elevations of about 8,300 feet, approximately 32 miles west of Cheyenne, it flows east to the plains. It then veers south, entering Colorado about ten miles west and six miles south of Cheyenne. Lonetree Creek joins the South Platte River approximately one-half mile below the mouth of the Cache La Poudre River, five miles east of Greeley, at an elevation of 4,580 feet. The creek drains an area of about 500 square miles (USBR, 1959).

The major headwater tributaries of Lonetree Creek are Goose and Duck Creeks. The only significant stream contributing surface water flows to Lonetree Creek once it reaches the plains is Owl Creek which is intermittent.

As defined, the Crow Creek sub-basin includes a total drainage area of about 1,824 square miles. Approximately 528 square miles, or 28.9% are located within Wyoming. The remaining 1,296 square miles 71.1% of the total, lie within Colorado.

The average annual precipitation in the headwaters of this sub-basin is about 16 inches per year, and is about 12 inches per year in the lower elevations on the plains (National Atmospheric and Oceanic Administration, U.S. Department of Commerce, 1974).

The headwater tributaries, as well as the main stems of Crow and Lonetree Creeks, are perennial in their mountain reaches. The source of these flows are both summer rainfall and some winter snowpack which melts in the spring.

Table 6-2 shows the area of the drainage basins in the mountains, the mean annual discharge, and the runoff per square miles of Lonetree Creek, and the computed mean annual discharge of Goose and Duck Creeks.

Table 6-2 Surface Water Runoff Characteristics of the Upper Reach of Lone Tree Creek and its Headwater Tributaries (Babcock and Bjorklund, 1956).

	Area of drainage basin, in square miles	Runoff per square mile, in acre-feet	Mean annual discharge, in acre-feet
Lone Tree Creek	23	64.5	1,483
Goose Creek	6	64.5	387
Duck Creek	15	64.5	967
Total	44	64.5	2,837

The perennial flow of the streams in the upper reaches of this sub-basin disappear within a short distance of the points where they issue onto plains. Some of the water in the streams is evaporated in and along the channels, some probably seeps into older sedimentary beds along the mountain front, and some may escape as storm flow. It is believed, however, that most of the water carried by these streams finds its way into the Ogallala groundwater formation (Babcock and Bjorklund, 1956).

Springs and seeps occur in this sub-basin along the escarpment south of the Colorado-Wyoming state line and in some of the valleys that have cut into it. Here, erosion has cut through the Ogallala formation and groundwater discharge is picked up by the streams. Normally, the channels of these streams are dry above this spring line to where they exit from the Laramie Mountains. In Crow Creek, however, there is usually a flow across the entire width of this area. Below the spring line the only water available for runoff is from summer rainfall when 70 to 80 percent of the average annual precipitation occurs. These rains are short duration - high intensity down-pours; the results are usually low volume flash floods of a local nature.

A significant part of the lower drainage in Colorado, especially on the headwaters of Owl Creek, is what might be termed, "Bad Lands." Much of the cross-drainage slopes are very steep and the vegetation is very sparse (USBR, 1959). The surface water runoff arising in this reach of the sub-basin is intermittent and very rarely reaches the main stem of the South Platte. It either is captured by reservoirs, percolates into the ground, evaporates, or is consumptively used. For a six year period, water years 1951-1957 when a USGS gaging station was established on Crow Creek at Barnesville, Colorado, no flow was recorded; these records are seen in Table C4-32, Appendix C.

There have been seven USGS gaging stations recording surface water runoff within the Crow Creek sub-basin at one time or another; their locations are shown in the preceeding Figure 6-1. Most were operated for less than ten years and their records are erratic and incomplete; none are in operation today. Information about these gaging stations can be seen in Tables C4-28 to C4-32, Appendix C.

With such scant information regarding the native runoff of the Crow Creek sub-basin, a value was "assumed." The figure chosen as being available to surface water diverters in the Wyoming portion of this sub-basin was 10,000 acre-feet annually. This was based on the runoff characteristics of Lonetree Creek, summarized in Table 6-2, and the records of a gaging station which was located on Crow Creek below Cheyenne, which are seen in Table C4-31, Appendix C. The flow assumed as being available to surface water diverts in the Colorado portion of this sub-basin was 50,000 acre-feet annually. This was a weighed judgement taking into account the computed total agricultural water demand, and the magnitude of groundwater pumpage within this portion of the sub-basin, as well as the imports of water to it from other watersheds.

6.1.2 *Existing Development of the Surface Water Runoff* - Both Crow Creek and Lonetree Creek originate in Wyoming and flow into Colorado. These two states have never engaged in litigation, and no compact or decree presently exists concerning the equitable apportionment of the minor, intermittent flows of the sub-basin that cross the state line.

Along the main stem of Lonetree Creek and its major tributaries in Wyoming, considerable hay ranch development has occurred due to the dependable perennial nature of their flows. In 1959 the USBR reported that there were 74 filings, totaling 390 cfs, for direct diversions from Lonetree Creek and its tributaries within Wyoming. In addition, they reported that this portion of the Crow Creek sub-basin supported decrees for six reservoirs with a total capacity of 1,700 acre-feet.

In Colorado, the natural surface runoff that appears in the Lone Tree Creek drainage is appropriated by no more than 125 absolutely and conditionally decreed direct flow and storage rights. Sixty-three of these have been decreed for the mainstem of Lone Tree Creek and 14 for its tributary, Owl Creek (Wilkinson, 1974).

According to the October 10, 1974 Colorado Water Rights tabulation, there exists a conditionally decreed storage right on Lone Tree Creek for a McGrew Reservoir to be located approximately 20 miles upstream from its mouth. The water right is for 12,828 acre-feet of water for irrigation purposes. It has an appropriation date of February 1, 1909, and is the largest decreed right on this creek in Colorado. This conditional decree has an adjudication date of January 15, 1914 and a previous adjudication date of November 21, 1895 (Wilkinson, 1974).

In 1924 there were adjudicated rights for diversions from Crow Creek and its tributaries above Cheyenne for the irrigation of 18,840 acres of land (USGS, 1958). In 1959 the USBR reported that there were 118 filings, totaling 563 cfs, for direct diversions from Crow Creek and its tributaries in Wyoming. In addition, they reported that this portion of the Crow Creek sub-basin supported decrees of 16 reservoirs with a total capacity of 14,170 acre-feet. Cheyenne operates two of these reservoirs which have a combined capacity of 12,000 acre-feet, (USGS, 1969a). They are used to store and regulate the native surface flows for municipal supply and power development. In addition, ten small reservoirs with a total capacity of about 400 acre-feet are located in this reach of the sub-basin and are used for irrigation and stock water (USGS, 1969a). It appears then that the remaining four decrees for reservoirs in this portion of the Crow Creek sub-basin were still of a conditional nature as of 1969.

Cheyenne has the most senior water right in Wyoming for Crow Creek water. Its appropriation for 12,481 cfs (approximately equivalent to 25,000 acre-feet per day) allows them to divert the whole creek when needed. Their return flows are in turn also completely appropriated. The Herford Ranch, the first diverter below Cheyenne on Crow Creek in Wyoming, has a right to virtually all of Cheyennes effluent for the irrigation of pastureland (Sherard, 1976).

In Colorado, the October 10, 1974 revised tabulation of Colorado water rights lists 17 direct flow rights and ten storage appropriations absolutely and conditionally decreed for water from the mainstem of

Crow Creek. The largest of the absolutely decreed storage rights is for 2,525 acre-feet for the Herford irrigation reservoir located just below the state line. The largest of the conditional storage decrees is for 67,268 acre-feet to be impounded in a proposed Greasewood reservoir to be located about 20 miles upstream from Barnesville, Colorado. In addition to these, their are several minor direct and storage rights both conditionally and absolutely decreed for the flows of various tributaries to Crow Creek in Colorado.

There are no exports of water from the Crow Creek sub-basin to uses outside of its drainage area. One diversion structure, the Cheyenne Pipeline, imports water to the Wyoming portion of the Crow Creek sub-basin; it brings in North Platte River water, which has been exchanged for Colorado River water, to Cheyenne for municipal purposes. Imports through this pipeline have averaged 7,316 acre-feet per year since its initial diversion in 1965. Additional information on Cheyennes importation facilities which include the piepline, a transbasin diversion tunnel, and various reservoirs, are reviewed in Part III in the section on the Little Snake River sub-basin.

Four major ditches, originating in the Cache La Poudre River sub-basin, import water to the Colorado portion of the Crow Creek sub-basin; these are the Pierce Lateral, the Larimer County Canal, the Larimer and Weld Canal (also called the Eaton Ditch) and the Greeley Number 2 Ditch (also called the Cache La Poudre Number 2 Ditch). Diversions through these ditches which are applied in this sub-basin have been estimated to average 66,404 acre-feet per year (Janonis and Gerlek, 1977). The majority of these imports, which consist mostly of CBT deliveries, are used within the lower 20 miles of the Lone Tree Creek drainage below elevations of 5,020 feet.

6.1.3 *Potentially Developable Surface Water Runoff Remaining* - In 1959 the USBR determined that the reach of Lone Tree Creek in Wyoming was fully developed. Furthermore, they stated that the water supply available in the Colorado portion of the Lone Tree Creek drainage is so small and undependable that there is no opportunity for development.

The surface flows of the Crow Creek drainage in Wyoming are also fully appropriated. There may be additional water available in the future in the form of return flows below Cheyenne, as the imports of that city from the North Platte River basin are expected to climb to 37,000 acre-feet or more, as municipal demands grow. Barring reuse, approximately two thirds of this imported water will appear as effluent and be available to downstream users. In 1959 the USBR reported that the native flow of this creek and tributaries within Colorado will not support additional surface water development.

6.2 The North Plains Tributaries Sub-basin

The North Plains tributaries sub-basin is defined here as that portion of drainage area north of the South Platte River-Plains sub-basin between the Crow Creek and Lodgepole Creek sub-basins. Figure 6-2 is a schematic drawing depicting the area.

6.2.1 *Physical Characteristics and Surface Water Runoff* - Wildcat, Pawnee and Cedar Creeks are the principal tributaries of this sub-basin. They drain about 2,400 square miles of land, the majority of which is located within Colorado. These streams originate on the southern edge of the Lodgepole Creek sub-basin at elevations of about 5,000 feet. They flow generally south to their confluences with the South Platte

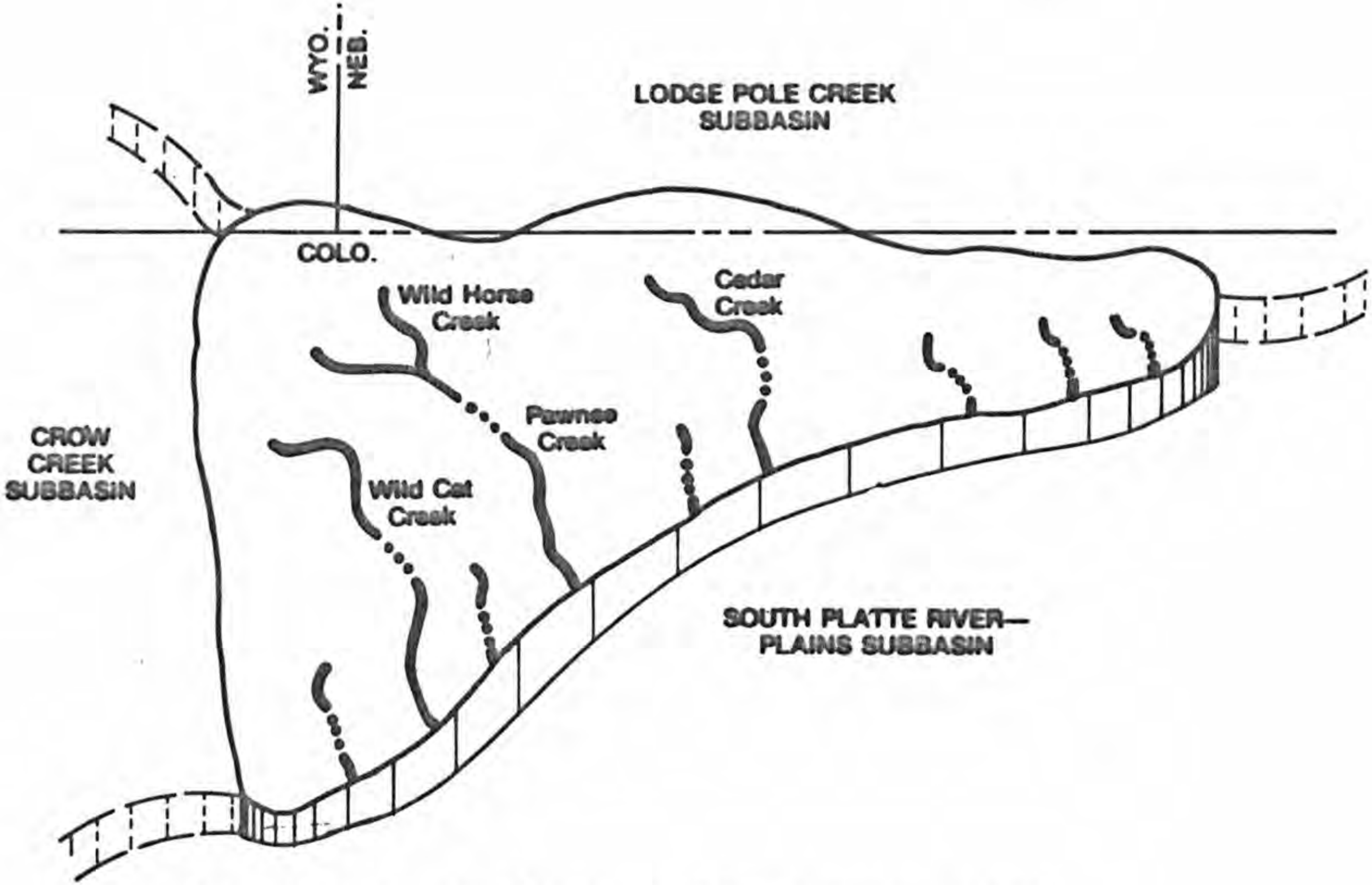


Figure 6-2: Schematic of the North Plains Tributaries Subbasin

River-Plains reach, which occur at elevations 4,210, 3,960 and 3,860 feet, respectively.

The precipitation in this sub-basin averages about 12 inches per year over its entire drainage area (National Atmospheric and Oceanic Administration, U.S. Department of Commerce, 1974).

Because of its low elevations and plains location, there is no winter snow pack; therefore it's streams are ephemeral. The surface water supply is derived from summer rainfall, when 70 to 80 percent of the average annual precipitation occurs. It occurs as short duration high intensity down pours; the results are usually low volume flash floods of a local nature. The surface water runoff contributed to the South Platte River is minor as most of the intermittent flows of these streams infiltrate to the groundwater reservoir.

While the creek beds of this sub-basin are generally dry, the upper reaches of Pawnee Creek, and its tributaries, Wildhorse and Spring Creeks, are fed by many springs and seeps. However, this flow disappears through evapotranspiration and seepage within a few miles.

No gaging stations have ever been maintained in this area by the U.S. Geological Survey. Because of this, it was necessary to "assume" a value of native runoff that would be available to surface water diverters in this sub-basin. Through the analysis performed by Janonis and Gerlek (1977) the figure chosen was 1,090 acre-feet per year. This was a weighed judgement taking into account the computed total agricultural water demand of, and the magnitude of groundwater pumpage within, this sub-basin.

6.2.2 *Existing Development of the Surface Water Runoff* - As there is very little dependable surface water runoff available from these creeks, there has been virtually no development in this sub-basin except for the irrigation of a few small tracts of land. However, in the lower valleys of these creeks near their mouths, irrigation with surface flows diverted from the mainstem of the South Platte River is prevalent. This developed area is located within the South Platte River-Plains sub-basin.

The October 10, 1974 revised tabulation of Colorado Water Rights lists 3, 5, and 16 absolutely decreed ditch rights for the native surface flows fo the mainstem of Wildcat, Pawnee, and Cedar Creeks respectively. All of these are for irrigation purposes and the majority are for less than five cfs. In addition to these direct flow rights and to others on various small tributaries, there are several storage appropriations in this sub-basin for small reservoirs. All of these are for under 80 acre-feet except Sterling Reservoir, sometimes called Point of the Rocks Reservoir, which is located on Cedar Creek and has a right for 84,000 acre-feet of the water in Cedar Creek. In addition it has a right for 84,000 acre-feet of Pawnee Creek flows which are delivered along with its surface appropriations from the mainstem of the South Platte through the North Sterling Canal. Both of these absolutely decreed storage rights have priority dates of June 15, 1908 with adjudication dates of July 5, 1928 and previous adjudication dates of June 11, 1913 (Wilkinson, 1974). Needless to say, there is very little yield from these rights on an average annual basis.

6.2.3 *Potentially Developable Surface Water Runoff Remaining* - In 1959, the USBR reported that other than the very small amounts presently being used, there is no further dependable native surface water supplies from these creeks than can be developed.

6.3 The Lodgepole Creek Sub-basin

The Lodgepole Creek sub-basin encompasses the entire drainage of Lodgepole Creek above the USGS gaging station #06763500 "Lodgepole Creek at Ralton, Nebraska." A major portion of this sub-basin is located in Nebraska, outside of the study area. However, for the sake of continuity, it will be discussed too, but in a briefer fashion. The lower five miles of Lodgepole Creek, and their drainage area below the gaging station, are located within Colorado and are included in the South Platte River-Plains Sub-basin. Figure 6-3 is a schematic drawing of the sub-basin.

6.3.1 *Physical Characteristics and Surface Water Runoff* - Lodgepole Creek has its origin in the Laramie Mountains east of Laramie, Wyoming. It flows generally east across Wyoming and Nebraska, and then dips south to its confluence with the South Platte River, which is near Ovid about ten miles upstream from where the South Platte River enters Nebraska. The creek is about 165 miles long, of which 65 miles are in Wyoming, 95 miles are in Nebraska, and five miles are in Colorado.

The Lodgepole Creek sub-basin has a maximum width of about 30 miles and includes 3,307 square miles of the high plains section of the Great Plains. Elevations within the sub-basin range from about 8,600 feet at its headwaters to 3,500 feet at its confluence with the South Platte River. The upper part of the drainage basin consists of gently rolling terrain having a gradient of about 125 feet per mile near the source. The lower part consists of relatively flat terrain with a valley slope averaging about 15 feet per mile across Nebraska (U.S. Department of the Interior, 1959).

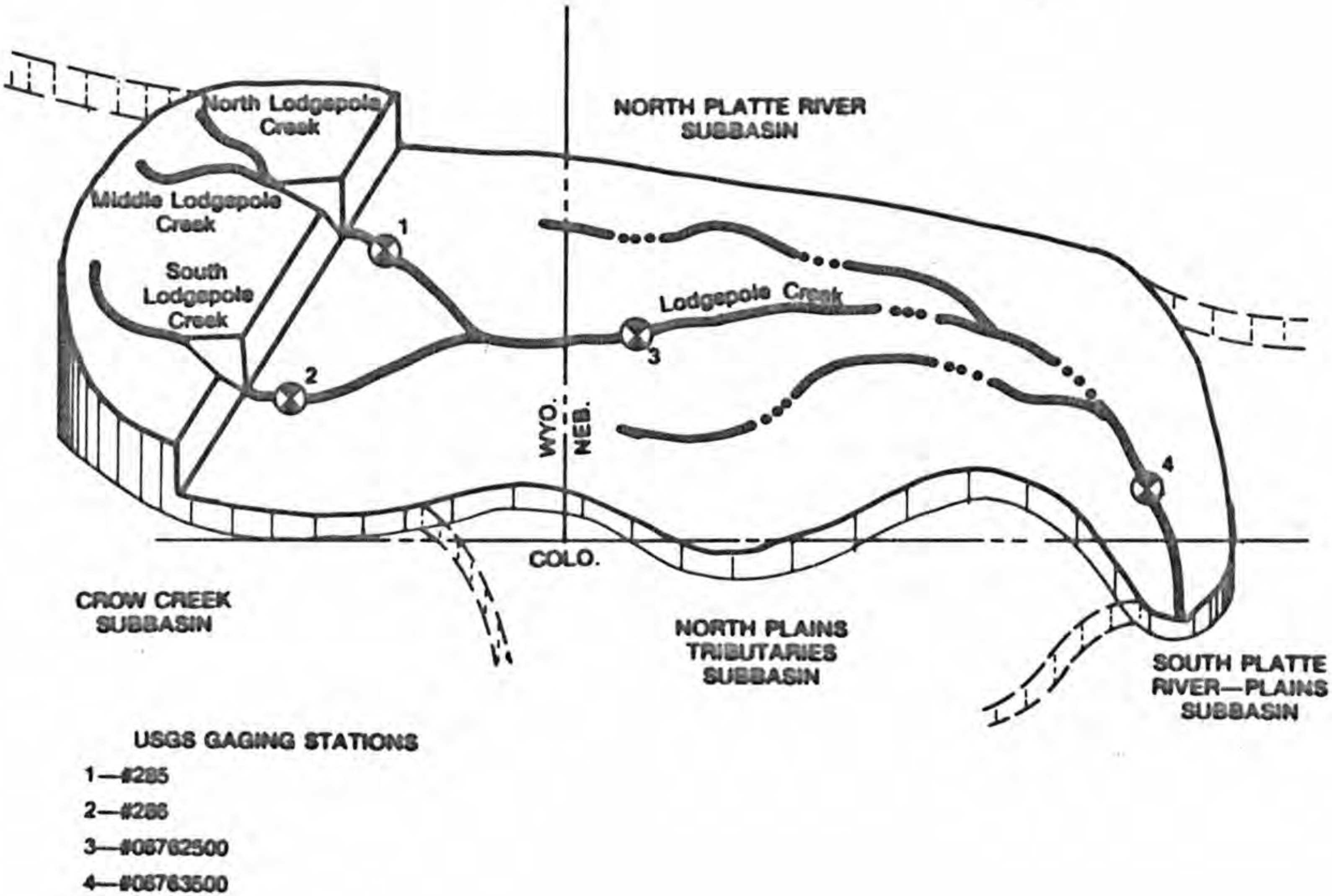


Figure 6-3: Schematic of the Lodgepole Creek Subbasin

About 1,361 square miles, or 41.2 percent of the sub-basin, is within Wyoming. The remaining 1,946 square miles, 58.8 percent of the total, are within Nebraska and outside of the study area. A negligible portion of the drainage area of Lodgepole Creek, which is above gaging station #06763500, overlaps into Colorado. The area of the sub-basin in Colorado was not determined.

The average annual precipitation over the entire Lodgepole Sub-basin is approximately 16 inches per year (National Atmopsheric and Oceanic Administration, U.S. Department of Commerce, 1974). While occasionally snow accumulates in the higher elevations to produce flows in the spring, the main source of Lodgepole Creeks surface water runoff is rainfall. Approximately 75 percent of the average annual precipitation falls as high intensity short duration summer rains.

Lodgepole Creek is a "gaining" stream over most of its course. There are several places, however, where it becomes a "losing" stream and surface flows disappear into the groundwater reservoir. A notable occurrence of this condition is a 17-mile reach from below Bennett Reservoir to about one mile east of Potter, Nebraska. The creek loses its perennial flow in the first six miles of this reach and is dry, except during floods. over the remaining eleven miles (U.S. Department of the Interior, 1959).

Several floods generally occur in Lodgepole Creek each year due to heavy precipitation within the drainage basin. Since the creek follows a meandering course, the progress of the flood is impeded and much of the adjacent meadow land is inundated, resulting in groundwater recharge to the valley alluvium. After the floods subside much of the water stored in the alluvium slowly seeps back into the stream (U.S. Department of the Interior, 1959).

Only two USGS gaging stations have ever been located in this sub-basin within the South Platte River basin study area. Both operated for six water years during the period 1933-1938. Information about these gaging stations and a complete listing of their runoff records are shown in Tables C4-38 to C4-39, respectively. Within the portion of the Lodgepole Creek sub-basin in Nebraska there have been three USGS gaging stations, two of which are still operating today. These two gaging stations are located at Bushnell and Ralton, Nebraska. These locations coincide approximately with the Wyoming-Nebraska and Nebraska-Colorado state lines, respectively. Information about these gaging stations and their yearly runoff records can be found in Tables C4-40 and C4-41, Appendix C.

The long term average recorded runoff at the gaging station at Bushnell, Nebraska was 8,550 acre-feet per year. However, at Ralton, Nebraska, even though the gaging station has 1,946 more square miles of drainage area, the average was 1,230 acre-feet per year less. While this is attributable in part to the natural infiltrating characteristics of the stream, groundwater depletion through pumpage causing further infiltration and the consumptive use of this sub-basins water supplies is also a cause.

Because of the nature of Lodgepole Creek, alternately disappearing and reappearing from the groundwater reservoir, point discharge measurements by gaging stations cannot be used to estimate the surface water availability throughout the entire sub-basin. Therefore, it was necessary to assume a quantity of water that would be divertable by surface water right holders. Through an analysis performed by Janonis and Gerlek (1977) the volume "chosen" for the study area of this sub-basin was 43,023 acre-feet per year. This was arrived at by subtracting the estimated yield of well permits in the Lodgepole Creek sub-basin in Wyoming from the total 1970 agricultural water demand in the Lodgepole Creek sub-basin in Wyoming. There is virtually no usage of Lodgepole Creeks runoff in the small area it drains in Colorado.

6.3.2 *The South Platte River Compact as it Pertains to Lodgepole Creek* - Lodgepole Creek starts in Wyoming, flows through Nebraska, and enters Colorado for its last five miles before joining the mainstem of the South Platte River.

The South Platte River Compact, ratified by the signatory states of Nebraska and Colorado in 1923 and 1925 respectively, was consented to by Congress, and therefore became effective, on March 8, 1926. While the main thrust of this compact was to apportion the flows of the South Platte River between the two states, provisions were included to likewise divide the waters of Lodgepole Creek.

Briefly, Nebraska is given the exclusive use and benefit of all waters flowing in Lodgepole Creek above a point two miles north of the Colorado-Nebraska state line. Colorado is allotted all of the water flowing into and accruing below. In addition, Nebraska is allowed to use, as a means of conveyance, the stream channels of the Colroado portions of Lodgepole Creek and the South Platte River. The South Platte River Compact in its entirety can be found in supporting Appendix D, Section D4.

6.3.3 *Existing Development of the Surface Water Runoff* - The state of Wyoming lists 92 water rights permits on Lodgepole Creek, most of which are for irrigation. Eighty three direct flow rights, totaling 210 csf are supplemented by nine storage appropriations worth 2,400 acre-feet (U.S. Department of the Interior, 1959).

The State of Nebraska lists 109 water rights on Lodgepole Creek, most of which are for irrigation. One hundred six direct flow rights, totaling 157 cfs, are supplemented by five storage appropriations worth 21,500 acre-feet (U.S. Department of the Interior, 1959).

By interstate agreement, Colorado had a right to all water flowing in Lodgepole Creek below a point of diversion on that creek in Nebraska, two miles north of its state line (South Platte River Compact, Article III, Section 1, 1926). According to the October 10, 1974, Colorado Water Rights tabulation, there are presently no rights attached to this water as it appears in the Lodgepole Creek Channel. It would seem that as this water is available, it flows into the mainstem of the South Platte and serves to satisfy downstream appropriators of South Platte flows instead.

6.3.4 *Potentially Developable Surface Water Runoff Remaining* - In 1959 the United States Department of the Interior reported that all of the surface flows of Lodgepole Creek are being used, primarily by irrigators, except for about 10,000 acre-feet per year. This amount, as measured at the gaging station at Ralton, Nebraska is the approximate amount leaving the sub-basin. However, as stated in the 1926 South Platte River Compact, this water is legally owned by Nebraska. Nebraska is outside of the study area of the project.

In Colorado and Wyoming, it can be asserted that there is very little potentially developable surface water supplies remaining in Lodgepole Creek.

6.4 The South Plains Tributaries Sub-basin

The South Platte tributaries encompasse the drainage of the South Platte River basin to the south of the South Platte River-Plains sub-basin and to the east of the South Platte River-Transition and Cherry Creek sub-basin. Figure 6-4 is a drawing depicting the major hydrologic elements of the sub-basin.

6.4.1 *Physical Characteristics and Surface Water Runoff* - The principal southern plains tributaries of the South Platte River included in this sub-basin are: Boxelder, Kiowa, Bijou, Beaver, and Badger Creeks. They drain about 4,276 square miles above the points where they enter the South Platte River-Plains sub-basin.

Boxelder Creek drains about 406 square miles of the western portion of this sub-basin; a long and narrow and sandy drainage. The stream starts in a cloudburst area at elevations around 7,000 feet. It flows in a northerly direction for about 85 miles to its confluence with the South Platte River, at an elevation of 4,550 feet near Hardin, Colorado. The major tributaries of Boxelder Creek and Ronk and Running Creeks in its upper reach and Horse Creek in its lower reach.

The precipitation in the headwaters of the Boxelder Creek drainage averages about 16 inches per year and about 12 inches per year in its lower valley (National Oceanic and Atmospheric Administration, U.S. Department of Commerce, 1974). The stream is ephemeral and the surface flows that occur are from intensive summer rainstorms. However they generally disappear by stream infiltration before entering the mainstem of the South Platte. No reliable streamflow records have been kept for Boxelder Creek.

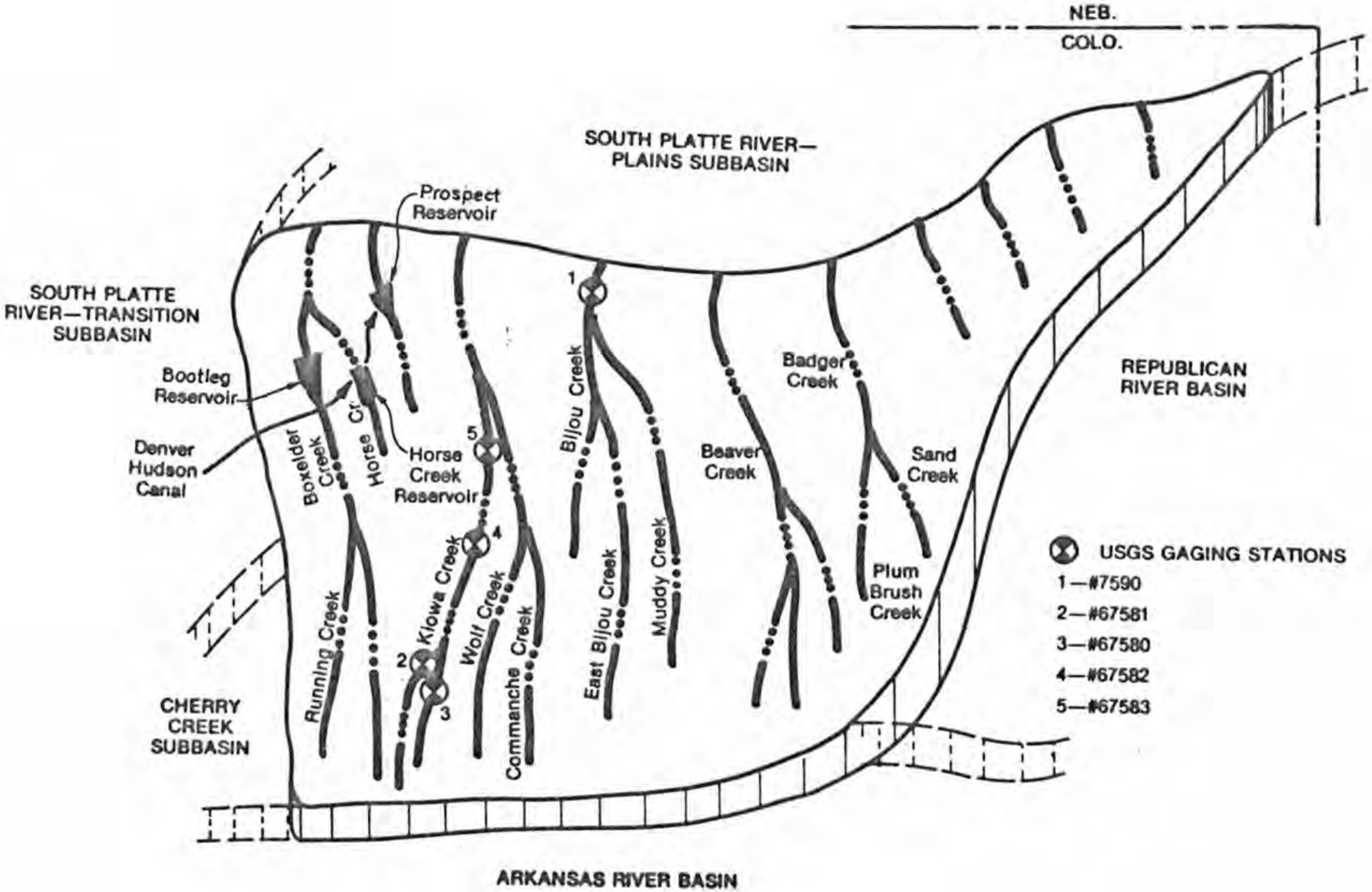


Figure 6-4: Schematic of the South Plains Tributaries Subbasin

Kiowa and Bijou Creeks are the two major streams that drain the middle portion of this sub-basin. This area is characterized by rolling high plains where the average rainfall is insufficient to maintain perennial streams. The creeks originate at an elevation of about 7,500 feet in the timbered Black Forest region of the plateau forming the divide between the South Platte and Arkansas Rivers. Kiowa and Bijou Creeks are both about 80 miles long and flow in a general northerly direction to their confluence with the South Platte at elevations 4,400 and 4,300 feet. Their drainage areas are 760 and 1,460 square miles respectively.

The watershed boundaries of the upper reaches of these creeks are well defined and characterized by wooded hills cut by steep rather short tributaries. The topographic gradient in the upper 40 miles of both drainages is about 40 feet per mile along the mainstem. Downstream the topography gradually flattens to a gradient of about 15 feet per mile at the confluence with the South Platte River Valley. Here the watershed boundaries are less defined, being replaced by a gently sloping divide covered by dune sand in many areas, (Duke et al., 1966). Near the middle of its drainage, the bed of Kiowa Creek is some 300 feet wide while near its confluence with the South Platte it narrows to about ten feet.

The major tributaries of Kiowa Creek are Rock and Mule Creeks in its lower reaches and Commanche Creek and its tributary, Wolf Creek in its middle reach. The major tributaries of Bijou Creek are Antelope, Muddy, and Big Muddy (Deer Trail) Creeks in its lower reaches, and West, East, and Middle Bijou Creeks in its middle and upper reaches.

The average annual precipitation in the drainage areas of these creeks varies from about 13 inches in their lower elevations to about 18 inches in their headwaters. This is equivalent to an average of 15.17 inches over the entire watershed which amounts to about 1,720,000 acre-feet of water annually. Most of the precipitation occurs from April 15 to the end of August (Duke, et al., 1966).

Kiowa and Bijou Creeks are intermittent surface streams; runoff occurs during occasional spring snowmelts or following summer thunderstorm activity. While flood flows in the Bijou Creek frequently reach the South Platte, those in the Kiowa Creek do not. There are a few reaches on Kiowa Creek and some of its tributaries which are perennial in nature, however, these reaches are very short. The perennial reaches usually occur in areas where the bedrock outcrops near the surface of the streambed, and the water thus forced to the surface quickly percolates back to the water table below such outcrop areas (Duke, et al., 1966). The severest flood of record in this area occurred on May 31, 1935. It caused the loss of nine lives; destruction of all bridges, and much damage to the towns of Elbert, Kiowa, and Byers, in addition to destroying several ranch houses in the valleys (U.S. Department of the Interior, 1959).

There have been five USGS gaging stations in operation at various times, recording the surface water runoff in this sub-basin. None are operated today. Four of these were located in Kiowa Creek and its tributaries and one was on Bijou Creek. Information about these gaging stations and their runoff records are shown in Table C4-33 to C4-37, Appendix C. The gaging station on Bijou Creek, near Wiggins, Colorado recorded an average annual flow of 6,660 acre-feet for the six complete water years it was in operation. In 1953 only 1,190 acre-feet passed the gaging station, while two years prior, in 1951, 24,070 acre-feet of runoff was recorded. A flood frequency analysis of the records of the Wiggens Gaging Station on Bijou Creek was performed by the Colorado State University Civil Engineering Department in 1966. The results are shown in Figure 6-5. Even though the short period of record limits the reliability of the analysis, the large variation in probable runoff it implies, is informative.

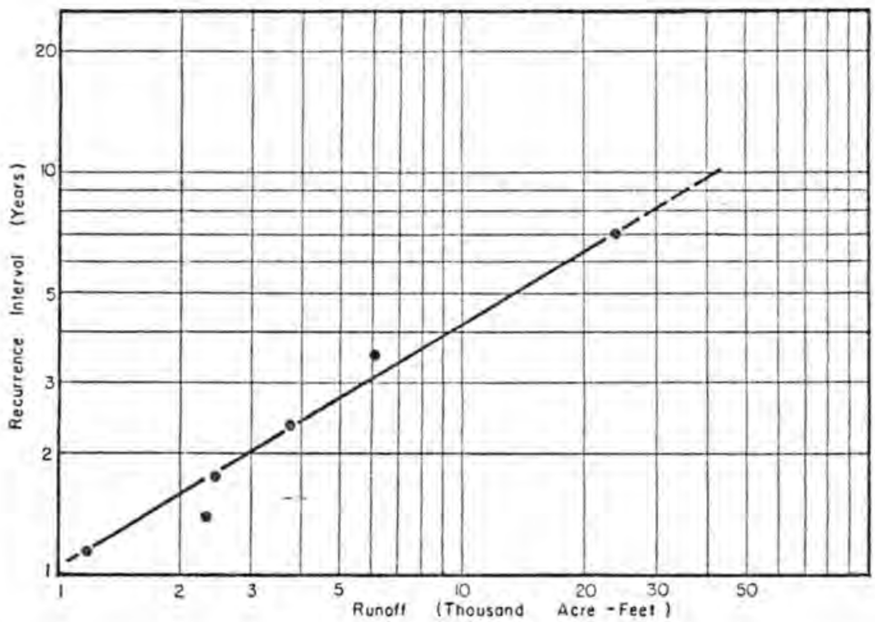


Figure 6-5 Expected Runoff for Bijou Creek near Wiggins, Colorado (Duke, et al., 1966).

Beaver Creek and Badger Creek drain an area of about 1,650 square miles of the eastern portion of this sub-basin. The southern boundary of their drainage area is the divide between the South Platte and Arkansas Rivers, elevation 5,500, and the eastern boundary is the divide between the South Platte and Republican River. Beaver Creek and Badger

Creek join the mainstem of the South Platte River near the town of Brush at elevations 4,130 and 4,230 feet, respectively. The tributaries of Badger Creek are relatively minor streams, most are unnamed. The tributaries of Beaver Creek include Sand, Plum Brush, Coal, and Middle Mist Creeks.

The average annual precipitation in this portion of the sub-basin averages 16 inches per year (NOAA, U.S. Department of Commerce, 1974). The flows of Beaver and Badger Creeks and their tributaries are intermittent since there is no winter snowpack available to them. The surface water supply is derived from rainfall which, in many instances, is of short duration and high intensity. This generally results in low volume flash floods of a local nature. The surface runoff that does appear generally disappears into the groundwater reservoir before leaving their individual drainage areas. No streamflow records have been maintained in this area.

Further east of these creeks within the South Plains Tributaries sub-basin, towards the neck of the South Platte River basin, there is Camp Creek, Twenty Two Slough, and several unnamed gulches. The surface water runoff of this area is characteristic of the rest of the sub-basin, intermittent and minor in amount.

Because of the complete lack of reliable information concerning the average or specific yearly amounts of surface water runoff in this sub-basin, it was necessary to "assume" a value. The volume chosen as being available to surface water diverters on the five major creeks and their tributaries was 50,000 acre-feet per year. This was purely a speculative estimate.

6.4.2 *Existing Development of the Surface Water Runoff* - In the lower valleys of the major creeks draining the South Plains Tributaries sub-basin, and adjacent to the South Platte River, there is rather extensive irrigation which uses surface flows diverted from the mainstem of the South Platte River. This area is located within the South Platte-Plains sub-basin. The use of the native surface water runoff of these creeks in the higher elevations above this developed area, is discussed below.

The minor water supply available from the intermittent surface flows of Boxelder Creek is currently used by irrigators below the existing Bootleg Reservoir. This reservoir was constructed on Boxelder Creek in about 1910, approximately 25 miles above its confluence with the South Platte River. The original capacity of 6,194 acre-feet appears to have regulated all flows since its construction; this is due partly to the high infiltration rate of flood waters in the upper reaches. Although several irrigation projects have been constructed on Boxelder Creek above Bootleg Reservoir, only a few are still in operation because of senior downstream water rights and sediment conditions (U.S. Department of the Interior, 1959).

The 1974 Colorado water rights tabulation lists 14 water rights for the surface flows of the mainstem of Boxelder Creek. These include six absolutely decreed direct flow rights for 500.0, 80.0, 21.0, 14.51, 10.0, and 9.8 cfs; four absolutely decreed storage rights for 3100.00, 714.5, 385.0, and .020 acre-feet; and four conditionally decreed storage rights for 6194.0, 2566.0 and 843.0 acre-feet (Wilkinson, 1974).

The surface waters that do accrue to Kiowa and Bijou Creeks and their tributaries have been heavily appropriated. Appropriation dates for surface decrees in this area date as early as April 26, 1886, i.e., Oaks Ditch No. 1, on Kiowa Creek, 2.0 cfs, basin rank 167 (Wilkinson, 1974).

According to H. R. Duke and R. A. Longenbaugh (1966) a total of 36 direct flow and four reservoir decrees have been issued on Kiowa Creek and its tributaries. On Bijou Creek there are 37 surface flow decrees and 39 reservoir decrees. Tables 6-3 and 6-4 list these surface water decrees for Kiowa Creek and Bijou Creek, respectively, showing their source, priority date, and amount filed for. Reservoir decrees are seen in Tables 6-5 and 6-6. Many of these surface water decrees were issued provisional to construction of the diversion system and use of the water. It is not known how many of these decrees were validated by use (Duke, et al., 1966). Only a very few of the surface diversion systems are known to exist today. Those that do exist are primarily used for supplemental irrigation of hay crops and for groundwater recharge. Most of these rights provide water only during periods of streamflow following snowmelt or summer thunderstorm activity.

Some of the surface diversion systems no longer in existence have been replaced with more reliable groundwater supplies but some have been abandoned entirely.

The flood flows occurring on Kiowa Creek and its tributaries are presently regulated by a series of about 64 retarding dams, (USGS, 1969a). While these decrease the chances of flood damage they also serve to increase the groundwater recharge rates of the surface water runoff. While surface water use in this sub-basin is minor, groundwater pumpage is extensive to the point of mining. Water table levels have been, and are presently, declining (Duke, et al., 1966).

Table 6-3 Ditch Decrees in the Kiowa Creek Drainage of the South Plains Tributaries Sub-basin (Duke et al., 1966).

Name of Ditch	Source	Date	Decree Sec-ft*
Oakes No. 1	Kiowa Creek	4-26-66	2.0
Wendling	Killin's Spring Run	4-1-68	5.0
Oakes No. 3	Kiowa Creek	5-1-68	15.0
Aux No. 1	Kiowa Creek	9-15-75	2.5
Dietrich No 1	Kiowa Creek	5-1-78	2.5
Dietrich No. 2	Kiowa Creek	9-10-79	1.5
Fred Bachman No. 2	Kiowa Creek	3-20-81	5.5
Fred Bachman No. 3	Kiowa Creek	7-3-82	1.0
George A. Wood	Kiowa Creek	4-10-83	3.0
Dietrich No. 3	Kiowa Creek	4-2-85	1.0
Ehrler	Kiowa Creek	3-15-86	1.0
Elbert	Kiowa Creek	2-8-87	1.0
Aux No. 2	Kiowa Creek	2-12-87	1.0
Fahrion	Kiowa Creek	9-20-87	1.0
Alex Brazelton	West Kiowa Creek	1-1-88	1.26
D. C. Bailey	Kiowa Creek	4-3-88	5.5
Renner No. 1	Kiowa Creek	6-1-88	10.71
Kruse and Mauldin	Running Creek	2-17-89	1.5
Comanche	Comanche Creek	12-2-89	4.0
Marki	Kiowa Creek	5-25-90	1.0
Gibson No. 2	Kiowa Creek	7-14-92	147.0
Egelhoff Grove	Kiowa Creek	5-15-93	46.0
Ell Triangle	Comanche Creek	10-15-95	52.0
Desert Ditch and Extensions	Kiowa Creek	10-23-95	140.0
Wahl and Epple	Kiowa Creek	10-1-00	115.0
Rock Bluff	Rock Bluff Creek	10-1-00	50.0
C. Wahl	Kiowa Creek	10-3-00	180.0
Living Springs Nos. 1 & 2	Comanche Creek	3-1-03	79.2
Wahl	Kiowa Creek	12-14-05	23.0
Desert Ditch and Extensions	Kiowa Creek	4-1-06	
Desert Ditch and Extensions	Kiowa Creek	4-1-07	c
Washita	Comanche Creek	5-28-07	17.82 c
Caroline Epple No. 1	Mule Creek	12-17-07	150.0 c
Caroline Epple No. 2	Mule Creek	12-17-07	150.0
Gleason	Kiowa Creek	6-20-08	5.16
Carnahan Underflow	Kiowa Creek	2-17-12	1.5

* c denotes conditional decree.

Table 6-4 Ditch Decrees in the Bijou Creek Drainage of the South Plains Tributaries Sub-basin (Duke et al., 1966).

Name of Ditch	Source	Decree Date	Decree sec-ft*
Meadow Springs	Meadow Springs Creek	6-1-70	2.0
Page and Foster	West Bijou Creek	2-10-88	8.0
Bijou	West Bijou Creek	2-23-88	30.0
Craven	West Bijou Creek	2-10-89	1.0
Bueck	East Bijou Creek	9-15-89	22.0
Bijou Reservoir Inlet	Bijou Creek	7-5-91	c
Bramkamp	Deer Trail Creek	2-15-92	5.0
Moore	Deer Trail Creek	11-6-93	c
East Gulch Ditch	East Gulch	11-14-95	6.8
Moore Enl.	Deer Trail Creek	11-24-95	127.55
Maguire	West Bijou Creek	4-10-96	5.3
Meadow Springs Enl.	Meadow Springs Creek	6-5-97	6.0
Bailey - Hack	Antelope and Little Antelope Creeks	11-14-04	36.0
Pipe Line of Bijou Valley Ditch and Reservoir System	Bijou Creek	5-15-06	27.0
Wassman	East Bijou Creek	5-18-06	14.0
Brewer	Deer Trail Creek	6-9-06	22.0 c
M. H.	Long Gulch	6-20-06	23.5 c
Moore 2nd Enl.	Deer Trail Creek	7-25-06	c
M. H. No. 2	East Bijou Creek	9-15-06	50.4
M. H. No. 3	East Bijou Creek	11-1-06	230.15
Adams Ditch and Pipeline	Meadow Springs Creek	2-8-07	3.0
Swanson	West Bijou Creek	2-15-07	17.5
Clark and James	West Bijou Creek	4-1-07	288.0
D. T.	Deer Trail Creek	4-23-07	71.72 c
Agage Res. and Ditch	East Bijou Creek	6-1-07	30.0
Conter	Bijou Creek	1-17-08	44.0
East Gulch Ditch & Reservoir Enl.	East Gulch	2-6-08	c
Upper Nile and Extension	Bijou and Antelope Creeks	6-9-08	c
Barnhouse	Antelope Creek	6-9-08	47.85
Lower Nile	Bijou and Antelope Creeks	6-9-08	c
Base Line Reservoir, Outlet	Deer Trail Creek	7-28-08	44.0
Bijou Valley Ditch and Reservoir System	Bijou Creek	9-1-08	c
D.T. No. 2	Deer Trail Creek	12-21-09	c
Outlet No. 1 of Supplemental Reservoir	Deer Trail Creek	4-24-10	c
Outlet No. 2 of Supplemental Reservoir	Deer Trail Creek	4-24-10	c
Maguire Enl.	West Bijou Creek	4-3-11	9.7
Brothe Ditch	Deer Trail Creek	4-1-12	200.0

* c denotes conditional decree

Table 6-5 Reservoir Decrees in the Kiowa Creek Drainage of the South Plains Tributaries Sub-basin (Duke et al., 1966).

Name of Reservoir	Source of Supply	Decree Date	Decree (ac-ft)*
Gibson No. 1	Kiowa Creek	11-15-92	
Gibson No. 2	Kiowa Creek	6-15-93	
Rock Creek No. 1	Rock Creek	6-1-07	460 c
Rock Creek No. 2	Rock Creek	9-5-09	643 c

* c denotes conditional decree

Table 6-6 Reservoir Decrees in the Bijou Creek Drainage of the South Plains Tributaries Sub-basin (Duke et al, 1966)

Name of Reservoir	Source of Supply	Date	(ac-ft)*
Base Line Enl.	Deer Trail Creek	1-20-10	167 c
Supplemental	Deer Trail Creek	4-24-10	57 c
Noonen No. 2 Enl.	Deer Trail Creek	3-26-12	3445 c
Noonen Seepage	Deer Trail Creek	5-1-12	176 c
Bijou	West Bijou Creek	4-27-89	2296
Bueck	East Bijou Creek	9-15-89	750
Bijou No. 1	Bijou Creek	7-5-91	c
Bijou No. 2	Bijou Creek	7-5-91	c
Bijou No. 3	Bijou Creek	7-5-91	c
Bijou No. 4	Bijou Creek	7-5-91	c
Bijou No. 5	Bijou Creek	7-5-91	c
Bijou No. 6	Bijou Creek	7-5-91	c
Bramkamp	Deer Trail Creek	2-15-92	193
Mary Lawless	West Bijou Creek	12-23-93	1713 c
Moore No. 1	Deer Trail Creek	4-1-94	114
Hopewell No. 1	West Bijou Creek	9-27-03	1840
Moore No. 2	Deer Trail Creek	4-1-05	23
Brewer "A"	Bijou Creek	6-9-06	65 c
M. H.	Long Gulch	7-17-06	70 c
Moore No. 4	Deer Trail Creek	7-25-06	860
M H. No. 2	East Bijou Creek and Gulches	9-1-06	256 c
M. H. No. 2 Enl.	East Bijou Creek and Gulches	12-9-06	522 c
Noonen No. 2	Deer Trail Creek	10-22-07	2662
Base Line	Deer Trail Creek	1-28-08	216 c
East Gulch	East Gulch	2-6-08	18 c
Adams	Bijou Creek	6-9-08	11040 c
Barnhouse	Antelope Creek	6-9-08	
Macarthy	Bijou and Antelope Creeks	6-9-08	0.2 c
Meadow Springs	Meadow Springs Creek	6-15-08	116
Reservoir "A" of the Bijou Valley Ditch and Reservoir System	Bijou Creek	9-1-08	487 c
Reservoir "B" of the Bijou Valley Ditch and Reservoir System	Bijou Creek	9-1-08	714 c
Reservoir "D" of the Bijou Valley Ditch and Reservoir System	Bijou Creek	9-1-08	253 c
Hopewell No. 2	West Bijou Creek	10-15-08	2700 c
New Kingsbury	Willow Creek	5-2-09	536 c
Bramkamp Enl.	Deer Trail Creek	9-27-09	2066 c
West Nile	Rock, Bijou, and Antelope Creeks	9-28-09	c

Table 6-6 Continued.

Name of Reservoir	Source of Supply	Decree Date	Decree (ac-ft)*
D. T. No. 1	Deer Trail Creek	12-21-09	138 c
D. T. No. 2	Deer Trail Creek	12-21-09	112 c
D. T. No. 3	Deer Trail Creek	12-21-09	125 c

* c denotes conditional decree

In 1908 the Nile Irrigation District was organized to irrigate 27,000 acres of land located about 16 miles west of Fort Morgan. The project as planned was to obtain water from Bijou, Muddy, Antelope, Rock, and Kiowa Creeks. Three reservoirs with a total capacity of 35,000 acre-feet and about seven miles of canal were constructed. The project failed because of inadequate water supplies (U.S. Department of the Interior, 1959). Very little evidence remains of the abandoned features which, according to local residents, were destroyed by the 1935 flood (Duke, et al., 1966).

Table 6-7 summarizes the water rights on the mainstem of Beaver and Badger Creeks as listed on the October 10, 1974 tabulation of Colorado water rights. Besides these, there are a number of other minor absolutely and conditionally decreed water rights issued for the various tributaries of these creeks.

6.4.3 *Potentially Developable Surface Water Runoff Remaining* - There is no potentially developable unappropriated surface water runoff remaining in the Boxelder Creek drainage. In 1959, the United States Department of the Interior located a potential reservoir site on Boxelder Creek about 50 miles above Bootleg Reservoir. They indicated that a small earth fill dam across the creek at this location would create a reservoir with a capacity of 4,000 acre-feet. By the regulation of spring runoff this reservoir could develop supplemental irrigation water by providing holdover storage for the average annual flow of approximately 1,500 acre-feet. However, because of the minor water supply involved and the fact that any development would interfere with downstream water rights, further study was not recommended.

Table 6-7 Decreed Surface Water Rights on the Main Stem of Badger and Beaver Creeks (Wilkinson, 1974)

Name of Structure	Type	Name of Source	Use	Amount	Type Adjudication	Adjudication Date	Previous Adjudication Date	Appropriation Date	Basin Rank
Badger Cr R Ca Co D 2	D	Badger Creek	I	500.00 cfs	S	01/15/1914	11/21/1895	08/30/1889	1239
Tuke Reservoir Ditch	D	Badger Creek	I	34.4400 cfs	S	01/15/1914	11/21/1895	05/01/1906	1615
Badger Creek Res	R	Badger Creek	I	9879.00 af	S,C	01/15/1914	11/21/1895	05/22/1909	1803
Noonen No 3 Reservoir	R	Badger Creek	I	3563.00 af	S,C	01/15/1914	11/21/1895	06/19/1909	1812
Tuke Res	D	Badger Creek	I		S,C	01/15/1914	11/21/1895	07/08/1909	1815
Schwindt Ditch PP	D	Badger Creek	I	2.7000 cfs	S	01/13/1936	01/05/1922	07/10/1930	2387
Beaver Ditch	D	Beaver Creek	I	44.0000 cfs	O	11/21/1895		05/01/1882	604
Thomas J Molloy Ditch	D	Beaver Creek	I	55.0000 cfs	S	01/15/1914	11/21/1895	02/07/1882	1223
Beaver Creek Ditch	D	Beaver Creek	I	16.0000 cfs	S	12/17/1900	11/21/1895	04/18/1889	1238
Badger Cr R Ca Co D 1	D	Beaver Creek	I	78.7000 cfs	S	01/15/1914	11/21/1895	08/30/1889	1239
Beaver Farmers Canal D	D	Beaver Creek	I	308.00 cfs	S	12/17/1900	11/21/1895	09/09/1889	1240
Wylie Light Follmann D	D	Beaver Creek	I	27.5000 cfs	S	01/15/1914	11/21/1895	12/22/1895	1261
Beaver Cr School Land D	D	Beaver Creek	I	50.0000 cfs	S	12/17/1900	11/21/1895	04/25/1898	1297
Bushman Ditch	D	Beaver Creek	I	152.00 cfs	S	11/04/1922	01/15/1914	03/21/1898	1962
Middlemist Ditch No. 1	D	Beaver Creek	I	143.90 cfs	S	06/29/1925	01/05/1922	05/19/1902	2150
Middlemist Reservoir	R	Beaver Creek	I	234.00 af	S	06/29/1925	01/05/1922	06/08/1903	2152

Key: Type
D = Ditch
R = Reservoir

Use
I = Irrigation

Type Adjudication
S = supplemental
O = original
C = conditional

The present situation regarding Beaver and Badger Creek is similar to the rest of the creeks in this sub-basin. While occasionally excessive floods carry unappropriated surface water runoff, they are not dependable sources of supply.

One need only look at the Nile Irrigation Districts ill fated attempt to develop additional surface water supplies from Kiowa and Bijou Creeks before deciding that very little, if any water is available for development in these drainages.

6.5 The South Platte River-Plains Sub-basin

The South Platte River-Plains sub-basin is not defined by well delineated drainage boundaries. Rather, it is defined for the convenience of this study, to include the plains reach of the South Platte River and the narrow corridor of irrigated agriculture which has developed on both banks of its lower valley. The boundaries have also been defined to include the half a dozen major off stream reservoirs which play a predominant role in the water supply of the irrigated acreage. The South Platte River-Plains sub-basin includes portions of Irrigation Districts #1 and 64. Figure 6-6 depicts the sub-basin schematically.

6.5.1 *Physical Characteristics and Surface Water Supply* - The reach of the South Platte River encompassed by this sub-basin begins at an elevation of 4575.77 feet, at the USGS Gaging Station #06754000, "South Platte River near Kersey, Colorado." It ends approximately 150 miles downstream, after a loss of 1129.01 vertical feet, at the USGS gaging station near the Colorado-Nebraska State Line #06764000, "South Platte at Julesburg, Colorado." The drainage area included in this sub-basin encompasses 1,956 square miles of plains type terrain.

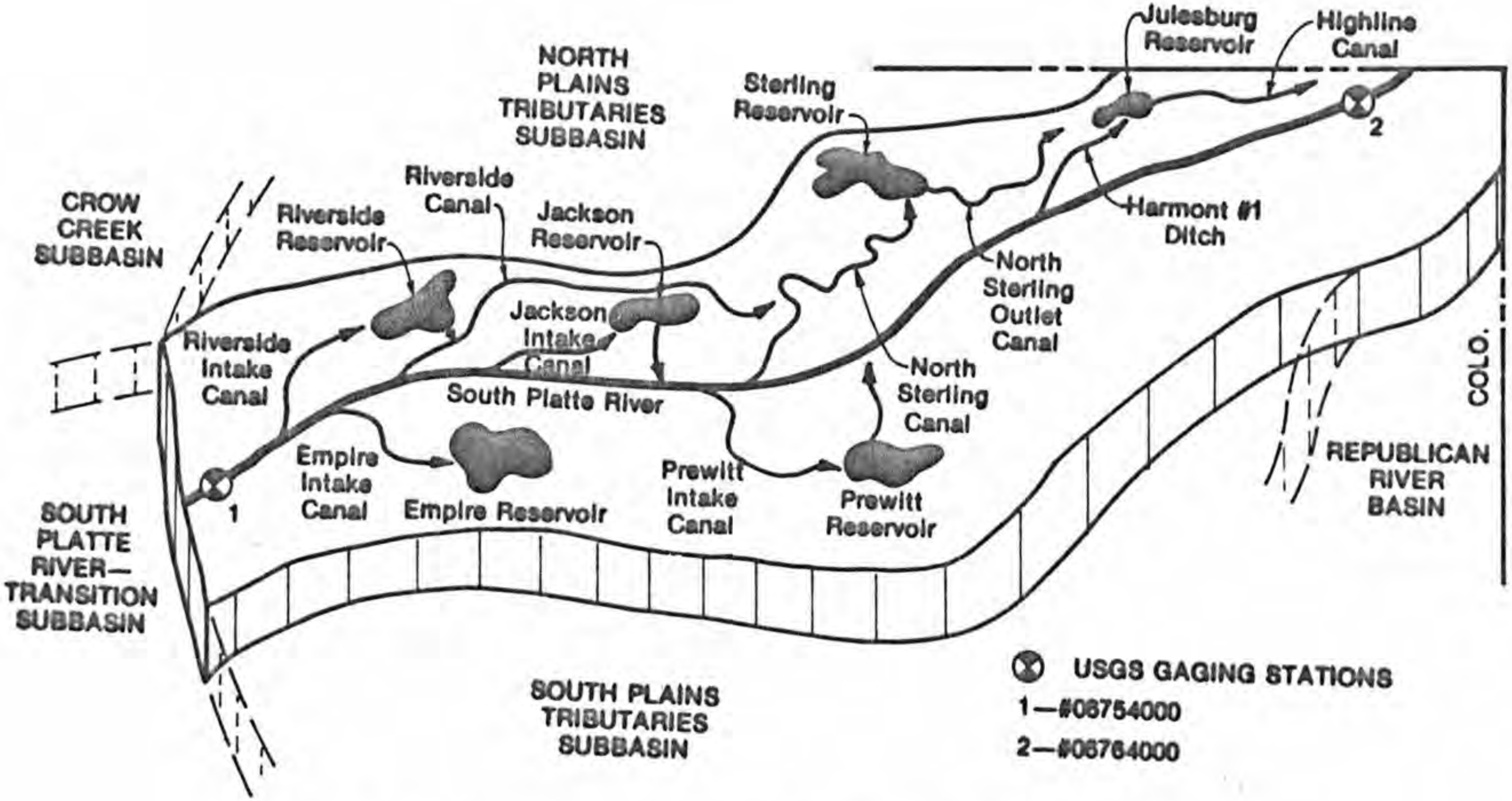


Figure 6-6: Schematic of the South Platte River-Plains Subbasin

Near Kersey, Colorado, the South Platte River flows through an area where the precipitation averages about 12 inches per year. As the South Platte continues through this sub-basin, the average annual precipitation gradually increases to about 16 inches per year at Julesburg. About 70 to 80 percent of the average annual precipitation in this sub-basin occurs in the summer months as short duration high intensity down-pours. The results are usually low volume flash floods which, for the most part, quickly infiltrate to the groundwater reservoir. It is assumed here that the native surface water runoff from this sub-basin is negligible. The primary source of surface water to this sub-basin is through inflow from surrounding tributary sub-basins, and from the mainstem of the South Platte River as it enters this, its plains reach.

The Bureau of Reclamation (1959) has estimated that the total tributary inflow to the South Platte River within this sub-basin averages about 30,000 acre-feet per year. Most of this surface water is assumed to arrive through the various tributaries draining from the Crow and Lodgepole Creeks, and the North and South Plains tributaries sub-basins. A negligible portion is assumed to reach the South Platte River through the various small tributaries and gulches included within the drainage area of this sub-basin.

The surface water entering this sub-basin through the mainstem of the South Platte River can be measured at the USGS Gaging Station #06754000, "South Platte River near Kersey, Colorado." This gaging station has been in operation since 1901, and it has recorded an annual average inflow of 561,342 acre-feet. Information about this gaging station and its historical yearly discharge measurements are shown in Table C4-27, Appendix C. The record of this gaging station show that this inflows are highly variable, ranging through an order of magnitude. The low was 159,000 acre-feet in the 1955 water year and the high was 1,599,000 acre-feet in the 1973 water year. Records show that serious flooding has occurred in this sub-basin in 1844, 1864, 1867, 1894, 1921, 1933, 1935, 1965, 1969, and 1973 (Western Engineers, 1976).

It has been estimated that today, a full 90 percent of the surface water entering this sub-basin through the mainstem of the South Platte are "return flows" (Dille, 1960). The source of this "secondhand" water is the non-consumptively used portions of water usage upstream that have returned back to the river.

In addition, the South Platte River-Plains sub-basins has direct allotments for water from the Colorado-Big Thompson Project. This water is delivered through the mainstem of the South Platte and through agricultural ditches and canals which enter this sub-basin in the higher valley elevations.

Prior to the 1860, when the high mountain tributary streams of the South Platte River were still in their natural state, spring runoff flashed down their channels, and in the winter and summer these same streams were almost dry. It has been told that the early pioneers following the South Platte trail sometimes had to dig holes in the sandy bed of the river to get water. The South Platte River-Plains was an influent (or infiltrating) stream. The spring runoff from the mountains probably reached the Platte River in Nebraska; however, the lower flows of summer, fall and winter probably were lost by seepage from the streambed.

As irrigation development in the upper tributaries progressed, it was thought that their would be no water left for the lands downstream, along the South Plattes plains reach. Then, as the soils and sub-soils of the growing irrigated area became saturated, there came the beginnings of the "return flows." Today, after more than 100 years of development, this groundwater "mound" of saturated soil extends virtually to the mouth of the basin. The reach of the South Platte River in the plains is now an effluent stream or "growing" river. While it has changed from an ephemeral stream to a perennial one, its flows are still highly erratic. The flow variation with distance is caused by innumerable diversions and returns along the entire reach. Moreover, diversions are not continuous with time and so the flow at any point is variable with time. In fact, some reaches of the South Platte, especially below major diversions, are completely dry.

A further development within this reach of the South Platte has been to develop the groundwater from the man made induced groundwater "mound" or reservoir. The first major irrigation well in the South Platte River basin was put down in the Beaver Creek Valley in 1910 (USBR, 1959). The drilling of new irrigation wells continued slowly until 1931 when there were about 550 wells pumping water in the whole South Platte River basin. The drought years, beginning in 1931, along with the introduction of high speed diesel engines, stimulated the growth of irrigation wells to a great extent. Reduced electric power rates were initiated also about 1930 (USBR, 1959). By 1940, 1900 wells were in use and by 1950, 5,000 wells withdrew 1,000,000 acre-feet of groundwater from the South Platte River basin. This pumpage, equivalent to 70 to 80 percent of the basin's average annual native runoff, has had serious effects on the groundwater reservoir fortuitiously built up through irrigation development of the surface water supplies. By decreasing the effectiveness of the return flow mechanism, surface water diverters dependent on these seeps into rivers have been injured. Occasionally, only a minor fraction of upstream reservoir releases reach diverters in the plains as the flows are not sustained in the river channel. Rather they infiltrate into the ground to replace the consumptive use depletions of pumpage from the aquifer. This recent upset of the equilibrium has given rise to such organizations as GASP (Groundwater Appropriators of the South Platte River Basin) within this sub-basin.

The strategy used by GASP is to appropriate, buy, manage, and lease water to be used for replacement purposes. By providing replacement water to reduce injury to senior surface water appropriators, they hope to reduce the necessity for the state regulation of their wells. The management scheme has not been subject to a dry year or series of dry years. It remains to be seen whether this is the most effective or efficient method of managing the total water resource system of this sub-basin within the constraints of present water laws.

The South Platte River plains reach is probably the most outstanding example in the west of return flow development. It has almost reached the apex in developing its total water resources system where additional water can only be made available through more efficient use and effective conjunction use management schemes.

The outflow from the South Platte River-Plains sub-basin is measured at the USGS Gaging Station #06764000, "South Platte at Julesburg, Colorado." This gaging station also marks the mouth of the South Platte River basin study area. It has been in operation since 1902 and has recorded an average outflow of 351,752 acre-feet per year.

No flow was recorded at this gaging station on August 18 to 20, 1902, and July 25 to August 7, 1903. However, irrigation development, and its perturbations of the previous natural system (i.e., return flows), have caused continuous flow at this point, although sometimes these are only a few cfs, ever since.

It has been estimated that the groundwater outflow from the South Platte River basin study area, through the aquifer directly beneath the Colorado-Nebraska state line, is about 20,000 acre-feet annually (Hurr, et al., 1975).

6.5.2 *The South Platte River Compact* - In 1916 the State of Nebraska brought a suit against Colorado water users on behalf of the Western Irrigation District which diverted water just below the Colorado-Nebraska line.

At that time the full development of the return flows in the South Platte River in Colorado had not received as far down as the state line. In periods of low flow Colorado ditches upstream sometimes diverted the entire flows, leaving no water for Nebraska ditches. Irrigation systems in Morgan, Washington, Logan and Sedgewick Counties organized the "Associated Ditches" and employed Attorney Delph E. Carpenter as legal counsel. Mr. Carpenter had been developing the principle of interstate compacts as an alternative to long expensive litigation between states which culminated in his major accomplishment, the Colorado River Compact (Dillie, 1960). Mr. Carpenter suggested a similar procedure to the Nebraska officials and the plan was favorably received. After several years of negotiations and study of the river conditions, including particularly a realization of the increasing return flows in that section of the stream, a compact was agreed upon. It was ratified by the signatory states of Nebraska and Colorado in 1923 and 1925 respectively and was consented to by Congress, becoming effective on March 8, 1926. The essential provisions of the South Platte River Compacts are:

1. Colorado has full use of the waters of the South Platte within that state between October 15 and April 1 of every year.

2. During the remainder of the year, Colorado cannot permit diversions from the "lower section" of the river, to supply Colorado appropriations junior to June 14, 1897, to the extent that will diminish the flow of river into Nebraska below 120 cfs. The term "lower section," defined in Figure 6-7, means that part of the South Platte River in Colorado between the Washington County line and the state line (Water District #64). It is also referred to as the "compact control area" by the Colorado State Engineer's Office. Therefore, if available in the "lower section," Colorado must led 120 cfs flow to Nebraska each year for 198 days; this amounts to 47,116 acre-feet per year on an annual basis.

3. Requirement two is subject to the exception that Colorado is not required to deliver any part of the flow past the gaging station if it is not needed for beneficial use by those entitled to divert water from the river within Nebraska.

4. The waters of Lodgepole Creek are also apportioned by the compact.

The South Platte River compact in its entirety, can be found in Appendix D, Section D4.

The return flows in the lower river have provided enough water at the state line so that it is not always necessary to shutoff any ditches in water district #64. On the average, annual and monthly outflows are

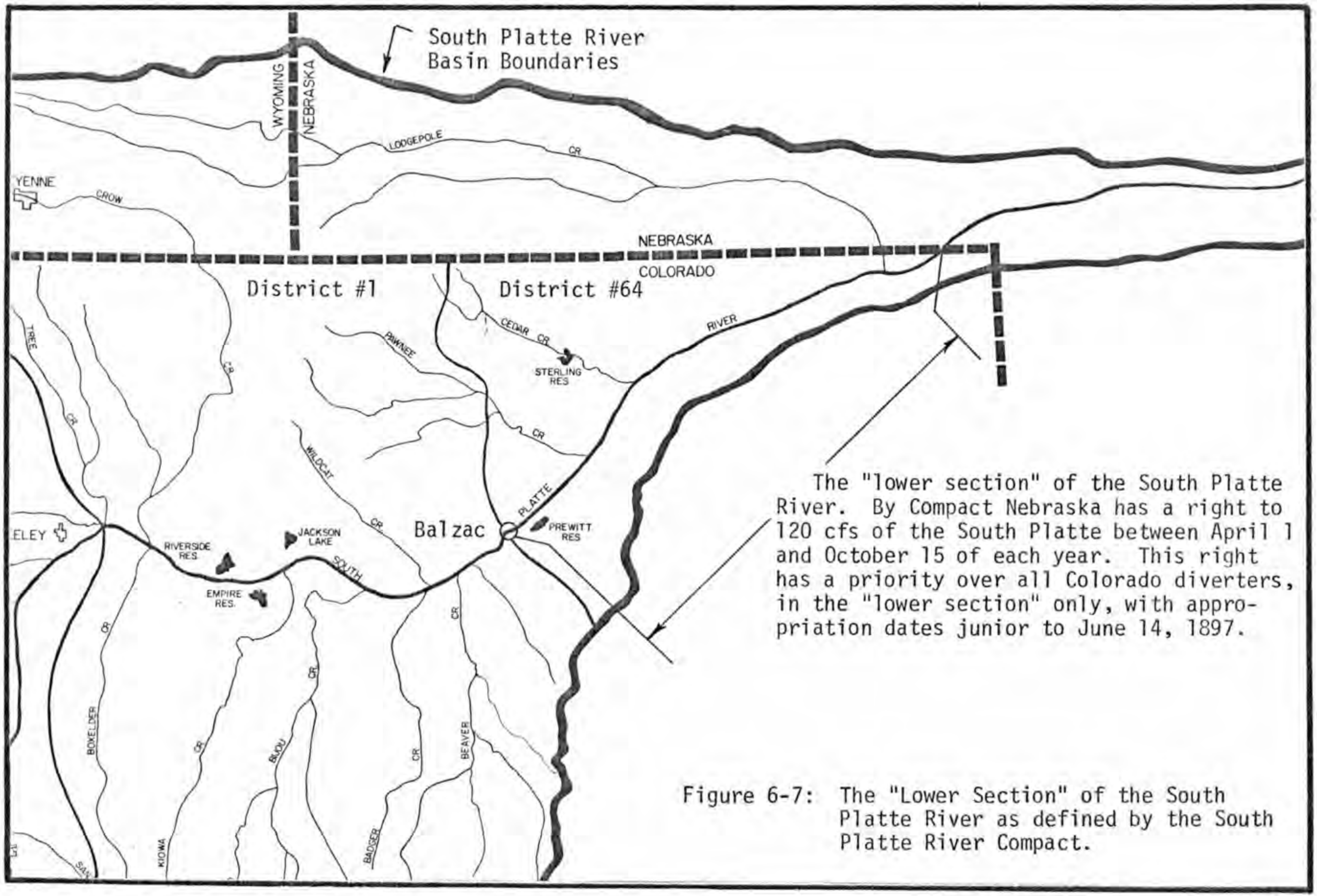


Figure 6-7: The "Lower Section" of the South Platte River as defined by the South Platte River Compact.

in excess of the compact amount. However, an occasion, between October 1 and April 15 of some years, 120 cfs of flow is not available at the state line even with the shut down of Colorado's "lower section" diverters junior to June 14, 1897. In 1970 the Colorado State Engineer reported that, "the flow did fall below 120 cfs this year for a period of about seven weeks, (i.e., August 1 to about September 15). The most junior ditch diverting during this period in the Compact Control Area was the Peterson Ditch, with an appropriation date of March 1, 1895."

6.5.3 *Existing Development of the Surface Water Supply* - Figure 6-8 and 6-9 show the major ditches and reservoirs of the South Platte River-Plains sub-basin. These diagrams provide greater detail than the overall schematic of Figure 6-6.

Direct Diversion Structures - There are no diversion structures importing water directly to this sub-basin from watersheds foreign to the South Platte River basin. Likewise, there are none exporting the water of this sub-basin to watersheds foreign to the South Platte River basin. However, the sub-basin does receive exogenous water, in the form of CBT allotments. These are delivered through the mainstem of the South Platte as well as through agricultural ditches and canals. The canals pick up this water from the South Platte at higher elevations and bring it to the outlying higher elevation valley lands within the sub-basin.

Of the several diversion structures which import water to this sub-basin, the most important are the Latham and Ogilvy Ditches, originating in the South Platte River-Transition and Cache La Poudre sub-basins, respectively. The diversions through these ditches for application in this sub-basin have been estimated to average 23,115 and

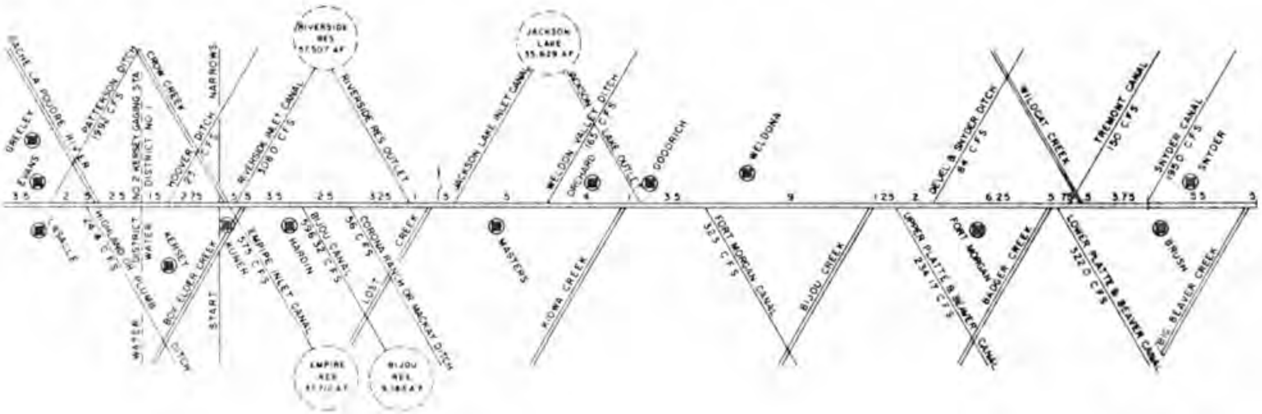


Figure 6-8: Ditch and Reservoir System, Middle Plains District, South Platte River, (Toups, 1975)

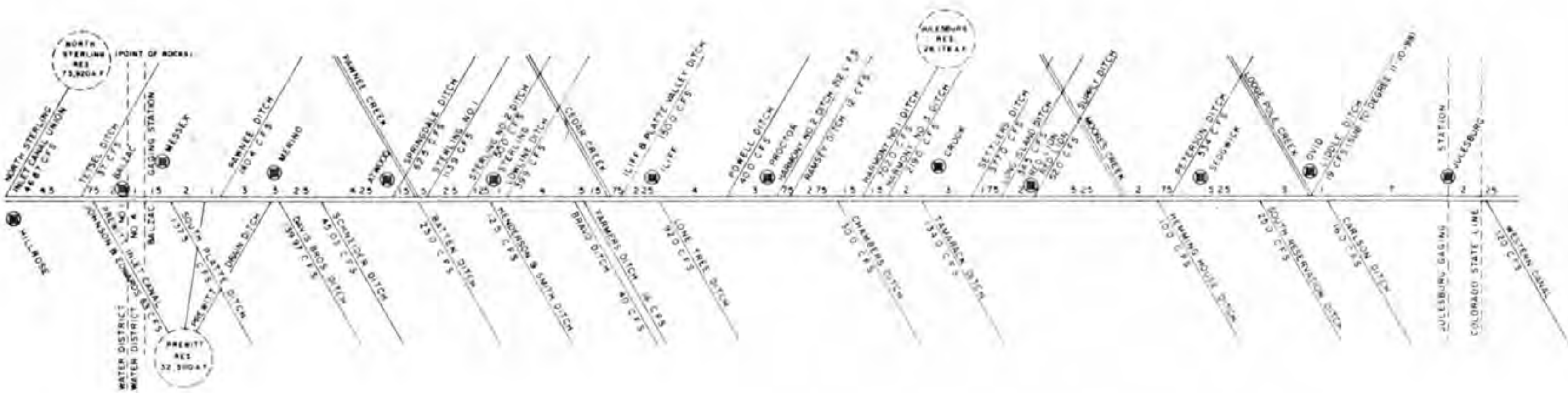


Figure 6-9: Ditch and Reservoir System, Lower Plains District, South Platte River, (Toups, 1975)

4,413 acre-feet per year (Janonis and Gerlek, 1977). These imports are assumed to include the CBT deliveries not brought into the sub-basin via the South Platte channel. There are no diversion structures exporting water from this sub-basin to other sub-basins of the South Platte River basin study area.

According to the Bureau of Reclamation (1959), their are 40 major canal systems serving irrigated agriculture within this sub-basin. The 1974 tabulation of Colorado water rights lists 170 absolute and conditional direct flow rights decreed to the reach of the main stem of the South Platte River within this sub-basin (Wilkinson, 1974). Table 6-8 lists 29 major diverters within this sub-basin along with their 1973 diversions. These diversions totaled 635,400 acre-feet during the 1973 year.

Storage Facilities - As there are no ditches or canals leaving this sub-basin, there are no reservoirs located outside of its boundaries that store exports. In addition, there are no reservoirs located inside of this sub-basin that store water imported to it from other watersheds.

The reservoirs located inside this sub-basin store its native surface water runoff and the tributary and mainstem South Platte inflows that arrive through their natural stream channels. All of these reservoirs are located off stream, with respect to the mainstem of the South Platte, their major source of water. This water is delivered by fairly long ditches diverting from the South Platte upstream at higher elevations. In some cases, after storage, this water is returned to the South Platte for transmittion.

Table 6-9 is a listing of the seven major reservoirs which provide the majority of storage for this sub-basin. This table shows their

Table 6-8 Major Surface Water Diversion Structures within the South Platte River-Plains Sub-basin and their 1973 Diversions (Toups, 1975).

Major Diverter	County	Stream Source (diversion point)	1973 Diversion (acre-feet)	Reservoir Storage
Prewitt Inlet	Morgan	South Platte River	45,600	Prewitt Res. 32,300 A.F.
No. Sterling Inlet Canal Union	Morgan	South Platte River	99,100	North Sterling Res. 73,920 A.F.
Snyder Canal	Morgan	South Platte River	N.A.	no
Tremont Canal	Morgan	South Platte River	N.A.	no
Lower Platte and Beaver Canal	Morgan	South Platte River	21,800	no
Duel and Snyder Ditch	Morgan	South Platte River	N.A.	no
Upper Platte and Beaver Canal	Morgan	South Platte River	27,800	no
Fort Morgan Canal	Morgan	South Platte River	32,100	no
Weldona Valley Ditch	Morgan	South Platte River	27,300	no
Jackson Lake Inlet	Weld	South Platte River	18,800	Jackson Lake 35,629 A.F.
Bijou Canal	Weld	South Platte River	24,800	Bijou Res. 9,183 A.F.
Bijou #2 Inlet	Weld	South Platte River	11,700	(same as above)
Riverside Direct	Weld	South Platte River	20,900	Riverside Res. 57,507 A.F.
Riverside Inlet	Weld	South Platte River	58,600	(same as above)

Table 6-8 Continued

Major Diverter	County	Stream Source (diversion point)	1973 Diversion (acre-feet)	Reservoir Storage
Empire Inlet	Weld	South Platte River	48,900	Empire Res. 37,710 A.F.
Empire Direct	Weld	South Platte River	21,300	(same as above)
Bravo Ditch	Logan	South Platte River	N.A.	no
Farmers Pawnee Creek	Logan	South Platte River	20,500	no
Harmony Seep #2	Logan	South Platte River	N.A.	no
Harmony #1 Ditch (Julesburg Reservoir Inlet)	Logan	South Platte River	21,000	Julesburg Res. 28,178 A.F.
Iliff and Platte Valley Ditch	Logan	South Platte River	13,500	no
Lowline Ditch	Logan	South Platte River	5,100	no
North Sterling Inlet Canal	Morgan	South Platte River	76,000	North Sterling Res. 73,920 A.F.
Peterson Ditch	Sedgewick	South Platte River	7,300	no
Schneider Ditch	Logan	South Platte River	6,100	no
South Platte Ditch	Logan	South Platte River	8,100	no
South Reservation	Sedgwick	South Platte River	N.A.	no
Springdale	Logan	South Platte River	N.A.	no
Sterling #1 Ditch	Logan	South Platte River	19,100	no
Total	-	South Platte River	635,400	-

Table 6-9 Major Reservoirs in the South Platte River-Plains Sub-basin; Their Capacities, Surface Areas, and Amounts in Storage During the 1970 Water Year.

Name	Capacity (acre-feet)	Surface Area (acres)	Amounts in Storage5/ (acre-feet)		
			11-1-69	5-1-70	10-31-70
Empire	37,710 1/	2,842 3/	15,811	33,853	10,010
Riverside	57,507 1/	3,840 2/	25,616	60,477	18,233
Jackson Lake	35,692 1/	2,200 3/	22,143	34,437	20,943
Julesburg R.	28,178 1/	700 3/	19,517	23,552	19,794
North Sterling	73,920 1/	2,870 3/	22,920	70,320	21,290
Prewitt	32,300 1/	1,280 3/	29,300	26,990	26,990
Bijou #2	9,000 4/	700 3/	0	4,300	4,300
TOTAL	274,307	14,432	135,307	253,929	121,560

1/Toups, 1975

2/Bjorklund et al., 1957

3/U.S. Soil Conservation Service, 1973

4/Dille, 1960

5/Division I Water Commissioners, 1970

individual capacity, surface area, and amounts in storage during the 1970 water year. Most of these reservoirs were built in the early 1900's. According to the 1974 Revised Tabulations of Colorado Water Rights, there are 26 absolute and conditional storage appropriations decreed for the reach of the mainstem of the South Platte River within this sub-basin (Wilkinson, 1974).

The following is a summarization by Toups (1975) of the work performed by Bjorklund in 1957, on the characteristics of some of these reservoirs. Studies conducted indicate that the Jackson Lake inlet canal lost about one cfs per mile while flowing at 145 cfs. The Empire intake canal lost one cfs per mile at a flow rate of about 250 cfs. Reduction in water impounded by reservoirs has also been investigated. Empire Reservoir which covers 2,842 acres when full, was found to require 90 cfs of water to maintain a constantly full reservoir. The observation took place at the beginning of the irrigation season when no supplies were being withdrawn. Water surface elevation subsided at a rate of 0.05 feet per day if the intake supply was stopped. A rate of decline twice normal was observed if the reservoir previously had been standing dry and mud cracks had formed. Of the 0.05 feet per day decline rate, 0.02 was attributed to evaporation and the 0.03 balance was designated to seepage. The Bijou Reservoir was observed to experience an even greater rate of loss than the Empire Reservoir. This relates to the fact that typical operation of Bijou Reservoir involved intermittent filling and emptying which provided time for bottom drying to occur. Riverside Reservoir encompasses an area of about 3,800 acres, corresponding to a water volume in storage of 57,507 acre-feet. In order to maintain constant gage height within the reservoir during the month of March, 1948, 4,120 acre-feet or water were introduced. The loss of water was totally attributed to seepage because evaporation was negated by an ice covering on the reservoir. The seepage loss was equivalent to a decline rate of 67 cfs of 0.035 feet per day. When evaporative losses are incurred in summer, 5,000 acre-feet of inflow was needed to maintain reservoir levels. This amounted to a loss of 84 cfs due to the combined effects of seepage and evaporation, or a loss of 17 cfs from evaporation alone. Expressed in terms of total loss, seepage accounted for 80 percent and evaporation accounted for 20 percent.

While the surface area of these reservoirs will fluctuate over any given year, the total surface area shown on Table 6-9 (14,432 acres) was used to estimate the average annual evaporation. The mean annual evaporation minus the mean annual precipitation for this area of the South Platte River basin is about 40 inches (Meyers, 1942). Therefore, the average annual evaporation was assumed to be 48,058 acre-feet. This was also assumed to be the case for the 1970 water year.

According to Hurr, et al. (1975), 28.7 percent of all diversions from the plains reach of the South Platte to storage are lost be seepage into the ground from the reservoirs and from the delivery ditches. It was assumed that on the average, because of their early winter rights, these reservoirs can be filled completely each year. It was further assumed that this would occur generally by the end of June. Therefore, 28.7 percent of total inflow to these reservoirs during the 1970 water year, (i.e., Table 6-9, total capacity minus amount in storage at the beginning of the water year on 11-1-69), 39,893 acre-feet is assumed to be seepage losses. Figure 6-10 is an assumed storage history for these reservoirs in aggregate, showing their operation during the 1970 water

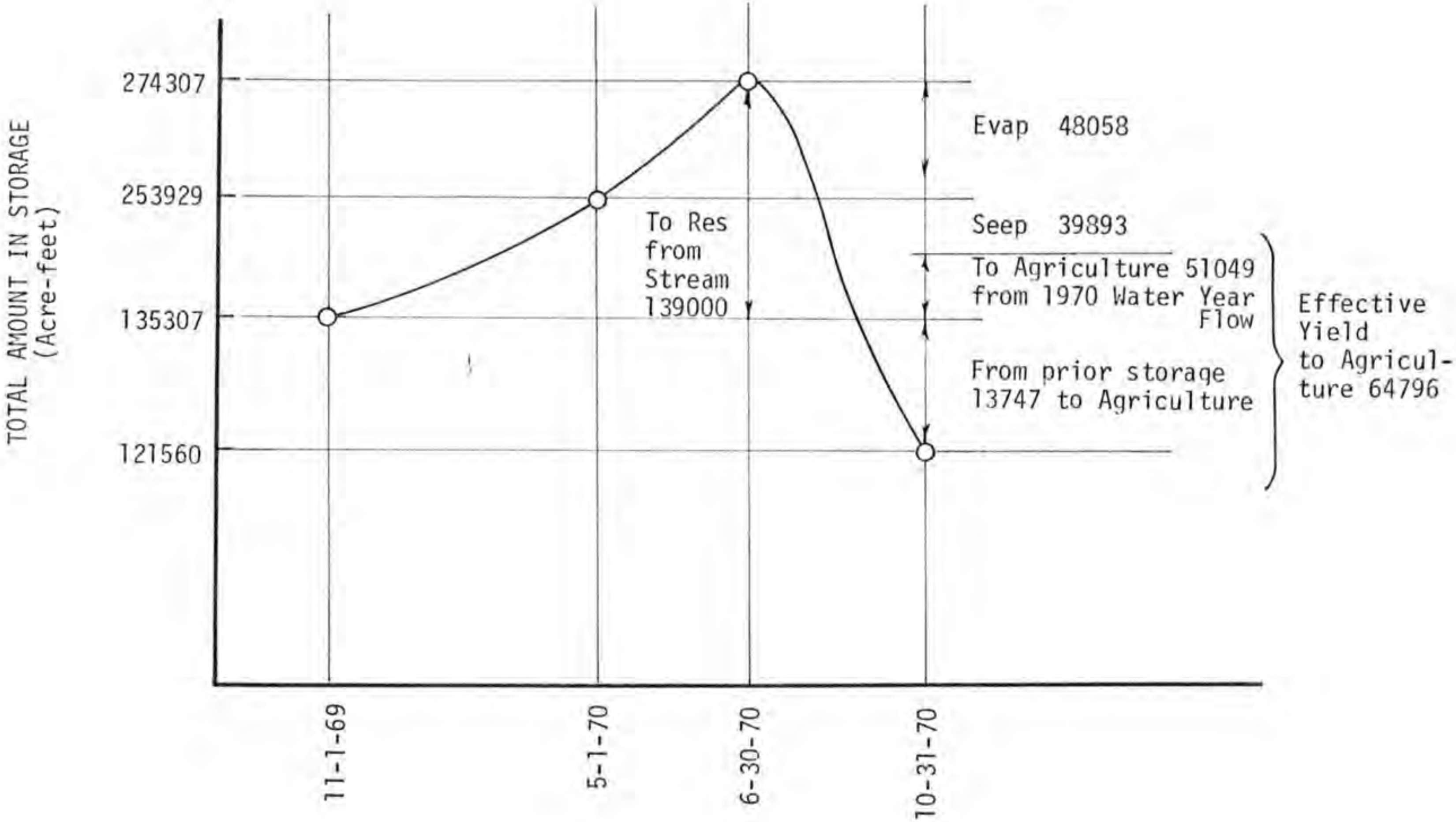


Figure 6-10: Aggregate Reservoir Storage History for Six Major Reservoirs in the South Platte River-Plains Subbasin (Constructed from data in Table 6-9)

year. The figure shows the approximate accounting for evaporation, seepage, diversions, etc. The accounting ignores inflows to the reservoirs after June 30, 1970 (which are believed to be minor).

6.5.4 *Proposed Development*

The Narrows Project - As far back as 1905, Coloradoans talked about daming up the South Platte River at the Narrows, and flooding the Weldona Valley, to store irrigation water (Neyberg, 1976). Following early investigations by private interests, the Corps of Engineers, and the Bureau of Reclamation, the Narrows Dam and Reservoir was eventually authorized as a unit of the comprehensive Missouri River Basin Project by the Flood Control Acts of 1946 and 1950. Preconstruction activities were initiated in 1947 and a "definite plan report" was prepared by the Bureau of Reclamation in 1951.

Meetings were held in 1951 with local interest groups to assess public opinion. In general, the public hearings disclosed that groups or interests residing upstream from the dam site were opposed to the project while groups or interests below were in favor. As a result of the lack of official support for project by the State of Colorado all preliminary construction and further planning activities, except for land classification, were terminated in 1952 (USBR, 1959).

On April 18, 1958 a resurgence of public interest in the Narrows Project was evidenced. A group of about 35 residents from the South Platte Valley, representing areas extending generally from below Denver to the state line, appeared before the Colorado Water Conservation Board at regular meeting in Denver and requested the board to reinitiate studies leading toward the construction of channel storage on the South Platte River.

During the next five years many discussions and meeting of interest groups were held. A steering committee was organized, and the Colorado Water Conservation Board advanced funds to the Bureau of Reclamation for the resumption of studies. The Bureau was requested specifically to make a hydrological study and cost comparison between the Narrows site and a site about 23 miles upstream in Weld County. At a meeting of the Colorado Water Conservation Board in Fort Morgan on September 11 and 12, 1964, the recommended Narrows site was officially approved by the Board as the desired site. The Board requested that further studies of the Narrows Dam and Reservoir be expedited. However, Public Law 88-442, approved August 14, 1964, deauthorized all units of the Missouri River Basin Project on which construction had not been initiated.

In 1970, Congressional approval and funding for the Narrows Project were provided for a second time and public hearings were held again. A final Environmental Impact Statement was submitted by the USBR on May 14, 1976. Land aquisition began in the fall of 1976 and construction was scheduled to begin in the summer of 1977. However, in the Spring of 1977, President Carter included the Narrows Project in what has come to be known by some as his "hit list." This mandate from the Executive Branch of the federal government required further investigation concerning the economic, social, and environmental aspects of dozens of planned and partially completed water resources projects nationwide. As of this writing, the fate of the proposed Narrows Project, after more than half a century of planning and controversy, is still unknown.

The Weldona Valley, the site of the proposed Narrows Reservoir, is shaped like a question mark and follows the South Platte for nearly 20 miles up stream from the Narrows, a natural dam site. It is located in Morgan County. It is a little more than three miles wide at its broadest, and is perhaps one half mile wide at its narrowest. It is also home for about 825 people living in the towns of Weldona, Goodrich, and Orchard, and outlying farms which would be inundated by the proposed reservoir, (USBR, 1976).

As presently envisioned, the Narrows Project facilities would be located on the South Platte River about seven miles northwest of Fort Morgan, Colorado. They would be located between the confluences of Bijou and Badger Creeks, outside of the "Compact Control Area." Figure 6-11 shows the location of the project and the configuration of its reservoir.

The project would supply supplemental irrigation water, and provide flat water for recreational and fish and wildlife development. The reservoir would have a flood control purpose also.

The Narrows Dam would have a maximum height of 147 feet and a crest length of 4.2 miles. It would cause the inundation of 33,995 acres of land of which approximately 40 percent is presently under irrigation (USBR, 1976). The proposed Narrows Reservoir would be Colorado's largest standing body of water.

The existing Jackson Reservoir, located about nine miles to the northwest of the proposed Narrows Dam, and just outside of the reservoir's high water line, would also be acquired. Jackson Reservoir is presently used for irrigation purposes. However, it would be converted and rehabilitated to serve in a dual recreation/fish-wildlife purpose.

The maximum storage capacity of the Narrows Reservoir would be 1,609,000 acre-feet, and its maximum surface area would be 40,813 acres.

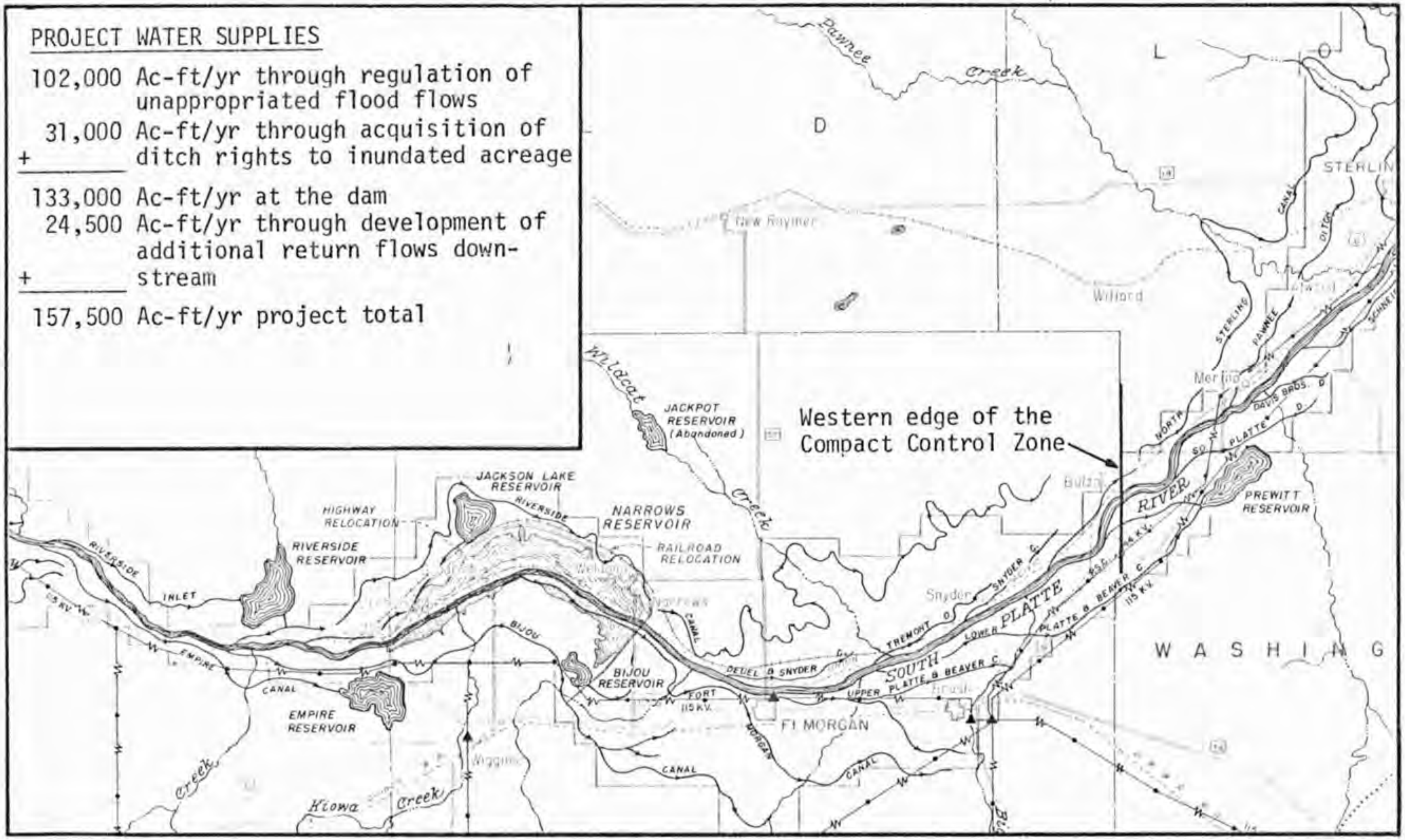


Figure 6-11: The Proposed Narrows Reservoir Project (USBR, 1959)

When full it would have a shore line of 40 miles. At the high elevations of the joint use pool, and inactive or minimum pool, the reservoir lengths would be 12.5 and six miles respectively. Table 6-10 is a breakdown of the area/capacity data of the Narrows Reservoir, showing the allotments to the various functions it would serve. It is estimated that the Narrows Project would take seven years to construct.

The following discussion of the water supply that would be developed by the proposed Narrows Project is from the Final Environmental Impact Statement (USBR, 1976).

A reservoir operation study was made utilizing streamflow runoff, precipitation, and estimated crop consumptive use data for the historical period 1947-1974. This study was undertaken to determine the optimum size of conservation storage capacity and the average annual water supply yield. The operation studies indicated that an average annual project yield of 102,000 acre-feet of water could be obtained from reservoir regulating of surplus streamflows. Additional water would be realized by acquiring the direct-flow water right currently held by the Weldon Valley Ditch Company. Lands currently served from this ditch along with the ditch and related diversion works will be inundated by Narrows Reservoir. These direct-flow rights have a priority date of October 26, 1881. The historic diversion (1947-1974) under this right averaged 31,000 acre-feet annually.

The total project water supply estimated to be available from the project, based upon the 1947-1974 period, is 133,000 acre-feet at the Narrows Dam. This includes 31,000 acre-feet of the acquired Weldon Valley Ditch water that would require minimal regulation to satisfy project delivery requirements.

Table 6-10 Narrows Reservoir Area-Capacity Data (USBR, 1976).

Item	Elevation (feet)	Area (acres)	Capacity - Acre-feet: Initial Increment	Initial Total	50 Year* Increment	50 Year* Total	100 Year* Increment	100 Year* Total
Top of Dam	4454.0							
Maximum W.S.	4448.5	40,813		1,609,000		1,579,000		1,549,000
Surcharge	4428.5	25,245	636,000	973,000	636,000	943,000	636,000	913,000
Flood Control	4404.3	14,963	475,000	498,000	475,000	468,000	475,000	438,000
Joint Use	4399.0	13,189	75,000	423,000	75,000	393,000	75,000	363,000
Conservation	4351.0	3,631	373,000	50,000	355,000	38,000	336,000	27,000
Inactive	4319.0		50,000		38,000		27,000	
Dead Storage Streambed	4307.0	-0-		-0-		-0-		-0-

*For space allocation purposes, all sediment is assumed to accumulate below the top of conservation pool. Sediment accumulation is estimated to be 60,000 acre-feet after 100 years of operation.

Since the South Platte River acts as a natural drain for the basin, the return flows from irrigation continuously accrue to the stream. It was estimated that project deliveries will result in an average of 24,500 acre-feet per year of additional divertable return flow downstream of Narrows Reservoir.

Usually, filling of the reservoir would begin in November of each year and continue into the spring, at which time releases for irrigation would cause a drawdown of the reservoir that would generally continue through the summer session to late fall, completing the cycle. As indicated by the operation study, the reservoir water level would have an average annual fluctuation of about six feet with a maximum within any one year of approximately 44 feet. During extended drought periods, the reservoir can be expected to be drawn down to top of inactive or dead storage.

All of this developed water initially would be used for irrigation. After a time, and as needs develop, some could be reallocated toward municipal and industrial demands.

By law, Narrows irrigation water will be limited to supplemental use on lands already being irrigated (Neyberg, 1976). None of the developed water could be used on fields presently raising dry land crops.

The total water supply from the project would be 157,500 acre-feet. This includes return flows downstream and water taken over by the project from lands inundated. The water would be used as supplemental irrigation water on 287,070 acres (USBR, 1976). This is equivalent to a gross application rate of 0.55 acre-feet per acre. A portion of this land, 166,370 acres, is located in the Lower South Platte River Water

Conservancy District, which lies immediately downstream from the proposed dam. Water requirements were computed for 23 of the 33 ditches in this district. The 23 ditches supply 154,200 acres of 92.7 percent of the irrigable land in the district. It was found that 19,600 acres of this land are presently irrigated intermittently; they are irrigated only in above average years when excess water is available from the South Platte. Historic form headgate water shortages for this land have averaged 2.13 acre-feet per acre (House Document No. 320, 1968). Historic farm headgate shortages on the 134,600 remaining acres of the study area were found to be 0.52 acre-feet per acre (House Document No. 320, 1968). This gives a total historic shortage of 111,740 acre-feet annually for 92.7 percent of the Lower South Platte River Water Conservancy District. Water service contracts with this water conservancy district were signed in July of 1976. It was allocated 116,375 acre-feet annually of the water that would be developed, by the Narrows Project.

The remainder of the land that would be benefited by the Narrows Project, 120,700 acres, is located within the Central Colorado Water Conservancy District. A water service contract with this water conservancy district, which allotted them 16,625 acre-feet per year, was also signed in July of 1976. Since this district is located above the proposed Narrows Dam, it is assumed that this water would be available by exchange.

The total amount of water contracted to be delivered to these water conservancy districts is 133,000 acre-feet per year. This amount includes the 31,000 acre-feet of water presently used by the Weldon Valley Ditch Company on lands which would be inundated by the project. The 24,500 acre-feet per year of return flows that would occur if the project is built will be reused fortuitiously. This water would be allocated according to the principals of the appropriation doctrine as set out in Colorado's water law statutes.

Because a mass balance is required when constructing an input output model, it was necessary to estimate evaporation and seepage losses from the proposed Narrows project. The assumptions involved are presented below and resulting values, 51,245 acre-feet/year evaporation and 133,000 acre-feet/year seepage, were used on the input-output matrix. The estimate on the evaporation from the Narrows Project was based on the surface area of the top of the joint use pool of 13,189 acres, plus the surface area of Jackson Lake, which is 2,200 acres. The mean annual evaporation minus the mean annual precipitation in and around the Narrows area is about 40 inches per year (Meyers, 1942). Therefore, the average annual evaporation for the Narrows Project was assumed to be 51,245 acre-feet per year.

It has been estimated that seepage losses for Empire, Bijou, and Riverside reservoirs are equivalent to a water level decline rate of about 0.03 feet per day (Bjorklund, et al. 1957). While this rate will vary with the head (elevation) of these reservoirs, it was assumed to be a constant. Moreover, the geological characteristics underlying these plains reservoirs are assumed to be similar to those of the proposed Narrows Reservoir. Therefore, a 0.03 foot decline per day for one year is equal to a total decline of 10.95 feet. This is equivalent to a volume of about 133,000 acre-feet, if one were to start at the top of the joint use pool of the Narrows Reservoir.

Subsequent to the construction of the matrixes whose scenarios dictated that the Narrows be on line, USBR estimates of evaporation and seepage losses were brought to the authors attention. These estimates were not as crude as those presented above and undoubtedly more accurately portray what is likely to happen. The USBR (1976) estimates that the average annual evaporation from the Narrows Reservoir would be 24,800 acre-feet per year. This was based on an operational study where the changing surface area was computed using the 1947-1974 historic South Platte River flows and expected reservoir releases.

The USBR (1976) estimates that seepage losses from the Narrows Reservoir would average 44,700 acre-feet per year. This was based on an electric analogy tray study using various permeability coefficients and the reservoir elevations that were found through the 1947-1974 operational study.

The water right filed for the Narrows project is presently a conditional storage decree for 718,147 acre-feet of water from the South Platte River. Its appropriation date is August 2, 1957 and the adjudication date is July 15, 1970; it has a previous adjudication date of January 13, 1936 (Wilkinson, 1974).

Because of the Narrows project location, its water rights and operation would not be subject to the stipulations of the South Platte River Compact. Table 6-11 shows the estimated effects the Narrows Project would have on the flow of the South Platte River at the state line.

6.5.5 *Potentially Developable Surface Water Supply Remaining* - The amount of water flowing into and through this sub-basin, in the form of return flows, has increased in the past and will do so in the future as additional water is brought in from the west slope and used upstream.

Table 6-11 Pre- and Post-Narrows Project Effect on the Flows in the South Platte River at Julesburg (U.S. Bureau of Reclamation, 1976).

	Average (1947-1974)					Wet Year (1973)					Dry Year (1954)					
	Preproject		Post project			Preproject		Post Project			Preproject		Post Project			
Month	Ac-ft	Cfs	Ac-ft	Cfs	Δ%	Ac-ft	Cfs	Ac-ft	Cfs	Δ%	Ac-ft	Cfs	Ac-ft	Cfs	Δ%	
Jan.	29,200	475	23,700	386	-19	41,000	667	12,200	198	-70	17,900	291	19,600	319	+10	
Feb.	32,000	556	28,900	502	-10	53,200	924	20,700	360	-61	14,300	248	15,700	273	+10	
March	33,100	538	28,100	457	-15	54,500	886	19,300	314	-65	15,300	249	15,800	257	+ 3	April 1
April	29,600	497	19,500	327	-34	94,700	1,590	26,600	447	-72	6,700	112	8,800	148	+32	↑
May	60,400	982	42,900	697	-29	528,100	8,586	518,300	8,427	- 2	4,200	68	6,700	109	+60	
June	83,500	1,358	50,700	825	-39	217,800	3,542	219,400	3,568	+ 1	1,700	28	6,900	112	+300	Compact
July	20,200	329	12,900	210	-36	20,900	340	3,500	57	-83	1,000	16	6,600	107	+569	Time
Aug.	8,700	141	8,600	139	- 1	7,400	120	3,900	63	-48	1,000	16	5,200	84	+425	Period
Sept.	9,300	156	7,000	117	-25	48,300	810	4,000	67	-92	1,400	23	4,800	81	+252	
Oct.	18,100	294	13,400	218	-26	86,100	1,398	46,100	749	-46	2,300	37	4,300	70	+89	↓ Oct. 15
Nov.	21,900	368	19,100	321	-13	47,600	968	69,300	1,164	+20	3,500	59	4,900	82	+39	
Dec.	24,200	394	21,100	342	-13	40,100	653	49,300	803	+23	6,200	101	7,600	124	+23	
Annual	370,200	-	275,800	-	-25	1,249,600	-	992,600	-	-21	75,500	-	106,900	-	+ 42	
Compact Time 1/ Period Total	220,750	-	148,300	-	-33	960,250	-	798,750	-	-17	17,150	-	41,150	-	+140	

1/ As stipulated by the 1926 South Platte River Compact, Nebraska has a right to 120 cfs of the South Platte River between April 1 and October 15 of each year; this amounts to 47,166 acre-feet per year. This right has a priority over all Colorado diverters with adjudication dates Junior to June 14, 1897 in the "Lower Section" only (that reach of the South Platte River in Colorado between the Washington County line and the State line (Water District #64)).

When the amount of outflow stipulated by the South Platte River Compact is compared to the historical average annual outflow, the difference yields a significant amount of additional water that Colorado is entitled by law to use each year; this amounts to 304,586 acre-feet. As a specific example, if some of the 337,700 acre-feet of water that left the sub-basin in 1952 could have been held back, it would have helped alleviate the water shortages and resulting economic damages of the 1953-1956 drought years.

This water flows out of Colorado because it generally occurs in the spring; its flow is out of phase with demands, which are usually greatest in the late summer. In other words, it leaves unused because of a lack of sufficient storage within this sub-basin. While there is still room for some additional storage further up in the basin, only a reservoir in the plains reach can take advantage of the return flows continuously accruing here. This is the purpose of the proposed Narrows project. The Bureau of Reclamation (1976) estimates the average annual depletion in outflows at the state line would be 94,400 acre-feet if the Narrows Project is built (Table 6-11).

However, there could be some 210,186 acre-feet per year of outflow still left for Colorado under the conditions of the South Platte River Compact. It is the opinion of the Colorado Water Conservation Boards that if the Narrows Reservoir is constructed, most of the economically usuable water allocated to Colorado will be depleted (Morrill, 1976). While this may be the case now, at some time in the future, water demands may grow to the point where it becomes necessary to capture more of this outflow. If this occurs, the location of an additional reservoir, in addition to the proposed Narrows Project will be critical. The further downstream such a reservoir is located, the more return flows it can store and regulate. This must be weighed against the fact that, barring an energy intensive pumping upstream scheme, the further towards the state line a reservoir is located, the less downstream acreage in Colorado can benefit. In this case too, there would be less downstream diverters to provide exchanges for upstream appropriators.

In addition, if located in the "Compact Control Area," besides senior Colorado appropriators downstream, by virtue of its water rights a new reservoir will always be forced to give way to Nebraska between April 1 and October 15. If located above the "lower section" of the South Platte River, it may operate like the Narrows will with senior Colorado diverters downstream as its only concern.

An additional constraint regulating the basins outflow in the future over and above the compact might be the salinity question. The basin must maintain its salt balance which requires certain minimum flows to flush out excessive buildups.

PART III

FOREIGH WATER SUPPLIES

OF THE SOUTH PLATTE BASIN

The legal term defining that water of a given drainage basin which has its origin outside the basin is "foreigh water." Foreign water in the South Platte basin goes back to 1890 with the the construction of the Grand River Ditch. Presently its use is very extensive and its availability is the margin of difference in the South Platte basin between having both thriving cities and an economically viable agriculture and a situation of water stress.

The purpose of this part is to delineate the past history and present use of foreign water, but to make an assessment of its future availability as well. These questions are examined in terms of surface water hydrology, present uses, and water rights for each of the three major river basin sharing coming boundaries with the South Platte, i.e., the North Platte, the Colorado, and the Arkansas. There is a brief exploration also in terms of the potential for water imports from other river basin.

All assessments are based upon extensive use of factual data. The chapter formats are set up to facilitate retrieval of this information for reference purposes.

CHAPTER 7

THE NORTH PLATTE RIVER BASIN

The North Platte River drains a large portion of the southeast quadrant in Wyoming. However, the stream derives a substantial amount of water from two drainage sub-basins in northern Colorado. As shown in Figure 7-1, these are designated: the North Platte River-Mountains Sub-basin, and the Laramie River Sub-basin. These sub-basins have been important sources of water for the South Platte River basin since about the turn of the century. Their relationships with the South Platte is discussed in the following sections.

7.1 The North Platte River - Mountains Sub-basin

7.1.1 *Physical Characteristics and Hydrology* - This sub-basin includes the upper most reach of the North Platte River, from its head waters on the eastern edge of the Continental Divide to the USGS gaging station #06620000, "North Platte River near Northgate, Colorado." This gaging station is located 4.4 miles south of the Wyoming-Colorado state line; the North Platte River above its drains an area of 1,431 square miles.

The North Platte River originates on the eastern edge of the Continental Divide at elevations attaining 13,000 feet. This sub-basin shares boundaries with the Colorado River Basin to the south and west and with the Laramie River Sub-basin to the east. From its headwaters, the North Platte River flows due North to Wyoming where it then veers east and south to meet the South Platte River in Nebraska. On its course through approximately 50 miles of Colorado within the sub-basin, the river loses more than 5,000 feet in altitude. Its principal tributaries

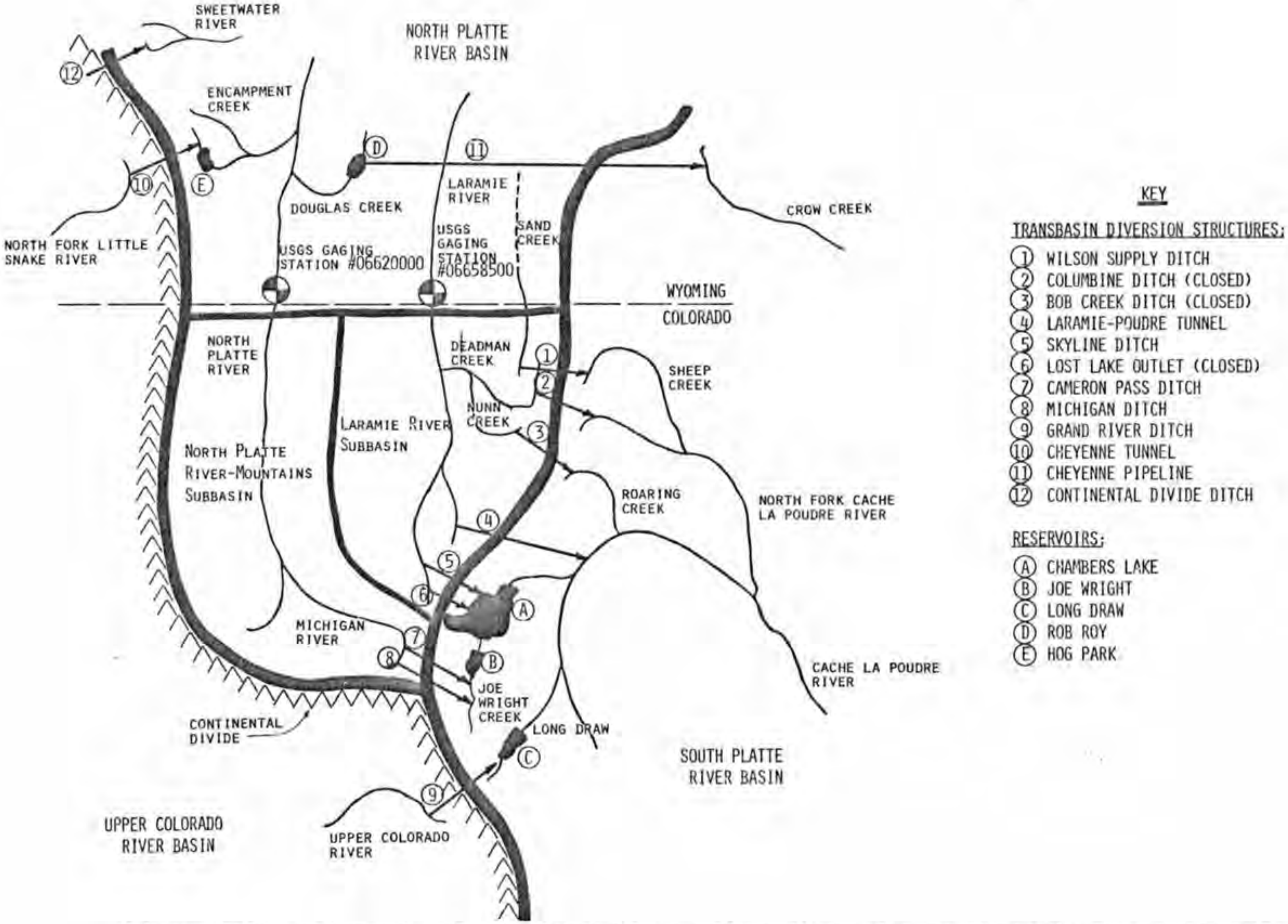


Figure 7-1: Schematic of the North Platte River-Mountains and Laramie River Subbasins, Transbasin Diversions are indicated also.

in this sub-basin are the Canadian and Michigan Rivers and Illinois Creek.

The upper valley of the North Platte River basin, a broad flat expance known as North Park is a prominent land feature. It is here, through the irrigation of approximately 130,000 acres of hay meadows, (USGS, 1975) that the most intensive use of its surface water supply is made. No water is imported to this sub-basin. However, water is exported from it through two diversion structures: the Cameron Pass Ditch and the Michigan Ditch. Both divert water to the South Platte River basin and are discussed subsequently. Also there are several reservoirs in this sub-basin; most of these are located in North Park in shallow offstream depressions.

The precipitation in the headwaters area of this river averages about 40 inches per year. However, this drops to 12 inches per year toward the lower elevations in the vicinity of North Park (National Oceanic and Atmospheric Administration, U.S. Department of Commerce, 1974). The precipitation in this sub-basin occurs mostly during the winter as snow from storms originating in the Pacific Northwest. The sub-basin lies in the "rain shadow" to the east of the Continental Divide; thus the winter storms generally produce less snow here than to the west, due to the orographic effect of the high mountains. The surface water supply of the sub-basin is derived principally from the resulting winter snow pack as it melts in the spring. Infrequently, severe floods are caused by spring rains combined with high rates of snow melt. During the summer rainfall amounts are usually insufficient to produce significant runoff (McCain, Jarrett, 1976).

The native surface water runoff of this sub-basin can be estimated from the flows recorded at the USGS gaging station at its mouth, #06620000, "North Park near Northgate, Colorado," (Appendix C, Table C1-1). The average annual runoff is estimated to be 478,326 acre-feet, as seen in Appendix A, Table A1-1.

The 1970 native surface runoff, as seen in Appendix A, Table A1-2, is estimated to have been 555,000 acre-feet (or 116.03% of average).

The native surface runoff available to this sub-basin during a 4-year drought period (1953-1965) is estimated, from Appendix A, Table A1-3, to average 282,844 acre-feet per year or 58.04% of average.

7.1.2 *Legal Constraints* - The North Platte River Decree is the legal document which allocates the waters of the North Platte River (excluding its tributary the Laramie River), between Colorado and Wyoming. In providing for this allocation the decree also delineates the amount of water which Colorado may export. However, it does not address exports within Wyoming.

In some cases this decree specifies acreages within the North Platte River basin where portions of Wyomings allotment of this water are to be used. In others, it does not. It is assumed that the decree relinquishes jurisdication over this water to Wyoming and its water laws. In this case, if the water is unappropriated, under Wyoming water law it may generally be exported to another river basin provided no harm is done to downstream appropriators. If the water is appropriated, then to be exported it must be acquired and an appeal to the Wyoming State Engineer has to be made to change the place of use. However, only the average annual consumptive use may be exported as downstream users have a vested right to the historical return flows.

The North Platte River Decree - This decree has its beginnings in the early 1930's with negotiations between Wyoming and Colorado concerning the use of waters from the North Platte River Basin. These ended abruptly on December 4, 1933 with Colorado insisting to divert more out of this basin than Wyoming was willing to conceed. Nebraska, who had previously avoided involvement fearing such negotiations might adversely affect her use of the river, filed a bill of complaint with the United States Supreme Court against Wyoming on October 15, 1934. This bill asked that Wyoming users on the North Platte River, that were junior to Nebraska users, be denied water if senior Nebraska appropriators place a call on the river. It sought to "fix and determine the respective priorities on the stream of Nebraska and Wyoming appropriators." Upon direction of the court, Colorado filed a cross bill on May 4, 1936 taking issue with the claims of both Nebraska and Wyoming, and thus becoming a party to the suit. With this action, Colorado sought to establish a claim to her equitable share of the North Platte River. Testimony on the issues began in the summer of 1936 with Nebraska presenting her case.

Almost 10 years later, on October 8, 1945, the United States Supreme Court entered a decree on the apportionment of the waters of the North Platte River basin (Nebraska vs. Wyoming 325 US 589).

With regards to Colorado, the North Platte River Decree specified that not more than 135,000 acres of land within Jackson County could be irrigated with these waters, (on June 15, 1953 an amendment to this decree changed this figure to 145,000 acres). The boundaries of Jackson County coincide almost exactly with those of the North Platte River-Mountains sub-basin. In addition, it severely enjoined Colorado from exporting more than 60,000 acre-feet of North Platte River Basin water out of Jackson County, to any other river drainage, in any period of ten consecutive years beginning with October 1, 1945.

With regards to Wyoming in some cases the decree was explicit as to irrigated acreage and limitations were placed on diversions for use and storage. It did not address exports from the North Platte River basin within Wyoming. As there were none at the time, this was not an issue.

The North Platte River Decree went on to state that it,

> shall not affect or restrict the use or diversion of water from the North Platte River and its tributaries in Colorado or Wyoming for ordinary and usual domestic, municipal, and stock watering purposes and consumption.

Thus it set up an order of preference for diversion of water from the North Platte River. A final point made by the court was that this decree was not to affect the prior apportionment between Colorado and Wyoming of the waters of the Laramie River, a tributary of the North Platte.

The North Platte River Decree, excerpted from Nebraska vs. Wyoming, 325 US 589 (1945) and the amendments as ordered on June 15, 1953 (345 US 981), are found in Appendix D, Exhibit D1-1.

7.1.3 *Transbasin Diversion Structures* - Two transbasin diversion structures export water from the North Platte River-Mountains sub-basin; the Cameron Pass and Michigan Ditches. Both divert water to the Cache La Poudre River sub-basin of the South Platte River Basin.

However, further downstream, in Wyoming, the Cheyenne Pipeline exports water to the Crow Creek sub-basin of the South Platte basin through an exchange program with Colorado River water. Details of the Cheyenne Importation Facilities are outlined in Section 8.8.2. Also downstream, the Continental Divide Ditch diverts water from the Colorado

River Drainage for use along Lander Creek, a tributary of Sweetwater River which drains into the North Platte. Figure 7-1 is a schematic map showing diversions from both the North Platte and Laramie River basins.

The Cameron Pass Ditch - This ditch diverts water from tributaries of the Michigan River and transports them through Cameron Pass at an elevation of 10,300 feet to Joe Wright Creek, a tributary of the Cache La Poudre River. The diverted water is regulated in the Joe Wright Reservoir and then further regulated in Chambers Lake for subsequent release. The water right for the ditch has a priority date of 1882 and was adjudicated in 1902, (United States Bureau of Reclamation, 1959).

All available records of the yearly diversions through this ditch are shown in Appendix B, Table B1-7. Diversions prior to the North Platte River Decree (1945) averaged 260 acre-feet per year, and 107 acre-feet per year thereafter. Much of this decrease can be attributed to the expense of maintenance. The Cameron Pass Ditch is owned by the Water Supply and Storage Company which uses the water imported for irrigation. There are presently no plans to increase diversions through this ditch through the aquisition of more water rights or through the improvement or expansion of its physical structure, (Johnson, 1976).

The Michigan Ditch - This ditch, formerly known as the Rist and McNab Ditch, also diverts water from tributaries of the Michigan River and transports them through Cameron Pass to Joe Wright Creek. In addition, storage is provided by the same facilities used by the Cameron Pass Ditch, i.e., Joe Wright Reservoir and Chambers Lake. The Michigan Ditch has a water right for 121.0 cfs, which was adjudicated in 1908 with a priority of July, 1902, (United States Bureau of Reclamation, 1959).

All available records of the yearly diversions through this ditch are shown in Appendix B, Table B1-8. Diversions prior to the North Platte River Decree (1945) averaged 3,389 acre-feet per year and 1,190 acre-feet per year thereafter. Again, much of this decrease can be attributed to the expense of maintenance.

The Michigan Ditch and its water right were brought from the North Poudre Canal Company by the City of Fort Collins in 1971. Although Fort Collins has had offers, it does not plan to purchase more water rights in the North Platte River Mountains sub-basin, (Liquin, October, 1976). It does, however, plan to upgrade the physical structure of this ditch and enlarge Joe Wright Reservoir to a 7,056 acre-feet capacity. These improvements are known collectively as the Joe Wright Project.

The water right for the Michigan Ditch is estimated to yield 4,000 to 5,000 acre-feet per year on the average from the North Platte River-Mountains sub-basin (Liquin, September, 1976). To help fill the enlarged Joe Wright Reservoir the city will impound also native Cache La Poudre River water from a 5.9 sqaure mile runoff area above the reservoir. Although this water is appropriated by other users, Fort Collins will "transfer water up to Joe Wright" through an exchange agreement, using replacement water from shares they own in ditches downstream.

Construction of this project is expected to take 2 years and Fort Collins is presently involved in the financial arrangements. Funds were originally sought for 1977 but the recent change in administration delayed their availability at this date. However, Fort Collins is petitioning the federal government to put a measure in the 1977 appropriation bill now before Congress which would pay for most of the project.

7.1.4 *Potential for Further Transbasin Diversions to the South Platte* - Historically, all exports from the North Platte River-Mountains sub-basin have gone to the South Platte basin in Colorado. The 1945 North Platte River Decree limits diversions from this sub-basin to other river drainages in Colorado to not more than 6,000 acre-feet per year. Prior to the decree exports averaged 3,649 acre-feet per year. Subsequent to it they have averaged only 1,297 acre-feet per year. Table 7-1 gives the annual amounts of water imported via each ditch and their combined totals since 1945. It is evident that the full entitlement under the decree is not being utilized. This can be attributable to several factors.

There are water right holders downstream in the North Platte River sub-basin which are senior to the rights for the two ditches. Thus diversions by the Cameron Pass and Michigan Ditches are generally allowed only during the high spring runoff, when plenty of water is available and calls on the river are few. This is also the time when South Platte River basin demands (principally agriculture) are at a minimum and when its streams are above their base flows. Under Colorado water law unless diversions can be put to beneficial use (i.e., directly to an application or to storage), they are not permitted. Thus, the priority of these ditches combined with a lack of sufficient storage has kept exports from the North Platte River-Mountains sub-basin from reaching the 6,000 acre-feet per year limit. However, the biggest problem has been the rising cost-of-upkeep of these ditches, which has caused them to fall into disrepair.

The planned upgrading the Michigan Ditch, and the creation of an adequate storage facility in the Cache La Poudre River sub-basin to

Table 7-1 Transbasin Diversions from the North Platte River-Mountains Sub-basin to the South Platte River Basin in Colorado since the Enactment of the North Platte River Decree in 1945.

Calendar Year	Cameron 1/ Pass Ditch	Michigan 2/ Ditch	Total 3/
1975	276	1,710	1,986
1974	296	1,790	2,086
1973	407	1,890	2,297
1972	111	1,770	1,881
1971	0	0	0
1970	0	0	0
1969	1	0	1
1968	103	1,40	1,543
1967	0	0	0
1966	0	0	0
1965	0	1,080	1,080
1964	0	484	484
1963	0	0	0
1962	0	0	0
1961	0	127	127
1960	156	1,470	1,626
1959	126	1,540	1,666
1958	0	0	0
1957	63	1,170	1,233
1956	264	1,860	2,124
1955	186	0	186
1954	133	0	133
1953	125	1,450	1,575
1952	116	2,080	2,196
1951	311	4,310	4,621
1950	131	2,070	2,201
1949	149	2,360	2,509
1948	0	1,910	1,910
1947	0	3,260	3,260
1946	262	1,940	2,202
1945*	0	0	0
31 year average	107	1,190	1,297

1/Appendix B, Table B1-7.
2/Appendix B, Table B1-8.
3/The 1945 North Platte River Decree limits exports from the sub-basin to other Colorado Basins to 60,000 acre-feet in any 10 consecutive years.
*Enactment date of the North Platte River Decree was October 1, 1945, the first day of the 1946 water year.

contain its diversions when they can be made, will allow the combined diversions to approach closer to the decreed amount. However, if rights with higher priorities were obtained for these ditches, the full 6,000 acre-feet could be diverted regardless of dry years.

Within the North Platte River basin in Wyoming there is no unappropriated water. The North Platte River Decree (1945) apportioned these flows between Wyoming and Nebraska. Wyoming is presently using all of her allotment within the North Platte River Drainage within her state; there is no remaining unappropriated water. Wyoming users in the South Platte River basin seeking water from the North Platte River must work within that state's water laws. Cheyenne exchanges water, for example, (i.e., it diverts from the North Platte and provides replacement water from the Colorado River Basin). Also purchase of existing North Platte River water rights and petitioning the State Engineer for a change in the place of use is another option. Once this water has been acquired construction of appropriate facilities would be necessary and then only diversions of the historical consumptive use of these rights could be made to the South Platte Basin.

Table 7-2 summarizes the present disposition of the average annual surface water supply arising in the North Platte River-Mountains sub-basin. A comparison is made also with the limits imposed by the North Platte River Decree. As noted, the decree would permit the export of some 4,000 acre-feet per year additional, subject to prior rights within Colorado, as noted previously.

Table 7-2 Disposition of the Average Annual Native Surface Water Runoff of the North Platte River-Mountains Sub-basin.

		Acre-feet Per Year	%
Average Annual Exports6/	Cameron Pass Ditch	107 1/	0.0
	Michigan Ditch	1,190 2/	0.2
Average Annual in Sub-basin Consumptive Uses		169,000 3/ 5/	34.7
Average Annual Outflow		317,029	65.1
Total Average Annual Native Surface Water Supply		487,326 4/	100.0

1/Appendix B, Table B1-7.
2/Appendix B, Table B1-8.
3/Appendix A, Table A1-1.
4/Appendix A, Table A1-1.
5/In basin use is limited, by the 1945 North Platte Decree as amended in 1953, to the irrigation of 145,000 acres of land within Colorado.
6/Exports of water from the North Platte River-Mountains sub-basin within Colorado, by the 1945 North Platte River Decree is not to exceed 60,000 acre-feet within any period of ten consecutive years.

7.2 The Laramie River Sub-basin

7.2.1 *Physical Characteristics and Hydrology* - This sub-basin includes the upper most reach of the Laramie River, a major tributary of the North Platte River. It encompasses 294 square miles from its headwaters on the North Platte-South Platte River basin divide to the USGS gaging station #06658500, "Laramie River near Jelm, Wyoming." This gaging station is located 0.2 miles north of the Colorado-Wyoming state line.

From elevations attaining 14,000 feet, the Laramie River flows due north to Wyoming before veering east to meet the North Platte River. On its course through approximately 35 miles of Colorado within the sub-basin, the river loses more than 6,000 feet in altitude. Its principal tributaries in the sub-basin are McIntyre, Nunn, LaGarde, and Sand Creeks.

The Most intensive use of water in this sub-basin is made through the irrigation of approximately 4,640 acres of hay meadows in its lower valleys, (USGS, 1975). There is no water imported to this sub-basin from other river drainages. This sub-basin has provided the surface flows for six diversion structures which export water from its drainage area. All divert water to the South Platte River basin and are discussed in the following section. There are very few reservoirs in this sub-basin.

The precipitation in the headwaters area averages about 40 inches per year dropping to about 20 inches per year in its lower elevation areas (National Oceanic and Atmospheric Administration, US Department of Commerce, 1974). The surface water supply of the sub-basin comes mostly from snowmelt, during the May through July period.

The unadjusted native surface water flows of this sub-basin are given on an annual basis in Table C1-2. These data are from records the USGS gagin station #06658500, "Laramie River near Jelm, Wyoming," located at the mouth of the Laramie River. The average native surface water runoff of the Laramie River sub-basin is estimated from these data to be 145,878 acre-feet per year; computations are given in Appendix A, Table A1-4. The 1970 native surface water supply of this sub-basin was determined, from Appendix A, Table A1-5, to have been 171,052 acre-feet (117.26% of average). The average native surface water runoff of the sub-basin during a 4 year drought period (1952-1956) was 93,756 acre-feet per year (64.27% of average), determined from Appendix A, Table A1-6.

7.2.2 *Legal Constraints* - The 1957 Laramie River Decree places a limit on the amount of water that may be exported out of the Laramie River Drainage within Colorado. It does not address exports within Wyoming. By virtue of the fact that Wyoming was apportioned all water remaining in this drainage after Colorado's allotment, it is assumed that the decree relinquishes jurisdiction over this water to Wyoming and its water laws. In this case, if the water is unappropriated, under Wyoming water law it may generally be exported to another river basin provided no harm is done to downstream appropriators. If the water is appropriated, then to be exported it must be acquired and an appeal to the Wyoming State Engineer has to be made to change the place of use. However, only the average annual consumptive use may be exported as downstream users have a vested right to historical return flows.

The Laramie River Decree - The history of this decree is perhaps most characteristic of the long involved dispute between Wyoming and

Colorado concerning the use of waters arising in the North Platte River basin.

In 1911, sparked by the construction of the Laramie-Poudre-trans-basin diversion tunnel in Colorado, Wyoming filed suit in the United States Supreme Court to prevent out-of-basin diversions of Laramie River water in Colorado. Wyoming held that the diversions through this tunnel would injure her prior appropriators of this river. Colorado, on the other hand, claimed the right to use all the waters within her borders because of the sovereignty of statehood. In its ruling of June 5, 1922 the Supreme Court held that Colorado could not claim all waters within her boundaries, but only an equitable share, (Wyoming vs. Colorado, 259 US 419, 496). The court also changed the 1902 priority date given to the Laramie-Poudre tunnel by the Colorado State Supreme Court to a 1909 priority date, and it set an upper limit on its annual diversions. The upper limit was changed to 15,500 acre-feet per year on October 9, 1922 (Wyoming vs. Colorado, 260 US 1, 43 Sup. Ct. Rep. 2). This amendment to the prior ruling went on to state that it does not prejudice Colorado's right to divert 18,000 acre-feet per year through the Skyline Ditch, or previous appropriations of the Laramie River via the Wilson Supply Ditch.

On October 6, 1930, suit was again filed by Wyoming against Colorado (Wyoming vs. Colorado, 298 US 573). This suit involved the interpretation of the earlier court decree. Here the court held that Colorado could apportion its share of the Laramie River in accordance with her own state laws, without violating the interests of Wyoming. This decision did, however, cause the discontinuance of two small transbasin diversions from the Laramie River drainage to the South

Platte River basin, the Bob Creek and Columbine Ditches. This did not end the battle between Wyoming and Colorado. In April of 1940 the United States Supreme Court had to render a decision of the enforcement of the previous decrees, (Wyoming vs. Colorado, 309 US 572).

It was not until February of 1957 that Colorado and Wyoming finally agreed to a mutually acceptable solution to the apportionment of the Laramie River flows. Arising out of Wyoming vs. Colorado, 353, US 953, this latest agreement placed a ceiling of 49,375 acre-feet per year on diversions of Laramie River water within Colorado. Wyoming was alloted "all water flowing and remaining in the Laramie River and tributaries after such diversion and use in Colorado." The decree went on to state that of Colorado's allotment, no more than 19,875 acre-feet per year may be diverted for use to areas outside the river's water shed. The remaining portion of Colorado's allotment, amounting to 29,500 acre-feet per year, was ordered to be used only within the Laramie River drainage within Colorado (the Laramie River sub-basin). The decree was explicit as to the acreage where this water could be used and with respect to the points of diversion. The Laramie River Decree did not, however, affect Colorado or Wyoming rights, including the right of the Wilson Supply Ditch, to divert water from "Sand Creek, sometimes spoken of as a tributary to the Laramie River." The case of Wyoming vs. Colorado 353 US 953 (1957), which sets forth the provisions of the Laramie River Decree, is found in Appendix D, Exhibit D1-2.

7.2.3 *Transbasin Diversion Structures* - Six transbasin diversion structures have, at one time or another, exported water from the Laramie River sub-basin; these include: the Wilson Supply, Columbine, Bob Creek, and Skyline Ditches, the Laramie-Poudre Tunnel and the Lost Lake Outlet.

They all diverted water to the Cache La Poudre sub-basin of the South Platte River Basin and can be seen in Figure 7-1. Today only three are in operation; they are: the Wilson Supply and Skyline Ditches and the Laramie-Poudre Tunnel. Presently there are no diversions of water from the Laramie River Drainage within Wyoming, nor are there imports of water to this sub-basin.

The Wilson Supply Ditch - This ditch, formerly known as the Sand Creek System or as Sand Creek ditch, diverts water at 8,600 feet from Sand Creek and at times from Deadman Creek, a tributary to Nunn Creek. It delivers this water to Sheep Creek, a tributary of the North Fork of the Cache La Poudre.

All available records of the yearly diversions through this ditch are shown in Appendix B, Table B1-1. Diversions from Deadman Creek are subject to the provisions of the 1957 Laramie River Agreement. These diversions have averaged 834 acre-feet per year since 1957 and 987 acre-feet per year prior to 1957. Diversions from Sand Creek are not constrained by this decree and have averaged 1919 acre-feet per year over the period records are available.

The Wilson Supply Ditch is owned by the Divide Reservoir and Supply Company, an irrigation water supplier, (Nentze, 1976). Construction of the ditch is believed to have commenced in 1899 and the first recorded diversions of water occurred in 1902 (United States Bureau of Reclamation, 1959). There are presently no plans to increase diversions through this ditch.

The Columbine Ditch - The Columbine Ditch was built by the Mountain and Plains Irrigation Company. This water organization was formed in the early 1900's by Roy A. Portner, a Fort Collins resident. This time period was one of the key note points in the history of water resource development of the South Platte River basin. The increasing agricultural demands in several of its sub-basins, notably the Cache La Poudre, were faced with water shortages due to the over appropriation of its endogenous (native) supplies during the growing season. It was private irrigation companies, such as this one, which mobilized the economic forces of the Agricultural Community so that additional water supplies could be developed through more costly reservoirs and transbasin diversions.

Water was first brought through this ditch in 1921. Exports averaged 121 acre-feet per year until the ditch was discontinued in 1957 by Court Order from the case Wyoming vs. Colorado, 289, US 573. All yearly diversions made over its 36 year operating period are shown in Appendix B, Table B1-2. This ditch diverted water at 10,300 feet from Deadman Creek, a tributary to Nunn Creek. to the North Fork of the Cache La Poudre River. The Columbine Ditch is now owned by the City of Greeley, (Evans, 1971).

The Bob Creek Ditch - This ditch diverted water at 9,900 feet from Nunn Creek at tributary to the Laramie River, to Roaring Fork, a tributary of the Cache La Poudre River. Water was first brought through this ditch in 1920. Diversions averaged 358 acre-feet per year until the ditch was discontinued in 1957 by Court Order from Wyoming vs. Colorado, 289 US 573. All yearly diversions made over its 37 year operating period are shown in Appendix B, Table B1-3. The Bob Creek Ditch was also built by the Mountains and Plains Irrigation Company and it is presently owned by the City of Greeley (Evans, 1971).

The Laramie-Poudre Tunnel - This tunnel, sometimes known as the Greeley-Poudre Tunnel, was the first tunnel constructed in the South

Platte River Basin for the transbasin diversion of water. It diverts water at 8,570 feet from tributaries of the Laramie River, via the Rawah and Lower Supply Collection Ditches, to the Cache La Poudre River about 8 miles downstream from Chambers Lake. The tunnel is 7.5 feet wide, 9.5 feet high, 11,306 feet long and has a capacity of 1,000 cfs, (United States Bureau of Reclamation, 1959). As a consequence of the disputes between Colorado and Wyoming over the apportionment of the Laramie River, the original 1902 priority date given to this tunnel by the Colorado State Supreme Court was changed to 1909 by the United States Supreme Court in 1922.

The initial diversion through the tunnel was made in 1914, all of its yearly exports since are shown in Appendix B, Table B1-4. Prior to the Laramie River Decree (1957) the Laramie-Poudre Tunnel diverted an average of 9,657 acre-feet per year. Presently they average 15,630 acre-feet per year.

Construction of this tunnel began in 1909. Although it was completed in 1911, diversions did not begin until 1914 because of the Laramie River apportionment disputes between Wyoming and Colorado. The ownership of this tunnel and its water rights are split between the Water Supply and Storage Company, which owns two thirds interest, and the Windsor Reservoir and Canal Company which owns one third interest, (Johnson, 1976). There are presently no plans to increase diversions through this tunnel through the aquisition of more senior water rights or through the improvement or expansion of its physical structure.

The Skyline Ditch - This ditch diverts water from the west branch of the Laramie River and from Two and One-half Mile Creek to Chambers Lake. The Skyline Ditch is located at an elevation of 9.100 feet, is

5 miles long, and has the physical capacity to deliver 400 cfs, (United States Bureau of Reclamation, 1959).

In 1891 heavy rains washed out Chambers Lake Dam which had been used up to that time to impound native Cache La Poudre flows for irrigation. Construction of the Skyline Ditch was started with reconstruction of the Dam. The first diversion through this ditch was in 1895. Appendix B, Table B1-5 shows all yearly exports since 1895. Diversions prior to the 1957 Laramie River Decree averaged 14,128 acre-feet per year, and 1,707 acre-feet per year, subsequently.

The Skyline Ditch is owned by the Water Supply and Storage Company. Since 1957 they have diverted by exchange through the Laramie Poudre Tunnel (which they own part interest in) some water previously exported through this ditch. The constraints of the Laramie River Decree cut down their previous import amounts and by transferring the water from Skyline to the Laramie Poudre Tunnel they are able to make the most effective use of what they have been allocated (Johnson, 1976). There are presently no plans to increase diversions through this ditch through the aquisition of more water rights or through the expansion or improvements of its physical structure.

The Lost Lake Outlet This ditch was built in 1898. Water was first brought through the ditch in 1899. It diverted water from the Laramie River at 9,180 feet to Chambers Lake. Exports averaged 215 acre-feet per year until it was ordered closed by the State Engineer of Colorado in 1950 (Evans, 1971). All yearly diversions made over its 52 year operating period are shown in Appendix B, Table B1-6.

7.2.4 *Potential for Further Transbasin Diversions to the South Platte* - Historically, all exports from the Laramie River sub-basin have gone to the South Platte River basin in Colorado. The 1957 Laramie River Decree (which excepts Sand Creek from its provisions) constrains diversions from this sub-basin, to other river drainages in Colorado, to not more than 19,875 acre-feet per year. Prior to this stipulation exports averaged 25,466 acre-feet per year, (not including those from Sand Creek). Since the 1957 decree total exports from this sub-basin (not including those from Sand Creek) have averaged 17,826 acre-feet per year. Table 7-3 summarizes the annual diversions since 1957.

The full diversion permitted by the decree is not realized during some years because during low runoff years the Skyline and Wilson Supply (Deadman Creek diversions only) Ditches and the Laramie-Poudre Tunnel must yield to senior Colorado Diverters downstream in the Laramie River sub-basin. Therefore, with their present rights, under Colorado State Water Law, the maximum allowable by Federal Law 19,875 acre-feet, is not available each and every year.

Diversions from Sand Creek are not constrained in any way by the Laramie River decree. This water is diverted by the Wilson Supply Ditch; the diversion is subject only to the rights of senior Colorado Water right holders downstream requiring 35 cfs (Neutze, 1976). The Sand Creek water rights for the Wilson Supply Ditch have yielded an average of 1,919 acre-feet per year to date.

Some additional imports to the South Platte River basin in Colorado could be available through the aquisition (i.e., purchase) of senior Laramie River water rights in Colorado. Such procurement could secure each year the 19,876 acre-feet allotment in addition to whatever else could be realized by aquisition of senior Sand Creek water rights.

Table 7-3 Transbasin Diversions from the Laramie River Sub-basin to the South Platte River Basin in Colorado since the Enactment of the Laramie River Decree in 1957.

Calendar Year	Diversions Subject to Decree (acre-feet)				Other Diversions (acre-feet)	Total Diversions from the Laramie River Basin (ac-ft)
	Skyline Ditch1/	Laramie-Poudre Tunnel3/	Wilson Supply Ditch (Deadman Ck. Diversions only)2/	Total4/	Wilson Supply Ditch (Sand Ck. Diversions only)2/	
1975	1,680	17,130	N.A.	N.A.	N.A.	20,760
1974	651	17,870	N.A.	N.A.	N.A.	22,861
1973	2,680	16,690	N.A.	N.A.	N.A.	20,750
1972	2,350	16,190	N.A.	N.A.	N.A.	20,910
1971	1,810	14,110	N.A.	N.A.	N.A.	16,773
1970	1,550	14,990	165	16,705	2,715	19,420
1969	3,710	15,000	1,273	19,983	343	20,326
1968	2,140	17,030	1,150	20,320	3,179	23,499
1967	1,500	10,740	920	13,160	1,476	14,636
1966	0	19,130	638	19,768	293	20,061
1965	772	18,300	900	19,972	2,194	22,166
1964	3,420	15,520	1,074	20,014	1,389	21,403
1963	2,590	16,670	655	19,915	409	20,324
1962	0	13,950	1,131	15,081	3,796	18,877
1961	1,300	10,400	211	11,911	940	12,851
1960	2,560	15,980	1,390	19,930	1,801	21,731
1959	1,420	17,920	871	20,211	1,236	21,447
1958	587	13,720	461	14,768	1,396	16,164
1957*	0	0	0	0	0	0
18-Year Average	1,707	15,630	834	17,826	1,628	19,720

1/Appendix B, Table B1-5
2/Appendix B, Table B1-1
3/Appendix B, Table B1-4
4/The 1957 Laramie River Decree limits annual exports from the sub-basin to other Colorado basins to 19,875 acre-feet per year.
*Enactment date of the Laramie River Decree was February, 1957, the fifth month of the 1957 water year.

Any additional imports would require further litigation at the Federal level to change the 1957 Laramie River decree. In view of the long history of such litigation this appears unlikely.

There are presently no plans to increase diversions from the Laramie River sub-basin to the South Platte River basin in Colorado through the aquisition of more senior water rights or through the improvement or expansion of the physical structure of the existing importation facilities.

Below this sub-basin, within the Laramie River Drainage in Wyoming, there is no unappropriated water left. The Laramie River Decree apportioned to Wyoming all the flows of the Laramie River after Colorado's allotment. Wyoming is presently using this water within the Laramie River drainage. Wyoming users in the South Platte River basin seeking these flows will have to work within that states water laws by providing exchanges or by purchasing existing rights and petitioning the State Engineer for a change in the place of use. Once this water has been acquired, construction of appropriate facilities would be necessary and only diversions of the acquired right's historical consumptive use could be made to the South Platte River basin.

Table 7-4 summarizes the present disposition of the average annual surface water supply arising in the Laramie River sub-basin. As noted, the annual exports from the basin amount to 13.5 percent of the average annual native surface water supply.

Table 7-4 Disposition of the Native Surface Water Runoff of the Laramie River Sub-basin.

		Acre-feet per year	%
Average[6/] Annual Exports	Wilson Supply Ditch	2,383[1/]	1.6
	Laramie Poudre Tunnel	15,630[2/]	10.7
	Skyline	1,707[3/]	1.2
	Total	19,720	13.5
Average annual in sub-basin consumptive use		6,032[4/7/]	4.1
Average annual outflow		120,126	82.4
Total average annual native surface water supply		145,878[5/]	100.0

1/Appendix B, Table B1-1.
2/Appendix B, Table B1-4.
3/Appendix B, Table B1-5.
4/Appendix A, Table A1-4.
5/Appendix A, Table A1-4.
6/The 1975 Laramie River Decree limits annual exports from the Laramie River basin to other Colorado basins to 19,875 acre-feet per year.
7/In basin use is limited by the 1945 Laramie River Decree to the diversion of 49,375 acre-feet per year less exports, which are limited to 19,875 acre-feet per year.

CHAPTER 8

THE COLORADO RIVER BASIN

The Colorado River has its uppermost origins in the Colorado and Wyoming Rockies and in the High Uintas of Utah. Figure 8-1 shows the extensive drainage system and tributary rivers which drain portions of seven states and Mexico. The drainage area is 242,000 square miles. The land within the basin is largely arid or semi-arid. The streamflow of the Colorado River is sustained largely by the spring snowmelt from the high mountains which are exceptions to the general arid climate.

The annual river flow at Lee Ferry, Arizona has averaged 14.8 million acre-feet during the period 1896 to 1975, and 12.92 million acre-feet for the period 1931 to 1964. During the former period the annual flow has varied from 5.6 million acre-feet in 1934 to 24 million acre-feet in 1917 (U.S. Department of the Interior, 1975). Figure 8-2 is an historical simulation of annual flows of the Colorado River at Lee Ferry, Arizona based upon statistical correlations with tree ring growths and flows in the river. This analysis indicates a long term average flow of 13.5 million acre-feet. The pregressive annual flow computed as a ten year moving average is shown in Figure 8-3.

8.1 Perspective on Use of Colorado River Water

8.1.1 *Interstate Water Allocations* - The allocation of the Colorado River flows is based upon the concept that any state having area within the Colorado River basin has a right to a portion of the flow. There are two basic interstate compacts which spell out the allocation: the 1922 Colorado River Compact and the 1948 Upper Colorado River Basin Compact. However, Arizona has filed suit on four occasions regarding

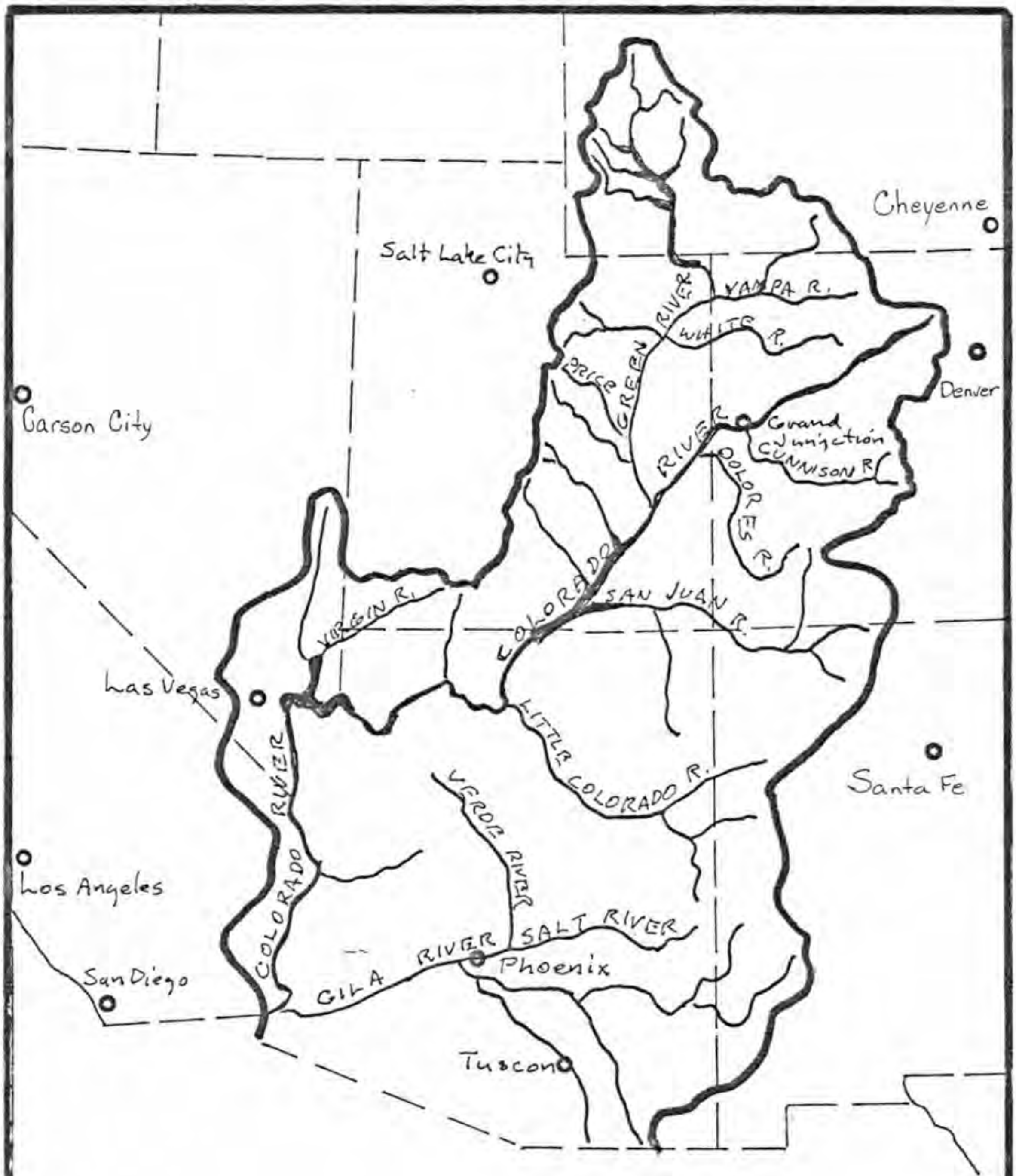


Figure 8-1: Colorado River Drainage Area

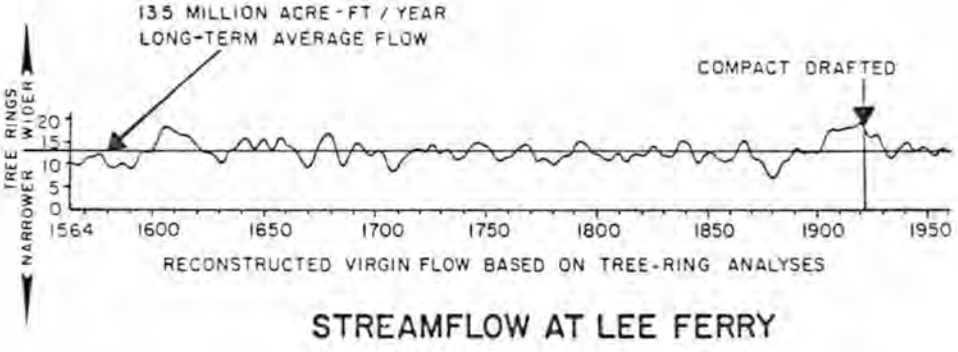


Figure 8-2: Reconstruction of Historical Flows of the Colorado River at Lee Ferry based upon Analysis of Tree Rings. (Jacoby, et.al., 1976)

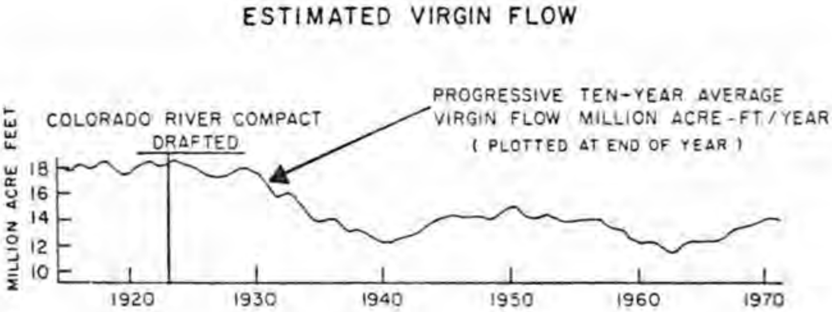


Figure 8-3: Annual Flow of the Colorado River at Lee Ferry Computed as a Ten Year Moving Average (Jacoby, et.al., 1976)

interpretation of the 1922 Compact vis a vis California, resulting in Supreme Court Decrees in 1931, 1934, 1936, and 1963. In addition, two other factors presently influence the interstate apportionment of the Colorado River flows; an international treaty with Mexico and the uncertanties arising from the perfection of Federal Reserve and Indian Water Rights.

The Colorado River Compact - The Colorado River Compact was precipitated largely by the proposal to build the Boulder Canyon Project. This project would stabilize irrigation in the Imperial Valley of California and also provide water to sustain the rapid growth of the Los Angeles metropolitan region. The proposed project was alarming to the other states of the Colorado River basin. Unless challenged, the de facto application of the doctrine of prior appropriation for the Colorado River as a whole would mean that the slower growing states would be left without water. Consequently, in 1919 the Governor of Utah began a movement among the seven states of the basin and in collaboration with the United States Reclamation Service, started an interstate study on the apportionment of Colorado River basin water. There was considerable political leverage to make such a study feasible. Since the Boulder Canyon Project was a huge financial undertaking federal involvement was imperative. The project was dependent upon an Act of Congress, i.e., the Boulder Canyon Project Act. Since California would be the only beneficiary of the project the other states had the power to impose some terms. It soon became apparent that the best solution was to develop a compact; consequently an appeal was made to Congress to begin negotiations. A series of conferences and public hearings were held by by accredited commissioners of the seven states and with Secretary Herbert

Hoover who represented the United States. On November 24, 1922, the Colorado River Compact was signed by the Commissioners.

Six of the seven states quickly ratified the compact. Arizona refused because of a dispute with California over the use of waters in the lower Colorado River basin. One provision of the compact, Article XI, Paragraph 1, was that all seven states need to ratify it before it became effective. Desiring the compact, even without Arizona, the six remaining states removed the stipulation of Article XI. Congress consented to this action and enacted the Boulder Canyon Project Act on December 21, 1928, as a result. Arizona finally ratified the Colorado River Compact in 1944, after which the compact became effective.

The basic thrust of Colorado River Compact was to divide the flows of the Colorado River between the Upper Basin States; Colorado, New Mexico, Utah, and Wyoming, and the Lower Basin States; California, Arizona, and Nevada. The Upper Basin is defined as that portion of the basin drainage above Lee Ferry, a point one mile below the mouth of the Paria River near the Arizona-Utah border. The Lower Basin is the rest of the Colorado River drainage area in the United States. Figure 8-4 shows this division of the basin.

Both Upper and Lower Basins were each apportioned for annual beneficial consumptive use, 7.5 million acre-feet of Colorado River Flows, (Colorado River Compact Article III, Paragraph A). However, the Upper Basin was mandated to not cause the flow at Lee Ferry to be depleted below an aggregate of 75 million acre-feet in any ten consecutive year period (Colorado River Compact, Article III, Paragraph D).

Also stipulated in this compact was that when there is insufficient surplus flow to meet any Mexican water obligations that might accrue as

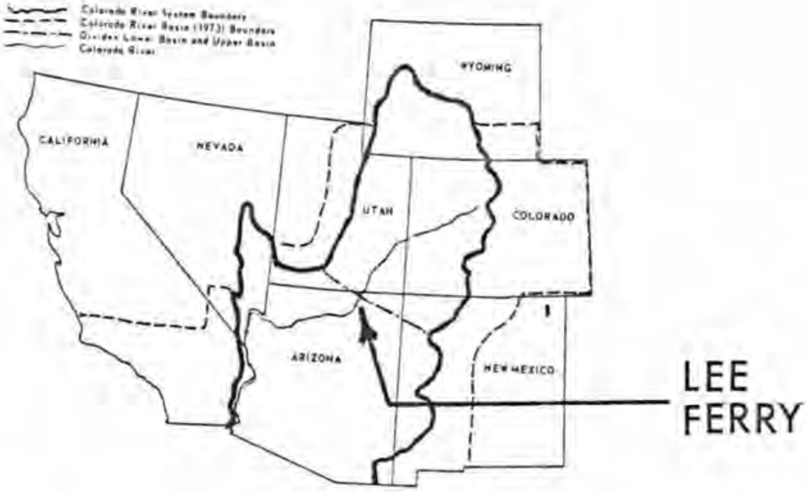


Figure 8-4. The Upper and Lower Basins of the Colorado River Basin. (From the United States Department of the Interior, 1975).

a result of international commodity, the deficiency shall be borne equally by the Upper and Lower Basins (Colorado River Compact, Article III, Paragraph C). The Colorado River Basin Compact in its entirety is found in Appendix D, Section D-2. It is crucial to note, as indicated in Figures 8-2 and 8-3, that the compact was drafted during a period when flows in the river exceeded the long term averages. This is a problem felt currently as the Upper Basin States proceed toward full development of their respective shares.

The Upper Colorado River Basin Compact - In 1946 negotiations began between the Upper Basin states on how the water allocated to them would be split. On October 11, 1948 the Upper Colorado River Basin Compact was approved by Congress after ratification by all states participating.

This compact apportioned to the Lower Basin state of Arizona 50,000 acre-feet of Colorado River water off the top of each years yield to the Upper Basin States (Upper Colorado River Basin Compact, Article III, Paragraph 9, Section 1). The remainder was apportioned for consumptive use in the following percentages: (Upper Colorado River Basin Compact, Article III, Paragraph A, Section 2):

Colorado	51.75%
New Mexico	11.25%
Utah	23.00%
Wyoming	14.00%

The Upper Colorado River Basin Compact is found in Appendix D, Section D-2.

The Mexican Water Treaty - In 1944 the State Department undertook negotiations with Mexico for a treaty to encompass the Rio Grande, Tijuana, and the Colorado Rivers, which lie partially in each country. Under the Mexican Water Treaty, ratified by the US Senate and made effective in 1945, the United States is obligated to deliver to Mexico 1.5 million acre-feet annually in the limitrophe section of the Colorado River (that stretch where the Colorado River is the boundary between the United States and Mexico), and some additional quantities if available. In cases of serious drought, or significant failure in the delivery system, Mexico could receive less than 1.5 million acre-feet (Article 15).

However, "there are some basic disagreements among the various states of the Colorado River as to the obligation of each state for the release of water to satisfy the Mexican treaty." (Sparks, 1974). In fact, there is one contention that the Upper Basin has never admitted any responsibility for Mexican Treaty water. Section III, of the Mexican Treaty, which deals with the Colorado River, is found in Appendix D, Section D-2.

8.1.2 *Colorado and Wyomings Equitable Share of the Colorado River* - As noted in previous sections, the annual virgin flow of the Colorado River during the period 1896 to 1975, at the Compact Point (Lee Ferry, Arizona), has varied from 5.6 million acre-feet in 1934 to 24 million acre-feet in 1917. For the period of 1906 to 1970, the average virgin flow is estimated at 14.80 million acre-feet; for the period 1931 to 1964, the flow averaged only 12.92 million acre-feet per year.

These figures have serious ramifications on the Upper Basins allotment, and consequently Colorado and Wyoming's equitable share. This in turn, affects the availability of water from the Colorado River to the South Platte basin. The Department of the Interior, in its 1975 Westwide Report, states that 5.8 million acre-feet is the assured amount remaining for use in the Upper Basin under adverse runoff conditions, after it has met its obligation to deliver 7.5 million acre-feet to the lower basin in each 10 years, and if it is required to contribute 750,000 acre-feet annually toward meeting the Mexican Water Treaty Obligation. Commenting on this report through its State Engineer, S. E. Reynolds (1976), New Mexico contends that it is their position that the assured annual consumptive use for the Upper Basin is no less than 6.3 million acre-feet annually.

In 1976, the Colorado Water Congress resolved to urge legislative action for a re-interpretation of the Colorado River Compact. In the interest of upper basin water users, especially in Colorado, they expressed concern over interpretations of the compact that do not "... divide the flow of the river equally between the upper and lower basins but rather guarantee an annual average flow of 7,500,000 acre-feet to the lower basin..." (Sparks, 1974).

In addition to the disagreement over the interpretation of the 1922 Compact and the Mexican Treaty, there are two other uncertainties which probably will loom larger in future years. These are: the perfection of Federal Reserve, and Indian Water rights.

Some tribes of the western Indian Nations are currently initiating litigation relative to their rights to the Colorado River System. According to the Westwide Study, "although it is difficult to predict the specific rulings in the many facets of Indian water rights court proceedings, it seems likely that through some means water to meet legitimate water requirements for Indian reservations will become available." (US Department of the Interior, 1975).

The consumptive and non-consumptive needs of water on public lands is also a future uncertainty. These demands cover a broad spectrum of uses such as improving the forest environment and providing sustained timber yields; livestock grazing; wildlife and fisheries conservation and management; recreation, domestic, municipal, and administrative site consumption; firefighting and fire prevention; wilderness preservation; flood and soil erosion control; and preservation of aesthetic and other public values.

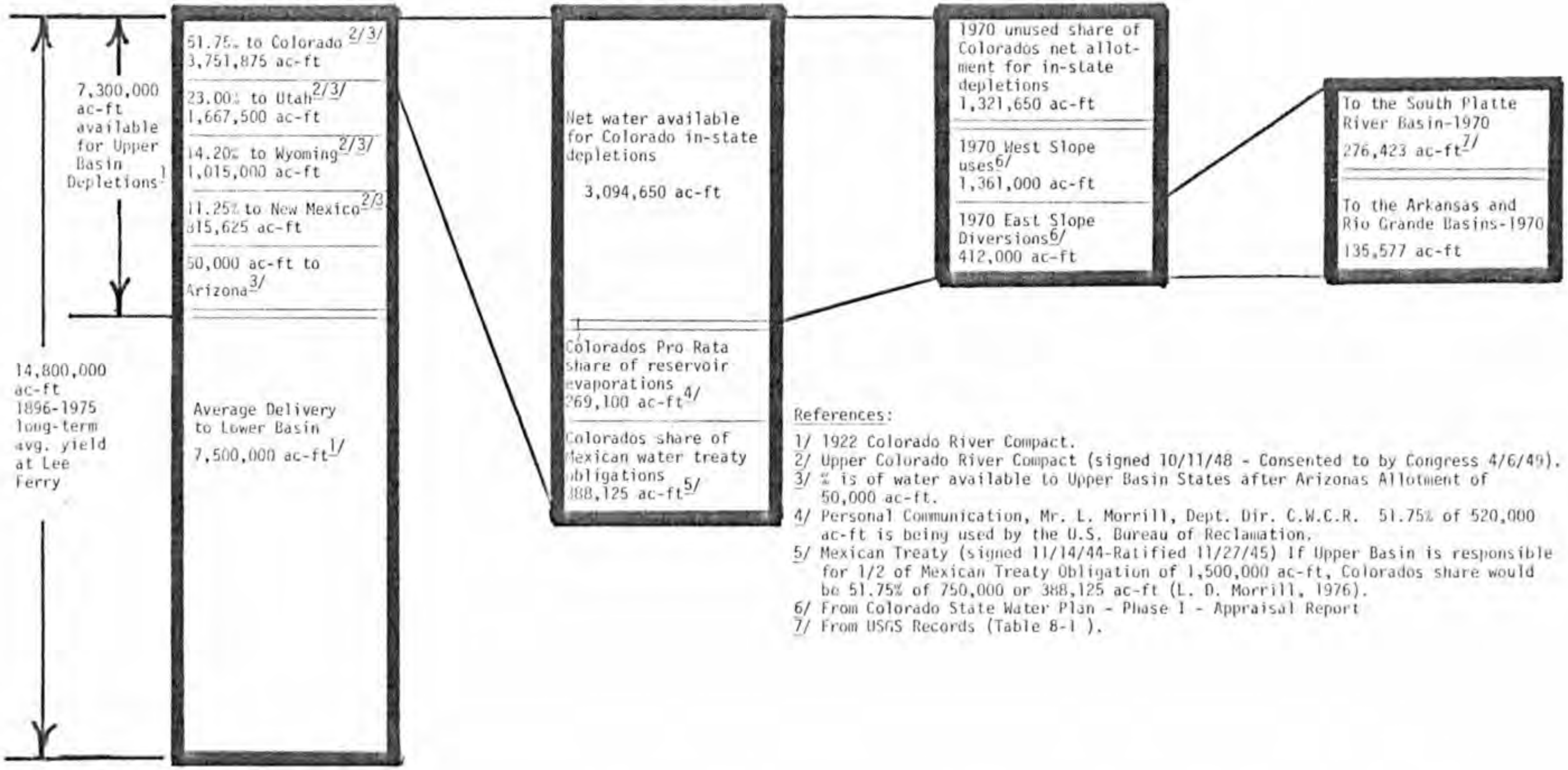
Urgent and critical energy requirements have raised questions about the responsibility of the federal government to provide or reserve water for development of the mineral reserves located on both public and on private lands where the federal government has reserved mineral rights. The present government policy is to place the responsibility for obtaining these water rights on the entity that develops the energy resource.

The perfection of Indian and Federal Reserve rights in the Colorado River Basin will mean that the Upper Basin and therefore Colorado and

Wyoming (which in turn effects the South Platte River Basin) will have less Colorado River water available for use. However, the specific resolution of the problems will come about most likely by the process of litigation, vis a vis legislation. Some attorneys feel that the process will take 50 to 100 years.

8.1.3 *Estimates of Colorado's Unused Share of its Colorado River Allotment* - According to Mr. Felix Sparks (1974) of the Colorado Water Conservation Board, "There has been a considerable amount of study together with a considerable amount of speculation, concerning the amount of water which is still available to the State of Colorado under the terms of the Colorado River Compact and the Upper Colorado River Basin Compact. The problem with any studies is that no one can actually define the precise amount of water to which Colorado is entitled under the terms of the compacts. At some future time it appears likely that these differences will be taken to the United States Supreme Court for resolution."

Acknowledging the problem noted by Sparks, that the terms of the compacts may be the subject of future litigation to clarify the apportionments, one can read these documents and interpret them literally for a lower limit assessment of Colorado's allocation. This involves also making an assumption about the annual flow at Lee Ferry. This is done graphically in Figures 8-5 and 8-6, which trace through graphically the water allocations based upon compact interpretations for the 1896-1975 average flow at Lee Ferry of 14,800,000 acre-feet and for the 1931-1964 average flow of 12,920,000 acre-feet respectively. The amount of water available to Colorado, from the two compacts and the Mexican Treaty, is



References:

1/ 1922 Colorado River Compact.

2/ Upper Colorado River Compact (signed 10/11/48 - Consented to by Congress 4/6/49).

3/ % is of water available to Upper Basin States after Arizonas Allotment of 50,000 ac-ft.

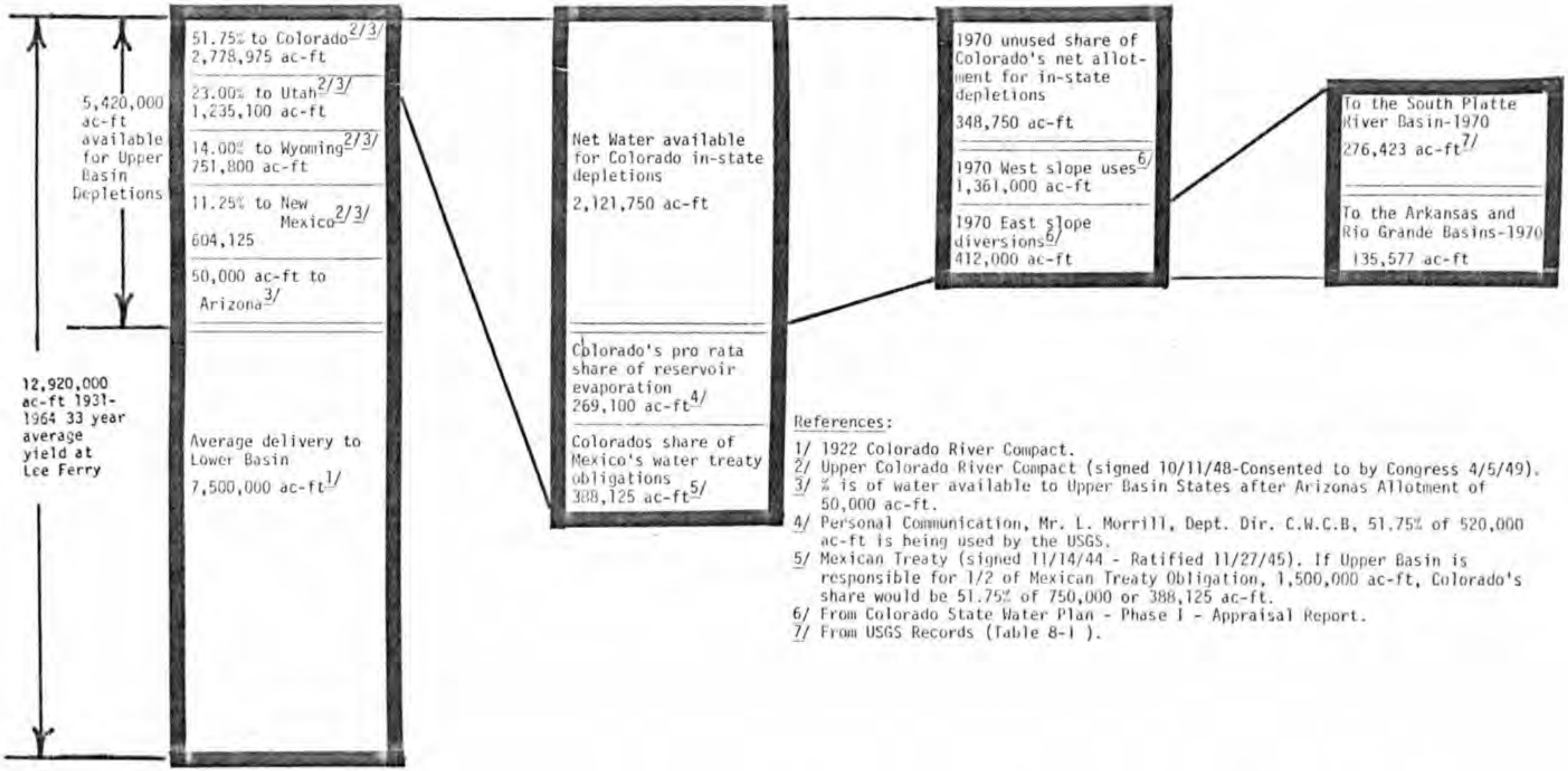
4/ Personal Communication, Mr. L. Morrill, Dept. Dir. C.W.C.R. 51.75% of 520,000 ac-ft is being used by the U.S. Bureau of Reclamation.

5/ Mexican Treaty (signed 11/14/44-Ratified 11/27/45) If Upper Basin is responsible for 1/2 of Mexican Treaty Obligation of 1,500,000 ac-ft, Colorados share would be 51.75% of 750,000 or 388,125 ac-ft (L. D. Morrill, 1976).

6/ From Colorado State Water Plan - Phase I - Appraisal Report

7/ From USGS Records (Table 8-1).

Figure 8-5: Calculation of Colorado's Annual Share of Colorado River Water if the Yeild at Lee Ferry is 14.8 Million Acre-Feet (Based upon an interview with Mr. L. Morrill, Deputy Director of the Colorado Water Conservation Board, 7/16/76).



References:

1/ 1922 Colorado River Compact.
2/ Upper Colorado River Compact (signed 10/11/48-Consented to by Congress 4/5/49).
3/ % is of water available to Upper Basin States after Arizonas Allotment of 50,000 ac-ft.
4/ Personal Communication, Mr. L. Morrill, Dept. Dir. C.W.C.B, 51.75% of 520,000 ac-ft is being used by the USGS.
5/ Mexican Treaty (signed 11/14/44 - Ratified 11/27/45). If Upper Basin is responsible for 1/2 of Mexican Treaty Obligation, 1,500,000 ac-ft, Colorado's share would be 51.75% of 750,000 or 388,125 ac-ft.
6/ From Colorado State Water Plan - Phase I - Appraisal Report.
7/ From USGS Records (Table 8-1).

Figure 8-6: Calculation of Colorado's Annual Share of Colorado River Water if the Yeild at Lee Ferry is 12.9 Million Acre-Feet (Based upon an interview with Mr. L. Morrill, Deputy Director of the Colorado Water Conservation Board, 7/16/76).

seen to be 3,094,650 acre-feet for the former flow assumption, and 2,121,750 acre-feet for the latter flow assumption.

Once Colorado's allocation (and Wyoming's) is determined, the intrastate allocation procedures govern allocation. By present law, in both Colorado and Wyoming, the doctrine of prior appropriation determines the availability of water. Figures 8-5 and 8-6, based upon 1970 Colorado uses, show both east slope diversions and west slope uses as being fixed (i.e., not subject to change with low flows since these figures represent uses by senior appropriators). The amount of unused water for the high average flow of Figure 8-5 is 1,321,650 acre-feet; however, it is only 348,750 acre-feet for the low average flow of Figure 8-6.

It should be kept in mind, however, that these "unused flows" are covered several times over by existing conditional decrees. While there is doubt as to Colorado's total share to begin with, it is nearly impossible to determine the future status of conditional decrees. In Colorado, water decrees are issued without regard to the availability of unappropriated water in the source. It is a certainty that many such decrees will not develop into actual useage, but existing conditional decrees already far exceed any ones guess of Colorado's unused share of the Colorado River.

A similar type of analysis was performed by Hansen (1975) based on a guaranteed annual consumptive use available to the Upper Basin States of 6.3 million acre-feet. He quotes this figure as being determined by Tipton and Kalmbach, Inc. during an engineering study entitled, Water Supplies of the Colorado River, 1965. Of Colorado's 51.75% allotment (3,234,000 acre-feet) he subtracts 1,828,000 acre-feet as present depletions (1975) and 269,000 acre-feet as mainstem reservoir losses to find that this state has 1,137,000 acre-feet of unconsumed water. Subtracting from this Colorado's committed Colorado River water to projects presently under way, 432,000 acre-feet (does not include potential depletions of Indian water rights presently not in use) he arrives at 705,000 acre-feet as available for future development and export. Hansen notes that all of this water is covered under conditional decrees. This amount coincides approximately with an assessment by Felix Sparks (1974) who states "there is at least 800,000 acre-feet of water available to Colorado on an annual basis which is not now being used although several times this volume of water is included in existing conditional decrees. This is true under the most restrictive interpretations of the available allocations under the interstate compacts and Mexican water treaty." Whatever the case, this presently unusued water is the prime source of future foreign water supplies for the Colorado portion of the South Platte as well as other River Basins in Colorado. At the same time it must be realized that it is also the prime source of water supplies for further development of Colorado's west slope.

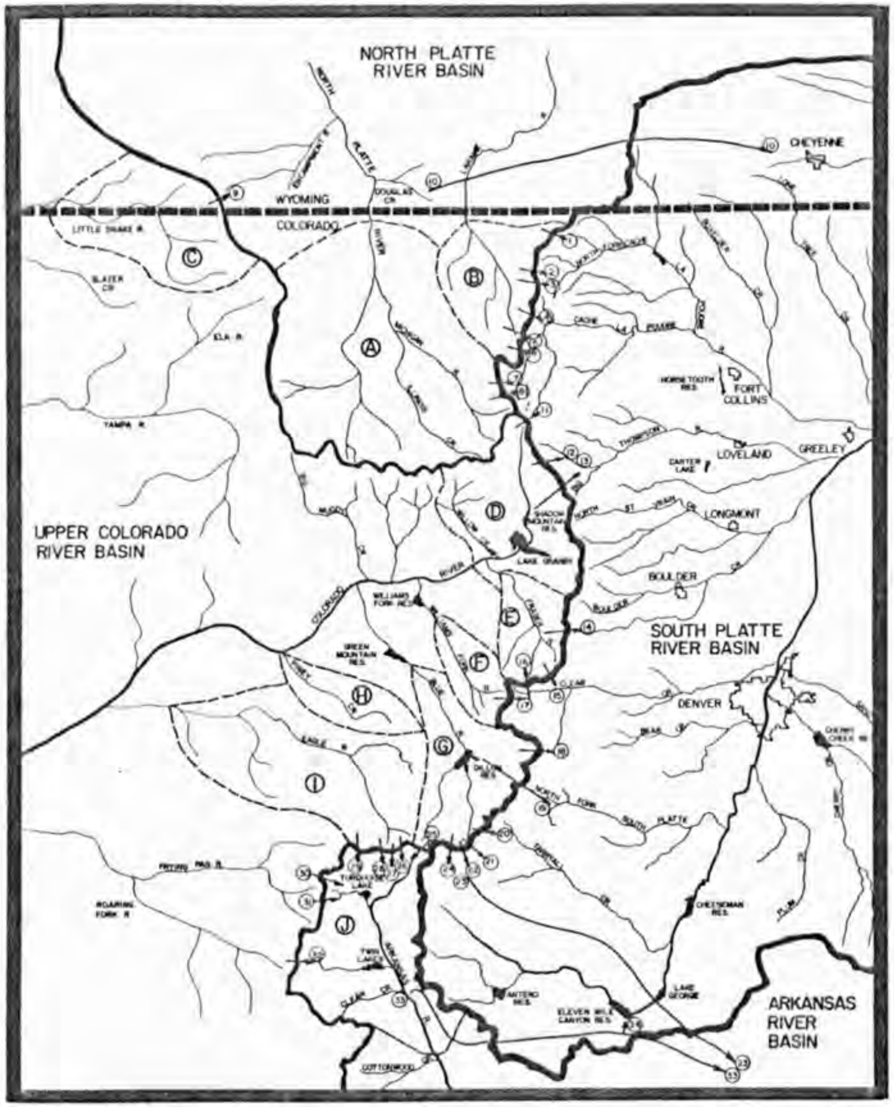
8.1.4 *Estimate of Wyoming's Unused Share of its Colorado River Allotment* - According to Hansen (1975), present depletions (1975) of Colorado River Basin water in Wyoming are 323,000 acre-feet and mainstem reservoir losses, 73,000 acre-feet. Based on the 6.3 million acre-feet available to the upper basin, of Wyoming 14.00% allotment (875,000 acre-feet), it still has 479,000 acre-feet of unconsumed Colorado River water. However, Wyoming has a total of 292,000 acre-feet of this committed to the Cheyenne-Laramie, Lyman, Savery-Park Hook, Fontenelle M & I, and Seeskadee Projects (Hansen, 1975). This leaves Wyoming with 187,000 acre-feet of Colorado River water for future development and export.

8.1.5 *Transbasin Diversion from the Colorado River* - The Colorado River is a prime source of additional water for the growing agrometropolitan regions within each of the seven states included in the basin. These regions are: Albuquerque-Santa Fe in New Mexico, the Front Range in Colorado, Cheyenne in Wyoming, the Wastach Front in Utah, Las Vegas in Nevada, Los Angeles and the Imperial Valley in California, and Phoenix-Tucson in Arizona. Figure 8-7 summarizes the present and future transbasin diversions from the Colorado River. A large portion of these diversions will go to the agro-metropolitan areas mentioned. The diversions to the Phoenix-Tucson region via the Central Arizona Project, which will amount to 1.2 million acre-feet annually, is not indicated because they are a part of the basin (i.e., the Gila River drainage).

The water diverted to the South Platte River basin from the Colorado River basin comes from the high elevation portions of the mainstem and tributaries along the Continental Divide. Figure 8-8 shows the present diversions (along with those from the North Platte River basin) and the tirbutaries involved. They include: the Colorado River mainstem, the Fraser River, Williams Fork River, Blue River, Eagle River, and the Little Snake River. Of interest also to complete the perspective of these high elevation diversions (but which is not a part of the present study) is the Fryingpan River which is the main source of water for the Fryingpan-Arkansas Project. The Charles H. Boustedd Tunnel and Turquoise Lake, shown in the lower portion of Figure 8-8 are components of this project.

The historical diversions from the Colorado River, above the Gunnison River, are seen in Figure 8-9 to the year 1957. Table 8-1 lists the 1970 diversions from the Colorado River basin in Colorado to

Figure 8-7: The Development of the Colorado River Basin as Indicated by the Existing and Projected Annual Maximum Trans-Regional Diversions (From the U.S. Department of the Interior, 1975).



THE NORTH PLATTE RIVER BASIN

Subbasins:

A - North Platte River-Mountains
B - Laramie River

Transbasin Diversion Structures:

1 - Wilson Supply Ditch
2 - Columbine Ditch (closed)
3 - Bob Creek Ditch (closed)
4 - Laramie-Poudre Tunnel
5 - Skyline Ditch
6 - Lost Lake Outlet (closed)
7 - Cameron Pass Ditch
8 - Michigan Ditch

THE COLORADO RIVER BASIN

Subbasins:

C - Little Snake River
D - Colorado River-Mountains
E - Fraser River
F - Williams Fork River
G - Blue River
H - Piney River
I - Eagle River

Transbasin Diversion Structures:

9 - Cheyenne Tunnel (Provides replacement water for diversions by the Cheyenne Pipeline)
10 - Cheyenne Pipeline
11 - Grand River Ditch
12 - Eureka Ditch
13 - Alva B. Adams Tunnel
14 - Moffat Water Tunnel
15 - Berthoud Pass Ditch
16 - Vasquez Tunnel (Part of the collection system for the Moffat Water Tunnel)
17 - Jones Pass Tunnel (Part of the Collection system for the Moffat Water Tunnel)
18 - Vidler Tunnel
19 - Harold D. Roberts Tunnel
20 - Boreas Pass Ditch
21 - East Hoosier Pass Ditch (closed)
22 - Hoosier Pass Tunnel
23 - Montgomery Pipeline (All imports through the Hoosier Pass Tunnel are subsequently exported by this pipeline)
24 - West Hoosier Pass Ditch (closed)
25 - Freemont Pass Ditch (closed)
26 - Columbine Ditch
27 - Ewing Ditch
28 - Wurtz Ditch
29 - Homestake Tunnel
30 - Busk-Ivanhoe Tunnel
31 - Charles H. Bonstead Tunnel
32 - Twin Lakes Tunnel

THE ARKANSAS RIVER BASIN

Subbasins:

J - Arkansas River-Mountains

Transbasin Diversion Structures:

33 - Homestake Pipeline (All imports through the homestake tunnel are subsequently exported by this pipeline. Occassionally, native Arkansas River water is exported also)
34 - Aurora -Homestake Pipeline (Turn-out from the Homestake Pipeline

Figure 8-8: Subbasins of the Upper Colorado River Basin and Transbasin Diversion Structures

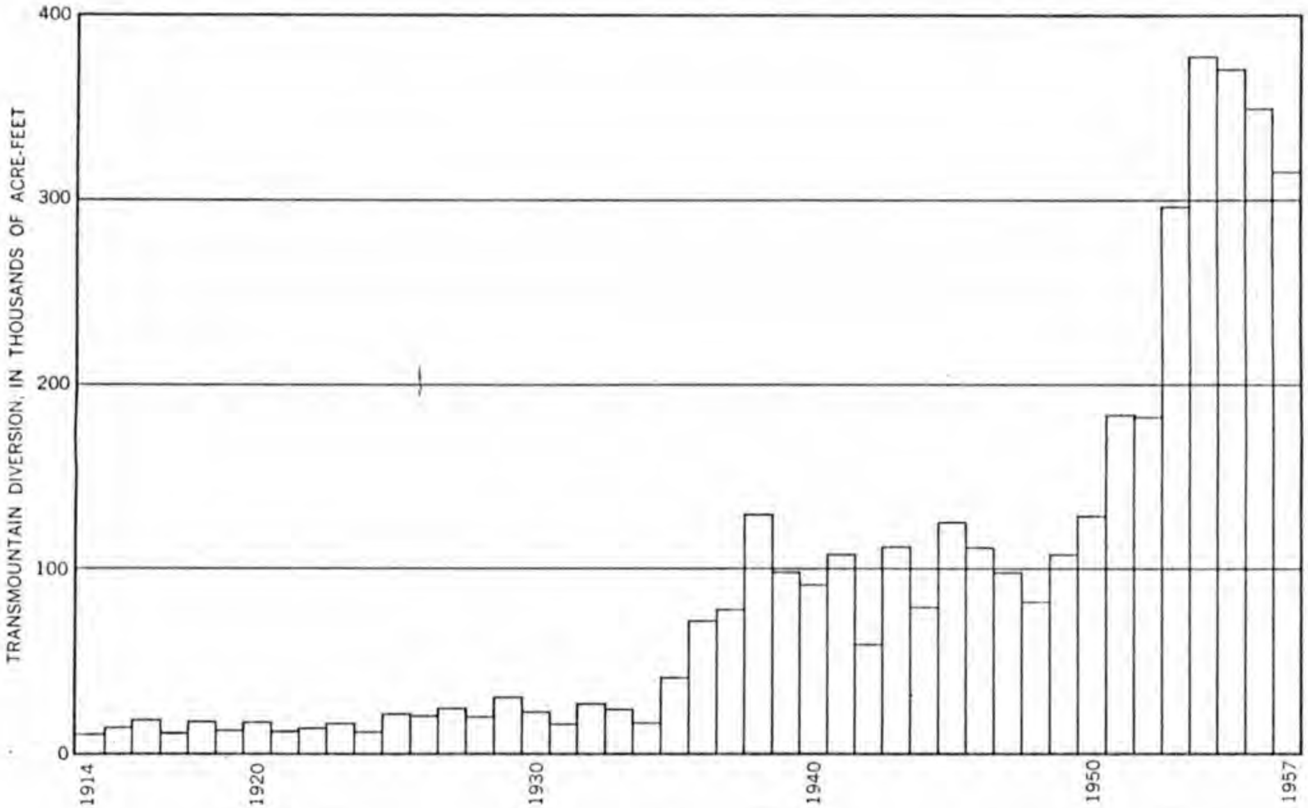


Figure 8-9: Transbasin Diversions from the Colorado River Basin above the Gunnison River in Colorado for the Water Years 1914-75 (Iorns, et.al., 1965)

Table 8-1 1970 Transbasin Diversions from the Colorado Portion of the Colorado River Basin to Other River Basins in Colorado1/

Diversion	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Water year
TO PLATTE RIVER BASIN													
09010000 Grand River ditch.......	0	0	0	0	0	0	0	0	2,910	7,440	2,020	471	12,830
09012000 Eureka ditch...........	0	0	0	0	0	0	0	0	22	7.3	2.1	0	32
09013000 Alva B. Adams tunnel....	18,380	16,620	19,920	20,300	23,700	25,950	19,290	18,800	0	10,400	18,120	13,150	204,600
09021500 Berthoud Pass ditch.....	0	0	0	0	0	0	0	0	47	171	73	0	291
09022500 Moffat water tunnel.....	3,360	2,630	2,040	1,670	1,310	1,180	1,150	516	10,680	10,930	6,550	2,660	44,680
09046000 Boreas Pass ditch.......	0	0	0	0	0	0	0	0	0	0	0	0	0
09050590 Harold D. Roberts tunnel	658	490	690	254	0	0	0	0	0	0	8,530	0	10,620
Total..........................	22,400	19,740	22,650	22,220	25,010	27,130	20,440	19,320	13,660	28,950	35,300	16,280	273,100
TO ARKANSAS RIVER BASIN													
09042000 Hoosier Pass tunnel.....	705	0	0	0	0	0	0	1,470	767	139	1,580	1,440	6,100
09061500 Columbine ditch.........	0	0	0	0	0	0	0	649	1,100	244	157	0	2,160
09062000 Ewing ditch.............	0	0	0	0	0	0	0	410	612	210	104	0	1,340
09062500 Wurtz ditch.............	0	0	0	0	0	0	0	1,370	1,850	467	188	0	3,870
09063700 Homestake tunnel........	131	1,510	2,700	1,300	1,110	2,930	2,860	1,990	0	1,300	3,680	3,510	23,010
09073000 Twin Lakes tunnel.......	909	741	363	329	324	244	300	13,990	25,480	12,450	2,530	4,370	62,020
09077500 Busk-Ivanhoe tunnel.....	117	0	0	0	0	0	0	1,920	4,240	1,110	209	312	7,910
09115000 Larkspur ditch..........	7.1	0	0	0	0	0	0	31	186	106	88	71	488
Total..........................	1,870	2,250	3,060	1,630	1,430	3,170	3,160	21,830	34,240	16,030	8,540	9,700	106,900
TO RIO GRANDE BASIN													
09118200 Tarbell ditch...........	0	0	0	0	0	0	0	0	0	37	316	33	386
09121000 Tabor ditch.............	0	0	0	0	0	0	0	377	259	125	78	208	1,050
09341000 Treasure Pass ditch.....	0	0	0	0	0	0	0	36	242	50	0	0	328
09347000 Piedra Pass ditch.......	0	0	0	0	0	0	0	0	29	26	0	0	55
09348000 Squaw Pass ditch........	0	0	0	0	0	0	0	0	72	37	0	0	108
09351000 Fuchs ditch.............	15	0	0	0	0	0	0	8.3	237	145	18	0	423
09351500 Raber-Lohr ditch........	43	0	0	0	0	0	0	0	529	440	47	0	1,060
Total..........................	58	0	0	0	0	0	0	421	1,370	860	439	241	3,410
Grand Total....................	24,330	21,990	25,710	23,850	26,440	30,300	23,600	41,570	49,260	45,830	44,290	26,220	383,400

1/United States Geological Survey, 1970. This table does not include diversions through the Vidler Tunnel (to the South Platte River Basin) or the Charles H. Boustead Tunnel (to the Arkansas River Basin) as they came on line in 1971 and 1972 respectively. Jones Pass Tunnel diversions to the South Platte Basin are brought back under the Continental Divide and to the Moffat Project Collection facilities via the Vasquez Tunnel. These diversions are included in the Moffat water tunnel imports.

2/Does not include 3,370 ac-ft of Colorado River water diverted into the South Platte Basin through the Arkansas River Basin via the Homestake Tunnel and the Aurora Homestake Pipeline.

3/3,370 ac-ft of these diversions were diverted to the South Platte River Basin via the Aurora Homestake Pipeline.

the South Platte, Arkansas, and Rio Grande River basins, showing the monthly amount through each diversion structure. Not listed are the Continental Divide Ditch and the Cheyenne Tunnel as they divert from the Colorado River Basin in Wyoming. No records of diversion by the Continental Divide Ditch are available. However, their magnitudes may be inferred as its appropriation permits are for 13.75 cfs dated 1902 and 1905, (United States Geological Survey, 1954). Cheyenne Tunnel diversions are exchanged for North Platte River water which is imported to the Wyoming portion of the South Platte River basin.

The seven sub-basins, shown in Figure 8-8 encompass a total drainage area of 2,835 square miles. The aggregate average annual runoff amounts to 1,642,309 acre-feet (Appendix A, Section A). All of these sub-basins are located in Colorado except the Little Snake, which drains portions of both Colorado and Wyoming.

The South Platte River basin presently receives from these sub-basins an average of 351,724 acre-feet per year, which represents 94.26 percent of its water supply from other basins. The collection of facilities presently transporting Colorado River water to the South Platte River basin (within both Colorado and Wyoming) consists of four ditches, eight tunnels, two pipelines; these structures are complimented by extensive collection, storage and distribution facilities.

8.1.6 *Colorado and Wyoming Water Laws Pertinent to Diversions from the Colorado River Basin* - The various interstate and international compacts and treaties governing the use of the Colorado River do not spell out limitations on in-state exports from this basin. The matter of where this water is used is within the jurisdication of these states and subject to their individual water laws. Portions of Colorado and Wyoming lie within both the Colorado and South Platte River Basins. Therefore, the use of the Colorado River water allotments by these states, within the South Platte River Basin, will be subject to their respective water laws.

Generally, in both Colorado and Wyoming, if the water within a river basin is unappropriated, it may be exported to other river basins provided no harm is done to downstream appropriators. However, an exception concerning the City of Denver is made through the Blue River Decree [The City and County of Denver vs. the Northern Colorado Water Conservancy District, 1954, (276 p. 2d 992)]. By this decree, Denver is mandated to use her South Platte River basin supplies to their fullest extent before diverting Colorado River Basin water from the Blue River.

In Colorado, if the water of a river basin is appropriated, changes in place of use is a well recognized right. Also the water may be purchased. However, only the average annual consumptive use may be exported as downstream users have a vested right to the historical return flows. In Wyoming, if the water is already appropriated, there must be an appeal to the Wyoming State Engineer to change the place of use, i.e., exported. As in Colorado, only the historical consumptive use of the right may be exported.

8.2 The Colorado River-Mountains Sub-basin

The term "Colorado River-Mountains Sub-basin" is the designation given in this report to the drainage area of the uppermost reach of the mainstem of the Colorado River from its headwaters on the western edge of the Continental Divide to gagin station #09034500, at Hot Sulphur Springs. The area of the sub-basin is 540 square miles. The tributary Frazer River drainage above gagin station #340, at Granby, is excluded in the designation. Figure 8-10 shows the sub-basin in proximity to other drainages, i.e., the North Platte and South Platte River basins, as well as the other upper tributaries to the Colorado River.

8.2.1 *Surface Water Supply* - The high elevation precipitation in the sub-basin on the 13,000 foot mountain ranges averages 40 inches per year. At the lower elevations within the sub-basin precipitation drops to approximately 16 inches per year, (National Oceanic and Atmospheric Administration, 1974). The principal form of precipitation is snow derived from winter storms moving eastward from the Pacific Ocean. The orographic effect of the Continental Divide generally causes the highest snowfall on the western slopes. The surface water supply of this sub-basin is derived principally from the spring runoff of the winter snow pack. Although there are summer rains the amount of rainfall usually is not sufficient to produce signficant runoff (McCain, Jarrett, 1976).

The average annual native surface water supply of this sub-basin is estimated in Appendix A, Table A1-1 as 378,474 acre-feet per year, based upon records of the USGS gaging station #09034500, at Hot Sulphur Springs, given in Appendix C, Table C2-1. The streamflows in Table C2-1 were adjusted for irrigation in the sub-basin and for the flows of the Fraser River. Table A1-1 shows the adjusted flows. About 5,000 acres of land are irrigated in the sub-basin.

The 1970 native surface water supply of this sub-basin is estimated to have been 491,743 acre-feet, or 110.9% of average (Table A2-2). The native surface water supply available to this sub-basin during the 1953-1956 four year drought period is estimated to average 234,767 acre-feet per year or 62.03% of average (Table A2-3).

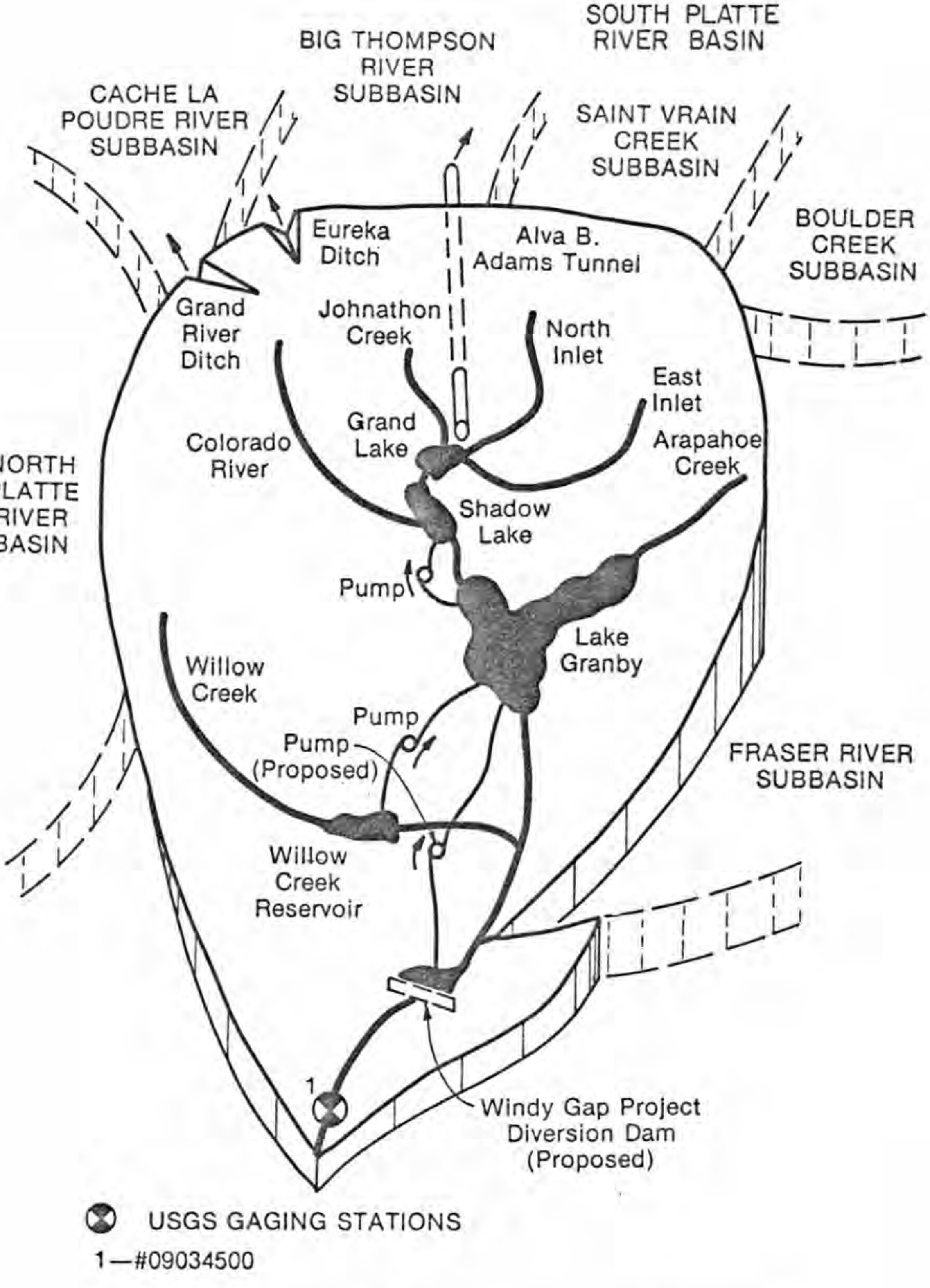


Figure 8-10: Schematic of the Colorado River-Mountains Subbasin.

8.2.2 *Transbasin Diversion Structures* - Three transbasin diversion structures export water from the Colorado River-Mountains sub-basin; they are the Grand River Ditch, the Eureka Ditch, and the Alva B. Adams Tunnel. All carry water to the South Platte River Basin. There are no imports of water to this sub-basin.

The Grand River Ditch - The Grand River Ditch is the oldest operating transbasin diversion between the Colorado and the South Platte River Basins. The structure intercepts the very high altitude runoff just under and along the west side of the Continental Divide and transports the water collected across the Continental Divide via La Poudre Pass, at an elevation of 10,190 feet, discharging into Long Draw Reservoir on the Cache La Poudre River. The North Feeder of the Grand River Ditch is 15 miles long, winding around the East Slope of the Never Summer Mountains; it has collection points on Baker Gulch and Red Gulch and on Mesquito, Lost, Big Dutch, Little Dutch, Saw Mill, Lulu, Lady, and Bennett Creeks. The South Feeder of the Grand River Ditch is 2 miles long and it diverts from Specimen Creek. The water rights for this ditch total 524.6 cfs (Johnson, 1976).

Construction on this ditch began in 1890. It was generally cut by hand into steep hill sides with the excavated material used to form the lower or outside bank. The first water was diverted in 1892. By 1908 the North Feeder was almost half complete, extending to Dutch Creek. Long Draw Reservoir was completed in 1929 with a capacity of 4,400 acre-feet. The North Feeder was further extended in the 1930's. In 1975 parts of the Ditch were lined and the capacity of Long Draw Reservoir was increased to 10,800 acre-feet.

The average annual diversion through the Grand River Ditch between 1934 and 1975 was 17,523 acre-feet per year. All records of yearly diversions through this ditch since 1896 are shown in Appendix B, Table B3-1.

Prior to 1975, during high runoff years, there was insufficient storage capacity to utilize the water right decree to the fullest extent. Long Draw Reservoir would fill early in the spring. Because flows in the South Platte River Basin would be high then also, demands were easily satisfied and since further imports through the Grand River Ditch could be neither used or stored they were not allowed.

Accroding to the U.S. Department of the Interior (1973), the recent 6,400 acre-foot expansion of Long Draw and the lining of parts of this ditch will increase the yield of the system by about 4,000 acre-feet annually. In addition, these improvements will provide a longer and more effective diversion season by making it easier to transport late season flows under the existing water rights. Analyses of the records of daily diversions over a 10 year period indicate that in high runoff years diversions could increase to the full extent of the 1975 Long Draw Reservoir storage increase (U.S. Department of the Interior, 1973). The Grand River Ditch is owned by the Water Supply and Storage Company. There is also the possibility that storage in Long Draw Reservoir will be further increased to capture still more of the high runoff year flows legally available under the present rights, of the Water Supply and Storage Company (Johnson, 1976).

The Eureka Ditch - The Eureka Ditch diverts waters from Tonahutu Creek, at an altitude of 11,850 feet, to Spruce Creek, a tributary of the Big Thompson River.

All available records of the yearly diversions through this ditch are shown in Appendix B, Table B3-2. The quantity diverted has averaged 82 acre-feet per year since 1950. The ditch is presently owned by the City of Loveland. The city has expressed a desire to sell it because of its deteriorating condition. The National Parks Service would like to buy it in order to revert the land back to its natural state, (Mullinix, 1976).

The Alva B. Adams Tunnel and the Colorado Big Thompson Project - The Alva B. Adams Tunnel is the key feature in the Colorado Big Thompson project (CBT). The project was constructed by the U.S. Bureau of Reclamation. The Northern Colorado Water Conservancy District (NCWCD) is the agency which contracts for and distributes the water from the project.

Historical Perspective. The concept of a transbasin diversion system capable of delivering large quantities of irrigation water from the Colorado River Basin to the agricultural lands in the South Platte River Basin originated more than 70 years ago. Several preliminary studies for such a project were conducted; these included a study by the State of Colorado in 1889, one by the United States Reclamation Service in 1904 and a private study in 1933 (U.S. Department of the Interior, 1959). The condition of chronic water shortage for much irrigated land in the basin with drought conditions in the early 1930's, precipitated definite action toward a federal project.

U.S. Bureau of Reclamation studies on what was to become the Colorado Big Thompson project began in 1935. The project was authorized by Congress in 1937 and construction began in 1938. On June 23, 1947 the first water was diverted through the Alva B. Adams Tunnel after interruption of World War II. The CBT project was completed in 1957.

Project Description. The principal features of the Colorado Big Thompson Project are shown in Figure 8-11. The key west slope storage facility is Lake Granby. Willow Creek Reservoir collects water from Willow Creek and pumps water to Lake Granby. Water is pumped from Lake Granby to Shadow Mountain Lake, flowing then to Grand Lake, where the intake for the Alva B. Adams Tunnel is located. Water levels, of both Shadow Mountain Lake and Grand Lake are maintained about constant, and so these lakes serve the project as "conduits" for CBT water. Green Mountain Reservoir, located on the Blue River was built as a part of the CBT project to provide replacement storage. From Grand Lake, the CBT water flows by gravity beneath the Continental Divide through the 13.1 mile Alva B. Adams Tunnel to the eastern slope, emerging in the Big Thompson River Sub-basin, about 4-½ miles southwest of the town of Estes Park. Here this water, at times augmented by Big Thompson River flows, is conveyed through canals, conduits, tunnels, regulating reservoirs, and hydroelectric power plants to Horsetooth Reservoir and Carter Lake, the principal east slope storage facilities. The specific facilities are seen in Figure 8-11. Water is released from these reservoirs for distribution through supply canals to the Cache La Poudre, and Big Thompson, Saint Vrain, Boulder and South Platte-Transition and plains sub-basins. From these streams the CBT water is then diverted through existing canal systems to provide supplemental irrigation water to some 720,000 acres of land included in the NCWCD service area.

The project includes 11 major reservoirs having a total capacity of almost 1 million acre-feet. West slope reservoirs of Shadow Mountain,

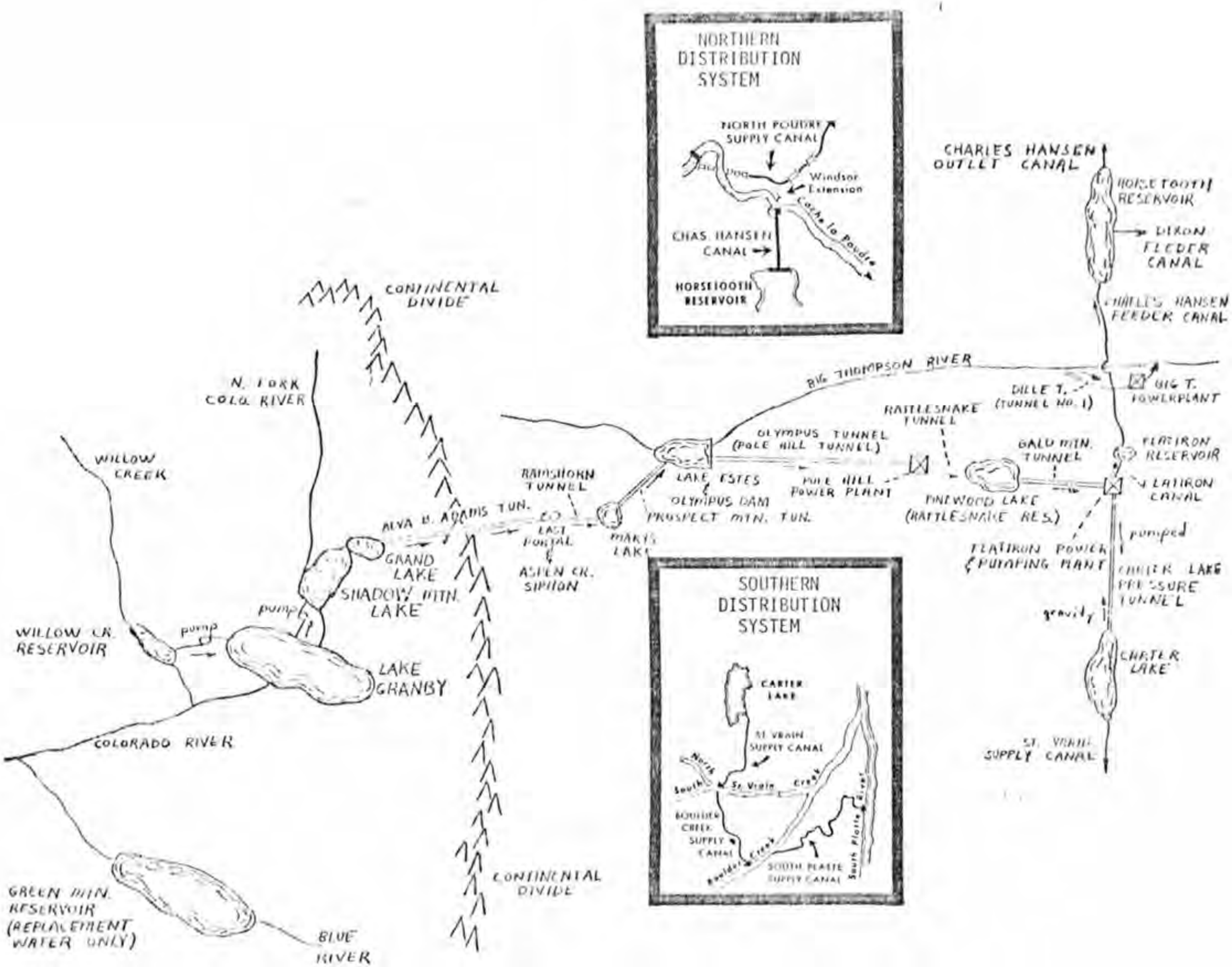


Figure 8-11: The Principal Features of the Colorado-Big Thompson Project.

Grand Lake, Granby, Willow Creek, and Green Mountain (replacement water only) have a capacity of 723,400 acre-feet (Simpson, 1976). East Slope Reservoirs of Mary's Lake, Estes Lake, Rattlesnake, Flatiron, Horsetooth and Carter have a capacity of 270,940 acre-feet (Simpson, 1976). Table 8-2 lists these reservoirs showing their storage limits. In addition, the intrastructure includes 27 dams and dikes ranging in height from 20 feet to 309 feet; 3 project pumping plants including the Flatiron plant which may be operated in reverse as a generating unit; 7 hydro-electric powerplants, including the Flatiron reversible pumping unit, with a total installed capacity of 183,950 kilowatts; 130 miles of canals and conduits, including the 13.1-mile transbasin diversion tunnel; and 780 miles of transmission line; and 42 substations.

Green Mountain Reservoir. The special role of Green Mountain Reservoir should be noted. It is located on the Blue River and holds 146,888 acre-feet of active storage. It was built to capture unappropriated spring runoff to provide 52,000 acre-feet for release during CBT diversions that would interfere with prior downstream rights, principally that of the Shoshone Power Plant. The remainder of the capacity was intended to provide storage for future municipal and agricultural growth in the Colorado River Basin within Colorado. The following discussion on the function of Green Mountain Reservoir is from the 1970 NCWCD annual report.

Green Mountain Reservoir on the Blue River was constructed as a part of the Colorado-Big Thompson Project as a result of negotiated agreements between East and West slope water user interests at the time the project was authorized for construction. These agreements became the "operating principles" for project operation on the Colorado River

Table 8-2 Reservoirs of the Colorado Big Thompson Project (USBR, 1968)

RESERVOIR	Total Capacity (acre feet)	Maximum Surface Area (acres)	Range in Storage (acre-feet)	
			Maximum	Minimum (Dead Storage)
Green Mountain	154,645	2,130	146,888	7,757
Willow Creek	10,553	303	9,067	1,486
Lake Granby	539,758	7,260	465,568	49,467
Shadow Mountain-Grand Lakes	18,369	1,853	17,863	506[1/]
Mary's Lake	927	42	887	42
Lake Estes	3,068	185	2,659	409
Pinewood Lake (Rattlesnake)	2,181	97	1,765	416
Flatiron	760	47	635	125
Carter Lake	112,230	1,144	108,924	3,306
Horsetooth	151,752	1,873	143,486	8,266
Project total	994,243	14,933	897,742	71,780

1/Shadow Mountain Lake only

and were so described in a Synopsis of Report on the project adopted by the U.S. Senate in 1937 as "Senate Document Number 80, 75th Congress." Green Mountain Reservoir is the key to successful fulfillment of these operating principles. It serves three vital functions of special interest to water users on both sides of the Continental Divide. Of primary significant to District water users, the reservoir provides 52,000 acre-feet of replacement water to protect the project's diversions at Granby and Willow Creek reservoirs. Some of the water that is physically available for diversion through Adams Tunnel would have to be by-passed in favor of senior, downstream appropriators, if it were not for this replacement storage. A second function that is little understood by District water users and little appreciated by water users on the Colorado River, is the 100,000 acre-feet of compensatory storage provided for the benefit of West slope appropriators. At no cost to them, irrigators and domestic water users on the Colorado River below Green Mountain may use releases of this water to fill natural shortages of streamflow. This water supply would not now be available to them without the Colorado-Big Thompson. All water released from the reservoir is used to produce hydroelectric energy, and this is the third man function of Green Mountain. The hydropwer thus produced, together with power generated at the other power plants on the East Slope, is sold; and revenues therefrom are used to repay project construction and operating costs not assigned to the District for repayment.

Project Yields. The original studies and the 1937 report on the Colorado-Big Thompson Project anticipated an average annual yield of 310,000 acre-feet of water based on the 1900-1936 period of study. Later studies made for a 1952 report indicated the yield would be 257,700 acre-feet annually during a climatic period similar to the years 1920 through 1947. This latter period is considered to be more representative of long range conditions (U.S. Department of the Interior, 1959).

The existing features of the CBT project were designed for an average annual diversion of 310,000 acre-feet. The annual diversions from the Colorado River Mountains sub-basin through the Alva B. Adams Tunnel have averaged 227,626 acre-feet since the completion of its east slope storage facilities in 1957. Willow Creek has been the source of 35,558 acre-feet of the CBT supply while the remainder, 192,068 acre-feet, has come from the mainstem of the Colorado River. All records of the yearly exports through the Alva B. Adams Tunnel since its initial diversion in 1947 are shown in Appendix B, Table B3-3.

The 52,000 acre-feet of replacement storage provided at Green Mountain Reservoir in accordance with the East slope—West slope agreements formalized in Senate Document 80 was established as the quantity of replacement storage needed to permit average annual diversions of 310,000 acre-feet through Adams Tunnel. So far, however, the watershed above the project collection system has produced an average divertable quantity of only 249,635 acre-feet. This means that there is at present 60,365 acre-feet of average diversion capacity in the system which is not being used and for which replacement storage has already been provided (NCWCD, 1970).

The average annual "system loss" of the CBT project, which includes evaporation and seepage losses from all its reservoirs and canals, as well as east slope water deliveries which exceed the amount ordered, is approximately 40,000 acre-feet per year (NCWCD, 1970, 1975). Table 8-3 shows the 1970 CBT project deliveries to the South Platte River Basin.

Table 8-3 Colorado-Big Thompson Deliveries to the South Platte River Basin as Ordered and as Measured for 1970 (NCWCD, 1970).

Delivery Point	Ordered Acre-feet	Delivered Acre-feet	Over Delivery	%
Cache La Poudre River	67,288	68,122	894	1.3
Big Thompson River	35,459	35,465	6	0
Little Thompson River	7,122	7,217	95	1.3
St. Vrain River	14,725	14,996	271	1.8
Boulder Creek	6,283	6,575	292	4.6
Canal Turnouts	21,400	21,524	124	0.6
Total	152,217	153,899	1,682	1.1

These amounted to 153,899 acre-feet. In that water year the Alva B. Adams Tunnel brought 204,600 acre-feet of Colorado River water under the Continental Divide (United States Geological Survey, 1970b). The difference, 50,701 acre-feet, went to storage on the East slope. Also in 1970 west slope storage in Willow Creek and Granby Reservoirs increased by 85,680 acre-feet, (United States Geological Survey, 1970b). Replacement released from Green Mountain Reservoir required during the 1970 water year to offset CBT diversions from the Colorado River-Moutains sub-basin amounted to 20,677 acre-feet (NCWCD, 1970).

Although the impetus for the CBT Project was to provide supplemental irrigation water to irrigators in the South Platte River Basin there are currently a variety of beneficiaries. In addition to providing supplemental irrigation water for 720,000 acres of land within the NCWCD, more than a dozen municipalities, approximately twenty rural domestic distribution agencies, and many industries own shares of this water (Engineering Consultants Incorporated, 1974). Figure 8-12 shows the trend toward municipal-domestic use of the Colorado-Big Thompson Project water since 1957.

The Windy Gap Project. Presently plans are progressing to develop the Windy Gap Project. This project would be an adjunct to the Colorado-Big Thompson Project, making use of its presently unused capacity to store and transport water. This project would divert water from the Colorado River-Mountains Sub-basin just below the confluence of the Fraser and Colorado Rivers and pump it to Granby Reservoir for storage Figure 8-13 shows the general features of the project while Table 8-4 provides more specific detailed information regarding sizes of facilities. The yield of the project is estimated at 54,000 acre-feet

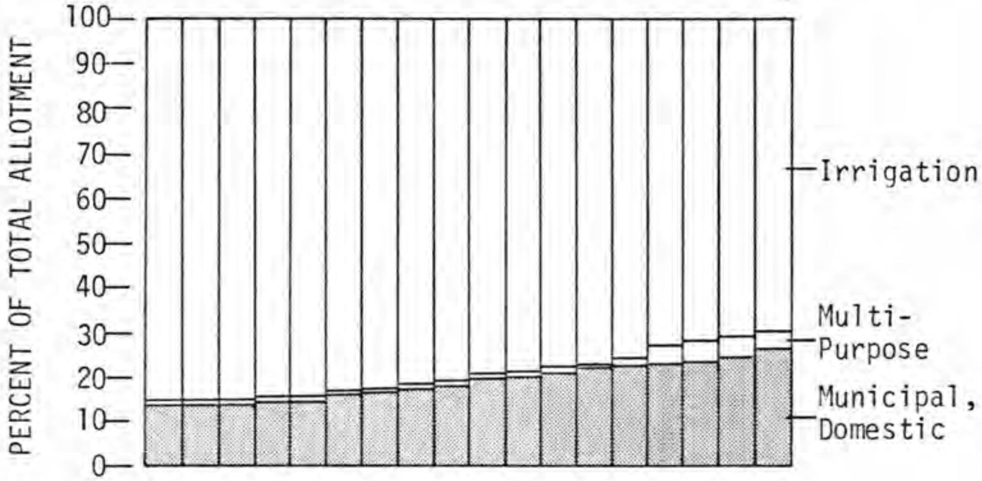


Figure 8-12: The Changing Character in the Use of Colorado-Big Thompson Project Water from 1957 to 1974 (Barkley, 1974).

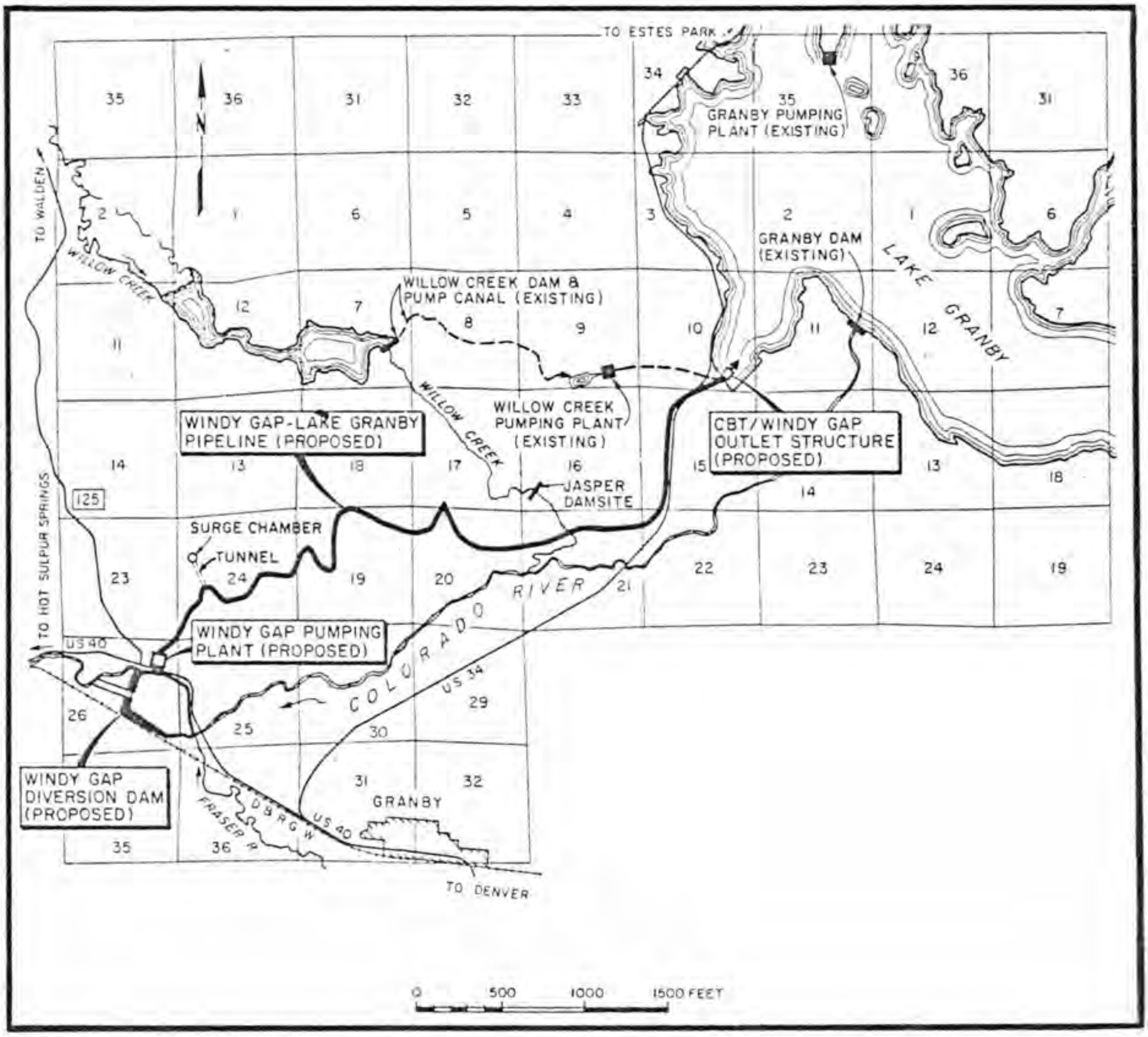


Figure 8-13: General Sketch of the Windy Gap Project (From NCWCD, 1975).

Table 8-4 Windy Gap Project Features (Simpson, 1976).

PROJECT FEATURES

WINDY GAP DIVERSION DAM

Embankment Section	
Length (ft)	3,375
Volume of fill (cu yd)	107,800
Service Spillway Section	
Discharge capacity (cfs)	63,000
Length (ft)	1,400
Pool Impounded	
Volume (ac-ft)	∿300
Surface Area (ac)	120
Outlet Works (Bypass Structure)	
Discharge Capacity (cfs)	75
Length of 42-inch-diameter, reinforced-concrete pipe (ft)	160

WINDY GAP-LAKE GRANBY PIPELINE

Pipeline	
Capacity (cfs)	400
Length (ft)	29,400
Diameter (ft)	8
Surge Chamber and Tunnel	
Chamber Length (ft)	500
Chamber diameter (ft)	12
CBT-WGP Outlet Works	
Discharge capacity (cfs)	740
No. of 8-ft x 8-ft control gater	2
Conduit length (ft)	750
Conduit diameter (ft)	10
Discharge channel length (ft)	5,000

WINDY GAP PUMPING PLANT

Maximum Discharge Capacity (cfs)	400
Installed Capacity (hp)	27,700
Installed Capacity (kW)	21,000
Maximum Total Dynamic Head (ft)	546
Number of 60-cfs Units	4
Number of 30-cfs Units	2

annually (Simpson, 1976). The project is to be administered by a municipal sub-district of the NCWCD, consisting of the cities of Boulder, Estes Park, Fort Collins, Greeley, Longmont, and Loveland. Each city was to have equal ownership. However, in 1975 the City of Fort Collins transferred all of its shares, and the cities of Estes Park and Loveland transferred one half of their respective shares of this project to the Platte River Power Authority (NCWCD, 1975).

The Windy Gap project is expected to start deliveries in 1980. Table 8-5 shows the activities involved in the completion of the project and the critical dates. As of December 1976, the NCWCD had adhered to this schedule, (Simpson, 1976). No further expansion plans for the CBT system are envisaged presently by the NCWCD (Reeb, 1976).

8.3 The Fraser River Sub-basin

The Fraser River begins at the western edge of the Continental Divide at elevations of up to 13,000 feet. It flows north-northwest for about 25 miles losing more than 5,000 feet in altitude, joining the Colorado River below Granby. Its major headwater tributaries are Saint Louis, Vasquez, Ranch, and Cabin Creeks. Its drainage area above USGS gaging station 340 near Granby is 285 square miles. Figure 8-14 shows the key features of the sub-basin.

There are about 6,500 acres of irrigated land in this sub-basin (USGS, 1964). Two diversion structures export portions of the native surface flows of this sub-basin. The most important is the Moffat water Tunnel. One diversion structure imports water to the sub-basin from the Williams Fork River. It is an extension of the collection system of the Moffat water tunnel. There are no major reservoirs in this sub-basin.

Table 8-5 The Windy Gap Project Schedule of Activities (from NCWCD, 1975).

WINDY GAP PROJECT Activity	Critical Path Schedule Data
Submittal of Windy Gap Project, Phase I - Environmental Progress Report	December 31, 1975
Submittal of Windy Gap Project, Phase I - Evaluation Study	February 13, 1976
Approval of development scheme by SUBDISTRICT	March 12, 1976
Investigation of possibility of obtaining additional Windy Gap water rights	March 31, 1976
Negotiation of engineering (final design) contract	March 31, 1976
Establishment of environmental criteria and preparation of project description	March 31, 1976
Completion of environmental field and office studies and submittal of draft of environmental assessment report to USBR	December 31, 1976
Approval of project operation by the USBR	December 31, 1976
Approval of project design by the State Engineer	December 31, 1976
Final approval of environmental impact statement	October 31, 1977
Award of contract for major electrical and mechanical equipment	October 31, 1977
Completion of final design, specifications, and contract drawings and documents for all civil works	December 31, 1977
Acquisition of all land required for the project	December 31, 1977
Completion by the USBR of design, specifications, and contract drawings and documents for new outlet works for Willow Creek and Windy Gap discharge into Lake Granby	December 31, 1977
Award of construction contract for Windy Gap Project	December 31, 1977
Start of construction by Mountain Parks Electric on project power facilities	March 1, 1978
Start of project construction	April 1, 1978
Start of pump and motor installation	August 1, 1979
Completion of all project construction	December 31, 1979
Start of diversion, pumping and conveyance of Windy Gap water for SUBDISTRICT credit	April 1, 1980

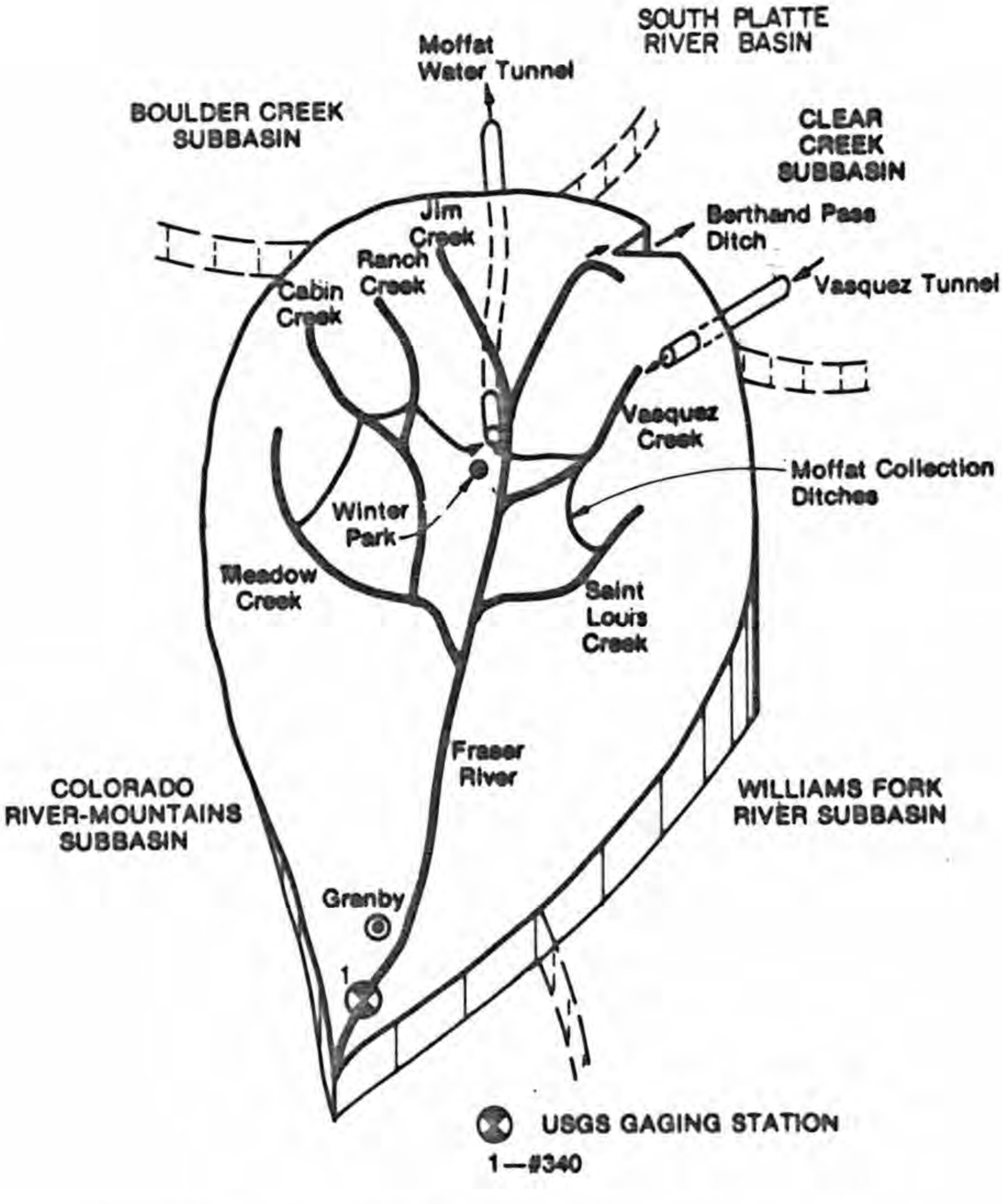


Figure 8-14: Schematic of the Fraser River Subbasin

8.3.1 *Surface Water Supply* - Annual precipitation in the sub-basin ranges from 40 inches per year in the headwaters area to about 16 inches in the lower elevation areas (National Oceanic and Atmospheric Administration, 1974).

Most of the annual runoff occurs during the spring from the melting of the winter snowpack. The flows recorded at USGS gaging station #340, "Fraser River at Granby, Colorado," are given in Table C2-2. The native runoff of the Fraser River is estimated to average 161,144 acre-feet per year, Table A2-4 shows how this value was obtained. The 1970 native runoff was 190,204 acre-feet, or 118.03% of average; computations are shown in Table A2-5. The average native runoff during the 1953-1956 four year drought period was 143,338 acre-feet per year, or 88.95% of average; computations are shown in Table A2-6.

8.3.2 *Transbasin Diversion Structures* - Two transbasin diversion structures export water from the Fraser River Sub-basin; they are the Moffat Water Tunnel and the Berthoud Pass Ditch. Both divert water to the South Platte River Basin.

Another structure, the Vasquez Tunnel, imports water from the adjacent Williams Fork River via the Jones Pass Tunnel. These tunnels are extensions of the collection system which delivers water to the Moffat Water Tunnel.

The Moffat Water Tunnel - Some 60 years ago Denver began seeking sources of water from the Colorado River. It was clear that the South Platte would not be able to supply both the agricultural uses and the growth seen in the City of Denver.

In 1921 engineering surveys were initiated, to ascertain possibilities for obtaining water from the Colorado River Basin. Progress was slow, however, due to legal difficulties and financial problems (U.S. Department of the Interior, 1959).

Today the water supply system for Denver includes four transbasin diversion tunnels, two reservoirs, and miles of ditches, which serve various purposes. Figure 8-15 shows Denver's existing and proposed water supply development within the Colorado River Basin. The Moffat Water Tunnel was the first of these transbasin diversion structures. Figure 8-16 shows the Moffat system in greater detail. The configuration of the Williams Fork collection system (i.e., the relationship between the Jones Pass Tunnel and the Vasquez Tunnel) should be noted.

Project Description. On January 3, 1929, the Denver Water Board obtained a 99-year lease on the 6.4 mile, 8 foot diameter pilot bore of the Moffat Railroad Tunnel which had been constructed 2 years earlier (Denver Board of Water Commissioners, 1969). By 1936, with the assistance of the Federal Public Works Administration, a portion of the pilot bore, now called the Moffat Water Tunnel, was enlarged and lined and the first water was delivered. At that time the collection system for the Moffat Water Tunnel included 3 collection ditches taking water from the main stem of the Fraser River immediately below the confluence of Jim Creek, and from Vasquez and Ranch Creeks. However, only the first few hundred feet of the Ranch Creek collection ditch were used as it was still under construction (USGS, 1954).

By 1950 the Ranch Creek Collection Ditch had extended to the Middle Fork of Ranch Creek. The ditch was extended to the North Fork of Ranch Creek by 1959. Also construction had begun about 1950 to extend the Vasquez collection Ditch to intercept flows of Saint Louis Creek; this was completed by 1959.

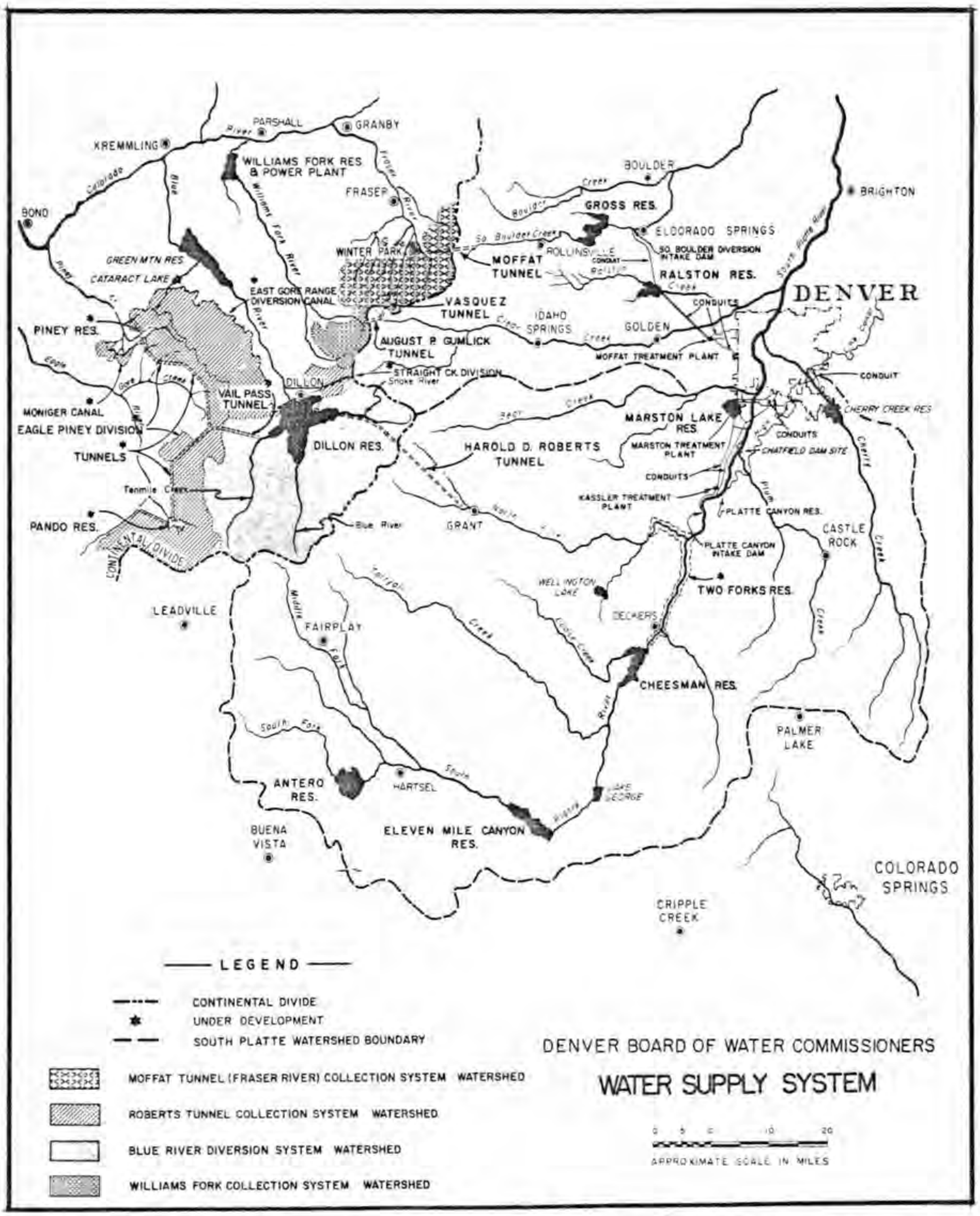


Figure 8-15: Water Supply System of the Denver Water Department (Denver Board of Water Commissioners, 1970).

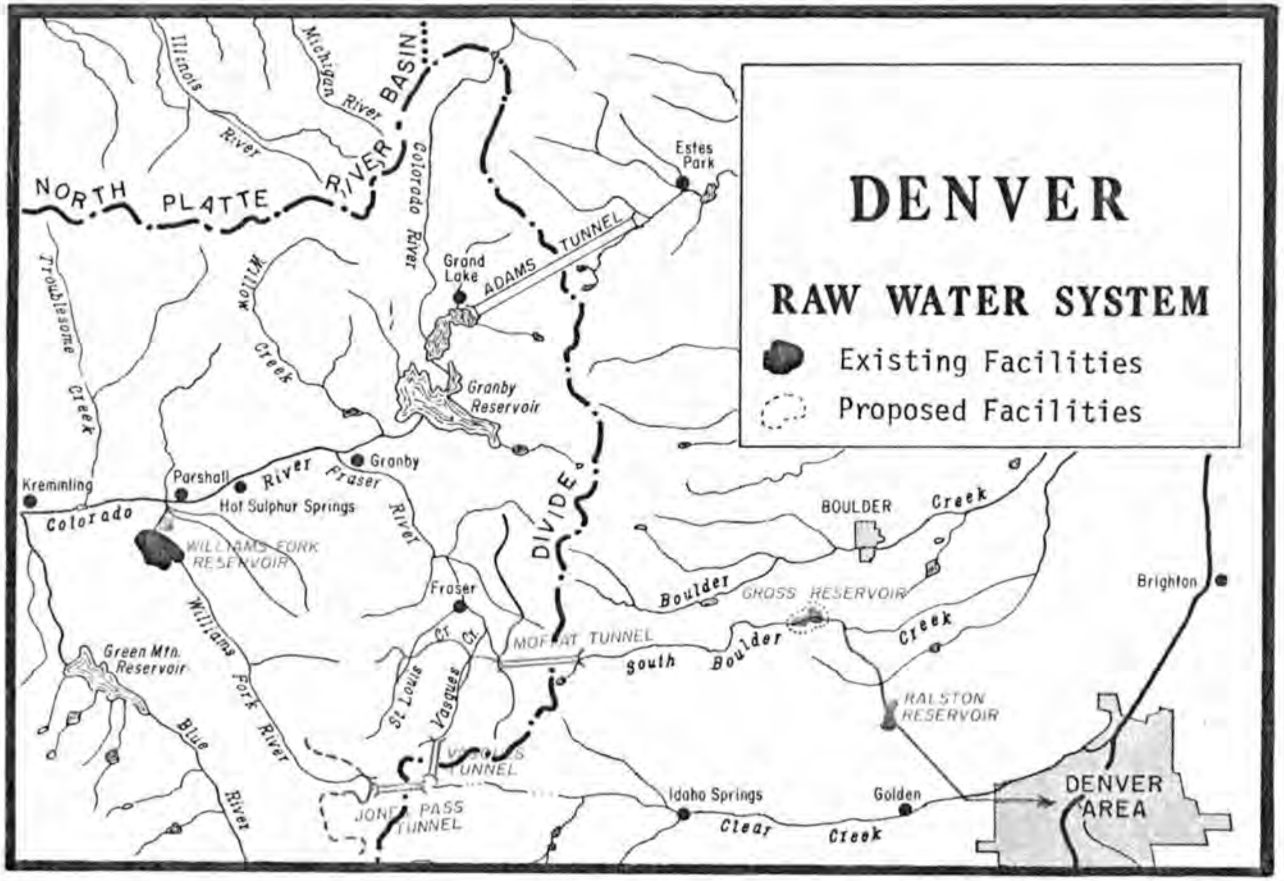


Figure 8-16: The Moffat Water Tunnel and its Collection System (from the USBR, 1959). Note its use of Collection ditches as opposed to the impoundment-diversion method of the Alva B. Adams Tunnel-CBT Project. Storage is provided for the Moffat Tunnel diversions only on the east slope.

Thus by 1959 the Fraser River collection system was 26.5 miles long, and included concrete and steel pipes, tunnels, siphons, and canals. Some 5.45 miles of the Vasquez collection canal, and Saint Louis Creek, were covered so that the system could function during the winter (Denver Water Board, 1969). In 1975 the Ranch Creek Collection Ditch was extended further to Cabin, Hamilton, and Meadow Creeks; which were the last of the untapped tributaries of the Ranch Creek drainage.

The expansion of the Moffat collection system to include diversions from the Williams Fork River Sub-basin began in 1957. A renovation of the Moffat Water Tunnel was began then also; it was enlarged to a diameter of 10 feet 6 inches, and it was fully concrete lined, with a length of 6.1 miles, and it was designed to be operated under pressure. The present flow capacity is 1,280 cfs. The intake on the Fraser River side has an elevation of 9,091 feet, while the elevation of portal on Boulder Creek is 9,205 feet, (Denver Water Board, 1969).

Since 1940 the Jones Pass Tunnel had diverted water from the Williams Fork River to Clear Creek, a tributary of the South Platte River. With the completion of the Vasquez Tunnel in 1958, the Jones Pass Tunnel was not used for this diversion. Instead, it was tied into the Vasquez Tunnel, as shown in Figure 8-16. The water formerly diverted from Williams Fork to Clear Creek, via the Jones Pass Tunnel, was brought to the Fraser River via the Jones Pass Tunnel-Vasquez Tunnel system, and then to the South Platte basin, via the Moffat Water Tunnel. The history of the Jones Pass Tunnel prior to 1958 when it became a component of the Moffat Water Tunnels collection system can be found in section 8.4.2. The Vasquez Tunnel's entrance portal lies immediately adjacent to the Jones Pass tunnels exit portal of 10,310 feet. It has a 7 foot horseshoe section, is 3.4 miles long, and has the capacity to deliver 550 cfs. The Vasquez Tunnel lets water into Vasquez Creek at 10,210 feet where it is picked up downstream by the Vasquez Collection Ditch. There this water is delivered to the Moffat Water Tunnel where, once again, it is transported to the South Platte River Basin, this time to South Boulder Creek as seen in Figure 8-16.

From the east portal of the Moffat Water Tunnel the water flows down South Boulder Creek to Gross Reservoir. Here it is stored and regulated. This reservoir was completed in 1954; its present capacity is 43,064 acre-feet (Denver Water Board, 1969).

Upon release from Gross Reservoir, the water is diverted from South Boulder Creek approximately 6 miles downstream at the South Boulder Diversion Intake Dam. It is transported to Ralston Reservoir through a diversion conduit nearly ten miles long, consisting of six siphons, five tunnels and six flumes, plus concrete liquid and unlined open channels and canals.

Ralston Reservoir located on Ralston Creek, was completed in 1937, has a capacity of 11,272 acre-feet and is used as a regulating reservoir and serves also as a settling basin (Denver Water Board, 1969). The water is delivered from Ralston Reservoir to the Moffat treatment plant via two conduits.

Project Yields. Between 1960 and 1974, the most recent (and longest) period when the Moffat water tunnels collection system was not in the state of expansion, total exports to the South Platte River basin averaged 54,332 acre-feet per year. The Fraser River-Williams Fork split was 49,782 acre-feet and 4,540 acre-feet, respectively. All records of the yearly diversions through the Moffat water tunnel, from each of the Fraser and Williams Fork River Sub-basins, since the initial diversion in 1936, are shown in Appendix B, Table B3-4.

Under Colorado water law, if Denver can not put her west slope diversions to direct use or storage, they cannot be made. Presently, Denvers average annual diversions through the Moffat water tunnel are still 51.5% less than the average annual yield of her existing absolutely decreed rights within the Fraser and Williams Fork River Sub-basins. With the existing Moffat collection system, these rights are estimated to yield 112,000 acre-feet per year on the average and 54,200 acre-feet per year during a drought (Denver Water Department, 1975).

Some of Denver's water that has been brought through the Moffat Tunnel has been let out of Gross Reservoir to flow into South Boulder Creek and out of Ralston Reservoir to flow into Clear Creek, where it travels to the South Platte River in exchange for water stored in Cheesman and Eleven Mile Reservoirs or for direct exchange (U.S. Department of Interior, 1959).

The Federal Court, in Civil Case No. 2782 (1955) recognized the right of Englewood (independent of Denver) to divert up to 19,500 acre-feet of water annually from the Fraser River sub-basin if the city requires and if it can use the water (USBR, 1959). Englewood had previously purchased conditional decrees of the Moffat Tunnel development company that were held on Hamilton, Hurd, Cabin and Meadow Creeks, all tributaries of Ranch Creek. The 1975 expansion of the Ranch Creek Collection Ditch, developed in part by Englewood, is the means she will use in exercising her right to Fraser River water. Englewood's present absolutely decreed water rights, which have priority dates of July 2, 1932, are expected to yield about 5,000 acre-feet annually (Denver Water Department, 1975). Englewood's intake on the South Platte River is located above the Moffat water tunnel project discharge to the Denver Metropolitan Area. Exchanging with Denver for its Ranch Creek water allows Englewood to divert South Platte River flows, otherwise available to Denver, at this intake.

Proposed Expansion - The Williams Fork Collection System Expansion and the Enlargement of Gross Reservoir - The Denver Water Board has plans for the expansion of the collection system of the Moffat Water Tunnel. This would divert, on the average, an additional 18,000 acre-feet per year from the Williams Fork River sub-basin. The rights for this water have been conditionally decreed and assigned a priority date. The Forest Service is presently preparing an Environmental Impact Statement on the project (Robert Fischer, 1976).

According to Mr. Robert Fischer, Water Resource and Development Officer of the Denver Water Board, given the set backs bound to occur in such an undertaking, the earliest this expansion could come on line is around 1981 while at worst, the latest will probably be 1986 (Robert Fischer, 1976).

There is also a possibility that Gross Reservoirs storage capacity will be increased. This will allow additional diversions through the Moffat Tunnel by providing storage to bridge the gap between times when water is divertable and when it is needed by Denver. However, Mr. Fischer reports that the expansion of this reservoir would be an extremely expensive project. The cost per unit volume of water made available each year would be very high relative to other alternatives.

The Berthoud Pass Ditch - This ditch, also known as the Church ditch, diverts water at 11,310 feet in altitude from First Creek, a tributary of the Fraser River. It transports this water through Berthoud Pass to Hoop Creek, a tributary of the west fork of Clear Creek.

The first water was brought through this ditch in 1910. The amount diverted has averaged 615 acre-feet per year. All yearly diversions to date by the Berthoud Pass Ditch can be found in Appendix B, Table B3-5. The ditch is four miles long and was constructed in 1909 for the importation of irrigation water. It has a 1902 absolutely decreed direct flow right of 43.40 cfs (Denver Water Department, 1975). Presently, the City of Golden and the Farmers Reservoir and Irrigation Company (irrigation water supplier) each own 26.7 cfs of the water rights. No plans for expansion are underway and no conditional decrees for more water have been sought (Davison, 1976).

8.4 The Williams Fork River Sub-basin

8.4.1 *Surface Water Supply* - The Williams Fork River sub-basin encompasses a drainage area of 184 square miles, above gaging station #09937500, "Williams Fork near Parshall, Colorado." The gaging station is located 6.3 miles upstream from the confluence of the Williams Fork River with the mainstem of the Colorado River. Figure 8-18 shows the stream in relation to other tributaries of the Upper Colorado mainstem. Figure 8-17 is a schematic of the sub-basin showing its major features. The stream originates on the western edge of the Continental Divide sharing this common boundary with the South Platte River basin. From elevations attaining 13,375 feet, the Fraser River flows North-Northwest for about 35 miles, losing more than 5,500 feet in altitude. Its major headwater tributaries are its South Fork, and Bobtail, and Darling Creeks.

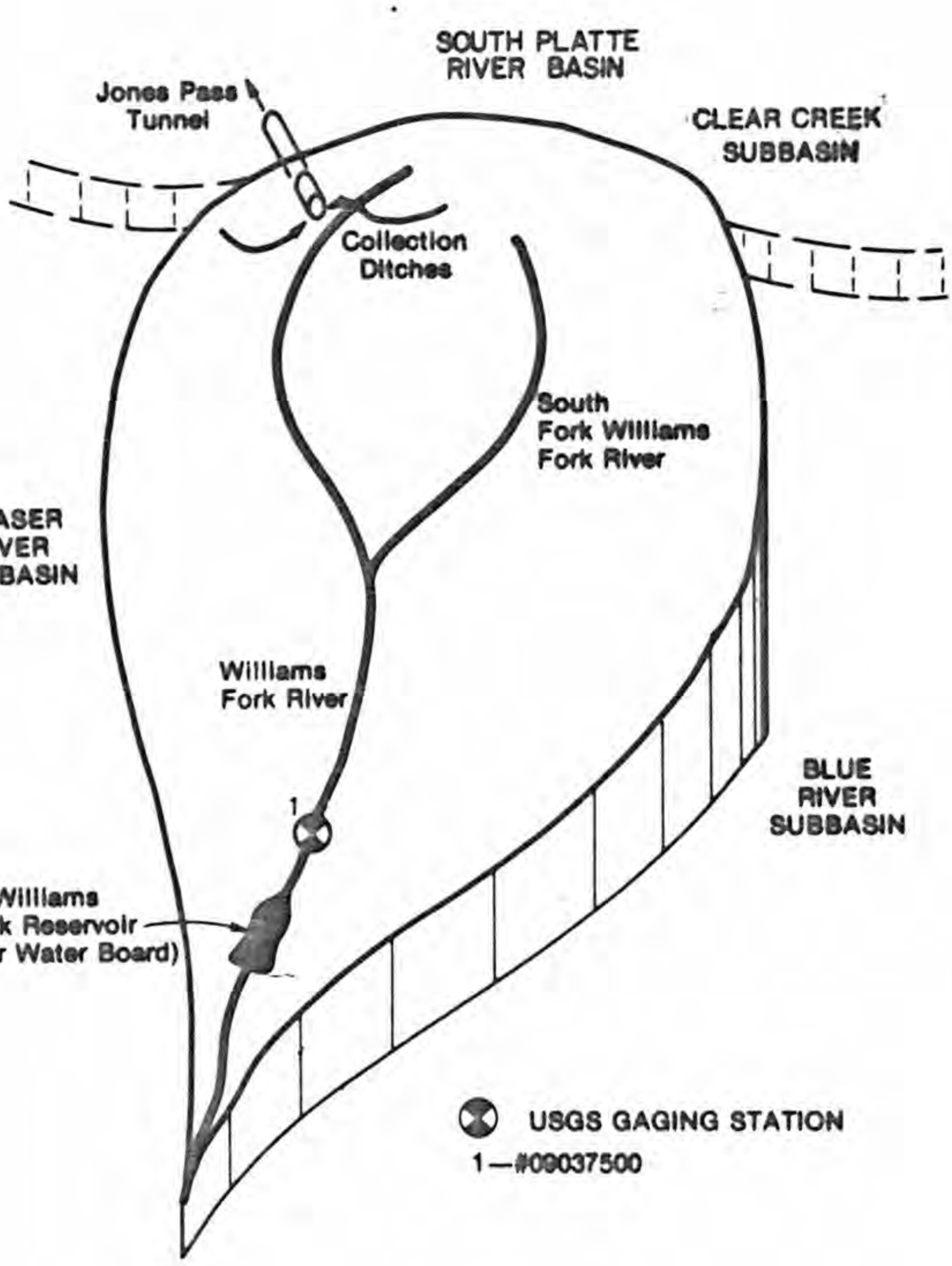


Figure 8-17: Schematic of the Williams Fork River Subbasin

There are approximately 1,300 acres of irrigated land above the gaging station (USGS, 1974). There is one diversion structure which exports the native surface water of this sub-basin, the Jones Pass Tunnel; discussed in the previous section. There are no diversion structures importing water to this sub-basin from foreign drainages. One storage feature, the Williams Fork Reservoir, is located on the stream, below the gaging station. It was built to provide replacement water for diversions through the Jones Pass Tunnel.

The precipitation in the headwaters area of the Williams Fork River average 40 inches per year and about 16 inches per year in its lower elevations, (National Oceanic and Atmospheric Administration, 1974). The surface water supply of this sub-basin is derived principally from snowmelt in the spring. The flows recorded at the USGS gaging station, #09037500, "Williams Fork near Parshall, Colorado," are seen in Table C2-3. From these records the average native surface waters of the Williams Fork River sub-basin is estimated to be 109,909 acre-feet per year; computations are shown in Table A2-7. The 1970 surface water supply of this sub-basin is estimated in Table A2-8 to have been 114,452 acre-feet or 104.13% of average. The native surface water supply available to this sub-basin during the 1953-1956 four year drought period is estimated to average 70,573 acre-feet per year or 64.21% of average; computations are shown in Table A2-9.

8.4.2 *Transbasin Diversion Structures* - The Jones Pass Tunnel is the only transbasin diversion structure which exports water from the Williams Fork River sub-basin. It delivers water to the Clear Creek sub-basin of the South Platte River basin. There are no imports of water to this sub-basin from other river drainages.

The Jones Pass Tunnel - The Jones Pass Tunnel, also known as the AKA August P. Gumlick Tunnel and as the Williams Fork Tunnel, was constructed during the period 1936-1940 by the Denver Department of Parks and Improvements. It was intended to provide dilution water for the South Platte River below a sewage disposal plant then being constructed. However, certain associated features, principally a regulatory reservoir on Clear Creek, were never constructed. Litigation developed over the White Cap Canal, another project feature, which would have diverted the water from Clear Creek to the South Platte River (United States Bureau of Reclamation, 1959). Consequently, the tunnel has never been used for its intended purpose but has been used by the Denver Water Board in conjunction with the Vasquez and the Moffat Tunnels since 1959.

The west portal of the Jones Pass Tunnel is 10,400 feet while its east portal is 10,313 feet; it crosses the continental divide under Jones Pass. The tunnel bore of 2.9 miles was completed in 1940; it was lined in 1957. The capacity is 550 cubic feet per second, which is equivalent to 1,091 acre-feet per day through a seven-foot horseshoe type cross section (Denver Board of Water Commissioners, 1969).

The collection system for the tunnel is in the upper drainage of the Williams Fork River. Water is diverted into the tunnel and flows by gravity into the West Fork of Clear Creek in the South Platte River basin.

To efficiently operate the Williams Fork collection system without harming downstream prior appropriators, replacement water storage was required. This was accomplished by the construction of Williams Fork Reservoir in 1938 on the Williams Fork River, two miles above its confluence with the main stem of the Colorado River. By storing unappropriated spring runoff, Jones Pass Tunnel could divert essentially at will knowing that calls on the river could be met by equal releases from this reservoir. The Williams Fork Reservoir was enlarged in 1956-1959 from 7,180 acre-feet to 96,822 acre-feet. It now functions as a replacement reservoir exchanging water for Denver Water Board Diversions in other parts of the Colorado River Basin as well.

The Vasquez Tunnel was completed in 1958, and since 1959, it has collected all of the Jones Pass Tunnel diversions and transported them back across the Continental Divide to the Fraser River Sub-basin. There this water flows down a tributary of the Fraser River, Vasquez Creek, to a collection ditch which connects to the Moffat water tunnel. The Moffat Water Tunnel then brings this water back into the South Platte River Basin, via South Boulder Creek. These two tunnels are now considered a component of the collection system of the Moffat water tunnel, as noted in the previous section.

Since its initial diversion in 1940, the Jones Pass Tunnel has exported an average of 5,510 acre-feet annually. All yearly diversions to date by this tunnel can be found in Appendix B, Table B3-6.

Prior to 1959, most of the water diverted by the Jones Pass Tunnel was exchanged for South Platte River water that had been stored by Denver out-of-turn in Cheesman or Elevenmile Canyon Reservoirs. Presently, the Denver Water Board has plans to expand the Jones Pass Tunnels Collection System (See Section 8.3.2).

8.5 The Blue River Sub-basin

8.5.1 *Surface Water Supply* - The Blue River encompasses a drainage area of 511 square miles above gaging station #09053500, "Blue River above Green Mountain Reservoir, Colorado." This gaging station is located approximately 18 miles upstream from the confluence of the Blue River with the mainstem of the Colorado River.

Originating of the western edge of the Continental Divide, the Blue River shares common boundaries with both the South Platte and Arkansas River Basins. From elevations in excess of 14,000 feet, the Blue River flows North-Northwest for about 35 miles, losing more than 6,000 feet in altitude. Its major headwater tributaries are Straight Creek, and Tenmile Creek, and the Snake River.

There are approximately 4,000 acres of irrigated land in this sub-basin (USGS, 1971). There are seven diversion structures which export the native surface flows of this sub-basin to both the South Platte River basin and Arkansas River basin. There are no major imports of water to this sub-basin. Dillon and Green Mountain Reservoir are two storages features of the sub-basin. Dillon Reservoir is a component of Denvers Harold D. Roberts Tunnel collection system. Green Mountain Reservoir was built to provide replacement water for diversions from the Colorado River via the CBT project.

The precipitation in the headwaters area of the Blue River averages 40 inches per year and about 16 inches per year at the lower elevations (National Oceanic and Atmospheric Administration, 1974).

The surface water supply of this sub-basin is characteristic of all the high mountain tributaries of the upper Colorado River. Run-off occurs mostly during the spring melt of the winter snows. The native surface water supply of the Blue River Sub-basin can be estimated from the flows recorded at the USGS gaging station at its mouth, "09053500, "Blue River above Green Mountain Reservoir, Colorado." These records are summarized in Table C2-4. Using these data in Table A2-10, the average native surface water supply of the Blue River sub-basin is estimated to be 323,481 acre-feet per year. The 1970 surface water supply of this sub-basin was 399,512 acre-feet or 123.50% of average; computations are seen in Table A2-11. The native surface water supply during the 1953-1956 four year drought period averaged 271,789 acre-feet per year, or 84.02% of the long term average; computations are given in Table A2-12.

8.5.2 *Transbasin Diversion Structures* - The first foreign water supplied to the South Platte River basin came from the Blue River. In 1860 a transbasin diversion ditch was constructed to provide water for mining in the area around Fairplay (Radosevich et al., 1976). While it appears that this ditch was reopened and extended in 1912 to provide water for Denver (Radosevich et al., 1976) no records of its diversions or final demise can be found.

Six other transbasin diversion structures have, at one time or another, exported water from the Blue River to the South Platte River basin; these include the East Hoosier Pass Ditch the West Hoosier Pass Ditch; the Boreas Pass Ditch, and the Vidler, Harold D. Roberts, and Hoosier Pass Tunnels. The East and West Hoosier Pass Ditches have been closed but all others remain active. Figure 8-18 is a schematic diagram of the sub-basin showing its major features.

In addition, the Blue River Sub-basin has supplied water to the Arkansas River Basin. This was done through the Freemont Pass Ditch until the water right was put to use within the Blue River Sub-basin instead.

There is one minor diversion structure importing water to this sub-basin, it is for mining development along Tenmile Creek. It brings

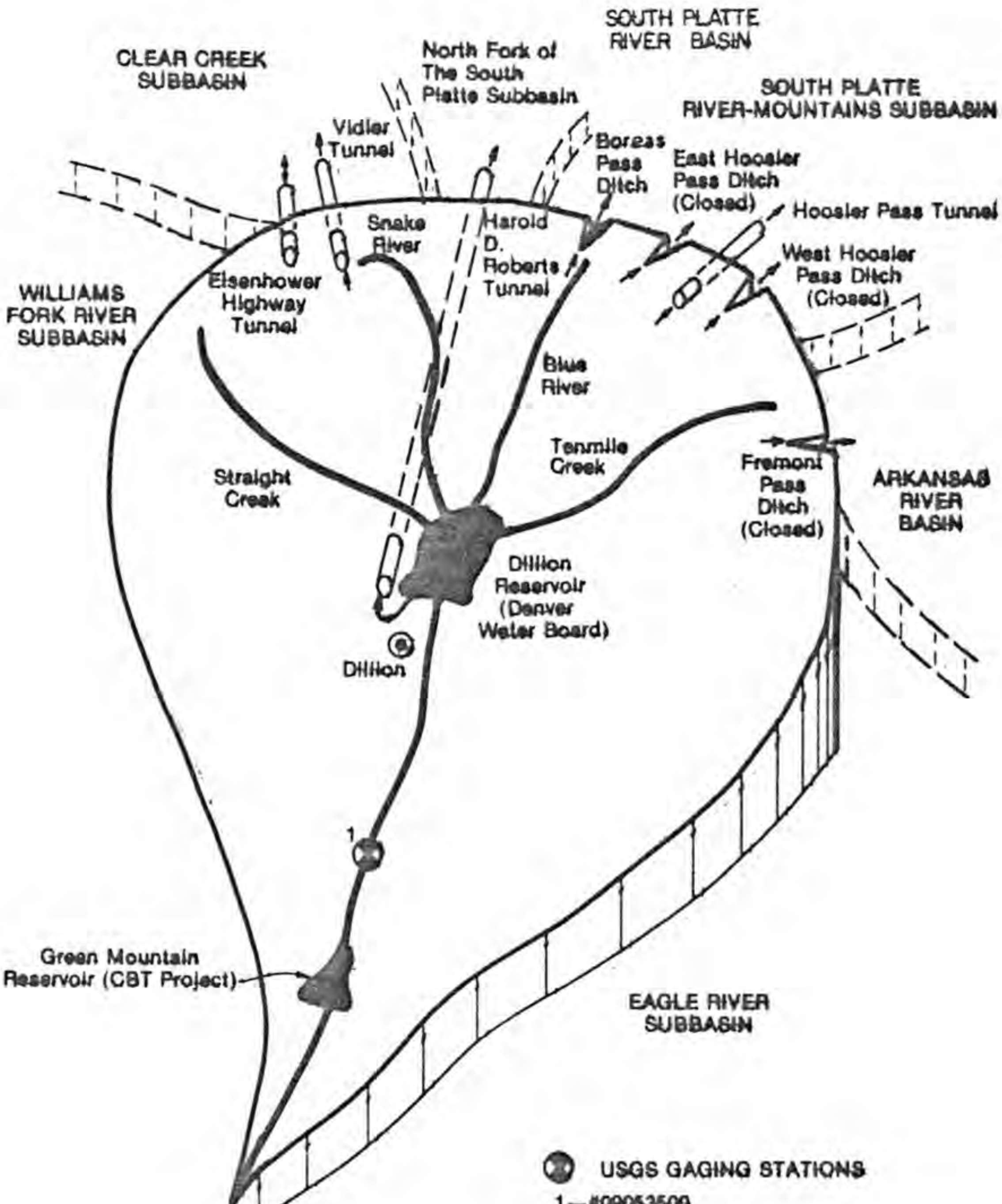


Figure 8-18: Schematic of the Blue River Subbasin

water in from Robinson Reservoir (capacity 2,520 acre-feet) in the Eagle River Sub-basin. No records of the diversions are available (USGS, 1954).

The Vidler Tunnel - The Vidler Tunnel diverts water from Peru Creek, a tributary to the Snake River. The tunnel is approximately ten feet in diameter and 15 miles long. It brings water under Argentine Pass to Leavenworth Creek, a tributary to South Clear Creek in the South Platte River basin.

The tunnel is owned by the Vidler Tunnel Corporation in Boulder which was incorporated in 1964. They have secured a absolutely decreed right yielding approximately 400 acre-feet of water per year from the Snake River drainage and have filed conditional decrees for additional water. The corporation presently has commitments for delivery of 100 acre-feet of water to the West Slope, leaving approximately 300 acre-feet for importation to the South Platte River basin annually (Morleland, 1976).

The first diversions through this tunnel were in 1971; they have averaged 48 acre-feet per year. All records of the yearly diversions are shown in Appendix B, Table B3-7. The east slope contract of the Vidler Tunnel corporations is with Saint Mary's Glacier Water and Sanitation District (Morleland, 1976).

The Sheephorn project, also known as the Vidler Project, has been proposed by the City of Golden and the Vidler Tunnel Water Company to increase diversions through this tunnel. Presently they are seeking a preliminary permit from the Federal Power Commission to conduct a three year feasibility study of the project to determine how much the project would cost and how much water it could supply (Morleland, 1976).

In articles on September 9, and May 13, 1976, the Steamboat Pilot of Steamboat Springs, Colorado reported that Sheephorn project facilities would be built on the Colorado River, Blue River, Muddy Creek, Sheephorn Creek, Piney Creek, Rock Creek, Yampa River, Fishhock Creek, Morrison Creek, Service Creek, Silver Creek and tributary streams. It would include the construction of seven major dams and reservoirs with a combined storage capacity of 666,800 acre-feet, two hydroelectric power plants with a total generating capacity of 62,000 kilowatts; seven pumping stations; 60 miles of water transmission tunnels; 130 miles of pipeline, and about 24 small dams and dikes for diverting and regulating water flows. It was also reported that, "no action on the water rights involved has taken place other than the initial filings heard in water court at Glenwood Springs, November 21, 1975. The applicant does not own any of the lands it contemplates using for the project and indicates that negotiation for private lands has been 'fruitless' to date." (Steamboat Pilot, May 13, 1976). The Vidler Tunnel company reserves for itself the right to sell the Sheephorn Project water to private corporations, quasi-municipal corporations, municipal corporations and persons, in order to provide revenue to pay for the project. While the Steamboat Pilot said that the specific quantities and destinations of the water to be diverted east of the Continental Divide had not been mentioned by the developers, it noted that under a contract between Golden and the Vidler Tunnel Company, Golden would receive at least 5,000 acre-feet of this developed water per year.

A conservation with Mr. Roland Fischer of the Colorado River Water Conservation District yielded the information that the Sheephorn Project Developers have filed with the courts to deliver 500 cfs, which is equivalent to approximately 1,000 acre-feet per day or nearly 365,000 acre-feet per year to the East Slope. The water developed by this project would not necessarily be exported to the East Slope via the Vidler Tunnel. Instead, this water could be legally transferred, by exchange, to an existing trans-basin diversion projects collection system for export (Moreland, 1976).

The Harold D. Roberts Tunnel - As part of their overall comprehensive planning involving diversions of water from the Colorado River basin, Denver has for many years worked on plans for bringing water from the headwaters of the Blue River. This was also the heart of a Bureau of Reclamation plan that was huge in scope and concept, the Blue-South Platte Project. This project involved an extensive 132 mile collection system in the Eagle, Piney, Blue, and Williams Fork River Sub-basins, five west slope reservoirs, and an 18.4 miles Montezuma Tunnel under the Continental Divide. The Blue-South Platte Project would have imported an average of 430,000 acre-feet per year and though hydroelectric plants generated more than one billion kilowatt-hours of electric energy annually (USBR, 1959).

Inasmuch as that project was never approved, Denver went ahead with its own plan and commenced construction in 1946 on what is now known as the Harold D. Roberts Tunnel. In October 1955 the Blue River Decree was entered by the United States District Court for the District of Colorado in Consolidated Cases Civil Nos. 2782, 5016, and 5017. This decree recognized the right of Denver to bring water from the Blue River subbasin under certain conditions (United States Bureau of Reclamation, 1959).

Project Description. Dillon Reservoir with a capacity of 254,036 acre-feet impounds water draining from the Blue River and its tributaries upstream. This reservoir, completed in 1963, necessitated the relocation of the town of Dillon, as well as various other structures. It is located at the confluence of the Blue and Snake Rivers and Tenmile Creek.

The west portal of the Harold D. Roberts Tunnel lies opposite Dillon Dam, at the base of Dillon Reservoir at an elevation of 8,845 feet. The tunnel is 23.3 miles long and has a diameter of ten foot three inches. It is fully concrete lined and is designed to be operated under pressure. When Dillon Reservoir is full the capacity of the tunnel is 1,020 cfs (Denver Water Board, 1969). The tunnel delivers water at an elevation of 8,667 feet to the North Fork of the South Platte River.

Project Yields. Diversions through the Harold D. Roberts tunnel began in October of 1963. Deliveries to the South Platte River basin have averaged 31,586 acre-feet per year; however, 1,645 acre-feet of these can be attributed to infiltration from groundwater. All records of the yearly transbasin diversions through this tunnel to date are shown in Appendix B, Table B3-8.

Under Colorado water if Denver cannot put her west slope diversions to use or to storage, they cannot be made. A further constraint, imposed by the Blue River Decree, is that Denver must use her endogenous South Platte River supplies to their fullest before diverting water from the Blue River. Presently, the average annual diversions through the Harold D. Roberts Tunnel are 82.3% less than the average annual yield of Denver's existing absolutely decreed rights within the Blue River sub-basin. With the existing Harold D. Roberts Collection system, these rights are estimated to yield 169,000 acre-feet on the average and 103,000 acre-feet during a drought, (Denver Water Department, 1975).

Proposed Expansion-Straight Creek, East Gore, Eagle-Piney and Eagle-Colorado Projects. Expansion of the Harold D. Roberts Collection system, as originally envisioned by the Denver Water Board, included construction of the Straight Creek Division project, the East Gore Range Division Project, the Eagle-Piney Division Project, and the Eagle-Colorado Division Project. Figure 8-19 shows these components in relation to one another.

The Straight Creek project involves the reactivation of an old ditch to make available approximately 9,000 acre-feet per year from Straight Creek within the Blue River Sub-basin (Engineering Consultants, Inc., 1974).

The East Gore Collection system would be comprised of a 40 mile gravity flow buried conduit set along the eastern slope of the Gore Mountain Range. It would collect approximately 70,000 acre-feet annually within the Blue River sub-basin and deposit it in the Dillon Reservoir for transport of the South Platte River Basin through the Harold D. Roberts Tunnel (Senate Report No. 94-172, 1975).

The Eagle-Piney Project would make an additional 100,000 acre-feet of water available to Denver each year. About 30,000 acre-feet of this water would come from the Upper Eagle River drainage. The remaining 70,000 acre-feet would come from the Piney and Gore Creek (Eagle River sub-basin) collection system. Approximately 21,000 acre-feet would come from Piney Lake and diversion points west within the Piney River sub-basin, where it would be stored in a 40,000 acre-feet reservoir constructed at Piney Lake. From there it would be piped south, picking up

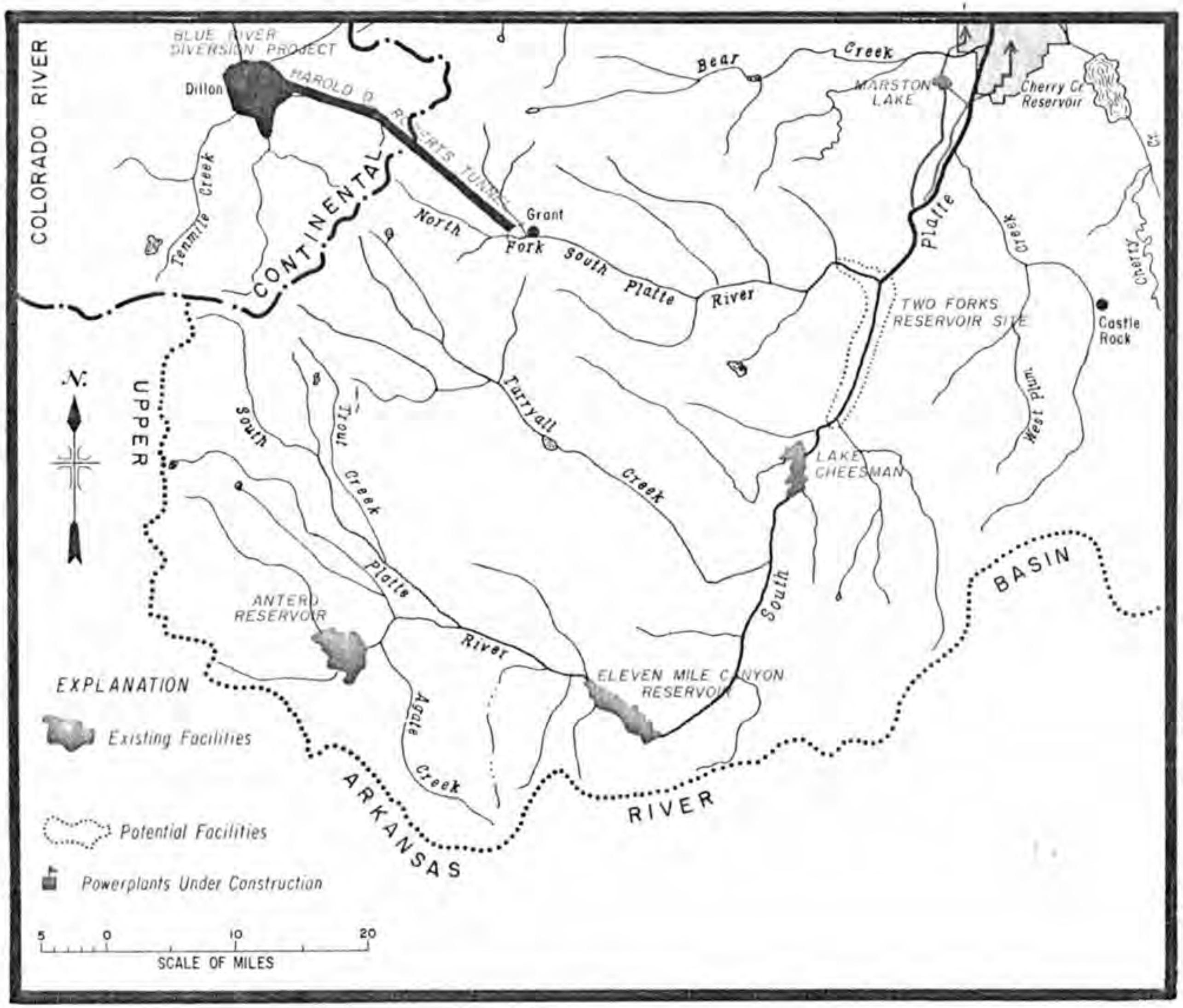


Figure 8-19: The Harold D. Roberts Tunnel Project
(From the USBR, 1959)

an additional 17,000 acre-feet of Piney sub-basin flows before turning east and collecting approximately 28,000 acre-feet from the Eagle River sub-basin from Booth, Pitkin, Bighorn, and Main Gore Creek directly above Vail. Near Main Gore Creek, the 70,000 acre-feet from the Piney and Gore Creek collection system would join the 30,000 acre-feet from the upper Eagle River Drainage and be piped through an eight mile tunnel to Dillon Reservoir (Senate Report No. 94-172, 1975).

The Eagle-Colorado Project involves pumping Colorado River water to a 350,000 acre-feet reservoir on the Eagle River near Wolcott, Colorado. From there, this water, along with some water from the Eagle river, would be lifted by pumps approximately 2,000 feet into a 35-mile long system of tunnels. Water would then flow into Dillon Reservoir and to Denver via the Roberts Tunnel (Denver Water Board, 1973). This project, which would be an expansion of the Harold D. Roberts Tunnel collection system, would be expected to yield approximately 80,000 acre-feet of water annually (Robert Fischer, 1976).

Other than the water from the Eagle portion of the Eagle-Piney Project, Denver does not have conditional decrees for the water rights needed to develop these projects (Robert Fischer, 1976). A pending written decision from a water referee, will be the first step in establishing a priority date for most of this water (Britton, 1976).

In showing due diligence in the development water from the Eagle River and the Piney River, the Denver Water Board states that they have spent more than two million dollars for Eagle-Piney studies, surveys, purchase of land, geological test drilling, and other activities that must be accomplished before construction of such a vast project can begin (Denver Water Board, 1973). However, on July 12, 1976, much of the land contained within the proposed Eagle-Piney Project, and some within the East Gore Project were incorporated into the Eagels Nest Wildnerness Area. Because construction is not permitted in wilderness areas, the design of these projects are severly altered. If they do come to fruition their costs will be greatly increased - unless a waiver is allowed to permit some construction within the wilderness areas.

Any future expansion of the Harold D. Roberts collection system necessarily requires additional east slope storage. The proposed Two Forks Reservoir, on the South Platte River, would be used to regulate and store these additional flows.

Because of the legal, political and environmental uncertainties involved with water resource projects of this magnitude, it is most difficult to assess when these proposed projects would start contributing water to the Harold D. Roberts collection system. With a most optimistic outlook construction could not even begin in the next five years.

The Boreas Pass Ditch - The Boreas Pass Ditch was constructed in 1909 and first diverted water in 1910 for the irrigation of hay lands in South Park within the South Platte River-Mountains sub-basin (USBR, 1959). It is a small ditch diverting water at 11,480 feet from the head of Indiana Creek, a tributary of the Blue River; over Boreas Pass, to Tarryall Creek, a tributary to the South Platte River. All available records of yearly diversions through this ditch, which begin with the 1933 water year, can be found in Appendix B, Table B3-9. To date the diversions have averaged 103 acre-feet per year.

In 1951, the City of Englewood purchased the Boreas Pass Ditch and its water right for municipal use. Mr. Bradshaw, Assistant Director of

Utilities for the City of Englewood, reports that they are presently leasing water to Coors and that they intend to sell the ditch at a future date (Bradshaw, 1976).

The East and West Hoosier Pass Ditches - The first diversion through these ditches were made in 1935. Exports through the East Hoosier Pass Ditch averaged 297 acre-feet per year and through the west Hoosier Pass Ditch 142 acre-feet per year. They were discontinued by court order in 1940 and 1939 respectively (United States Geological Survey, 1954). Both of these ditches diverted water at 11,540 feet from tributaries of the Blue River. They brought this water over Hoosier Pass to Platte Gulch, a tributary of the Middle Fork of the South Platte River. All of the yearly diversions through these ditches during their short period of operation as shown in Appendix B, Table B3-10.

The Hoosier Pass Tunnel - Three collection conduits, originating at Monte Cristo and, Bemrose Creeks, and McCullough Gulch, and intercepting intermediate tributaries, converge at the North Portal of this Tunnel in the Blue River Sub-basin. Water is brought under Hoosier Pass at 10,986 feet to Montgomery reservoir on the Middle Fork of the South Platte River. These imports are not available to South Platte water users as they are owned by Colorado Springs. Once in the South Platte River basin they are again diverted, through the Montgomery pipeline, to South Catamount Creek in the Arkansas River Drainage.

Diversions began June 30, 1952 and have averaged 8,249 acre-feet per year. All records of the yearly diversions through this tunnel to date are shown in Appendix B, Table B3-11.

The Freemont Pass Ditch - This ditch formerly diverted water from tributaries of Tenmile Creek at 11,320 feet to the East Fork of the

Arkansas River in the Arkansas River Drainage. Since August of 1943 the water rights of this ditch have been used at Climax (USGS, 1957).

Appendix B, Table B4-1 shows all of the available records of the yearly diversions through this ditch. They begin with the 1929 water year and averaged, 1,230 acre-feet per year.

8.6 The Piney River Sub-basin

8.6.1 *Surface Water Supply* - The drainage area of the Piney River sub-basin is 86.2 square miles above gaging station #09059500, "Piney River near State Bridge, Colorado." This gaging station is located approximately five miles upstream from the confluence of the Piney River with the main stem of the Colorado River.

Nested between the Eagle and Blue River sub-basins, the river starts in the Gore Range at elevations of around 13,500 feet. It flows northwest for approximately 30 miles, losing about 6,000 feet in altitude. The major tributaries of the Piney River are the North Fork, Dickson, Freeman, and East Meadow Creeks.

There are approximately 400 acres of irrigated hay meadows in the sub-basin (USGS, 1974). There are presently no diversion structures in this sub-basin either importing or exporting water. There are no major reservoirs located here either. Figure 8-20 is a schematic diagram of the sub-basin.

The precipitation in the headwaters area of the Piney River averages about 20 inches per year, dropping to about 16 inches per year in the lower elevations (National Oceanic and Atmospheric Administration, 1974). The surface water supplies of this sub-basin are mostly from the melting show pack. The bulk of the runoff occurs during the period May through July.

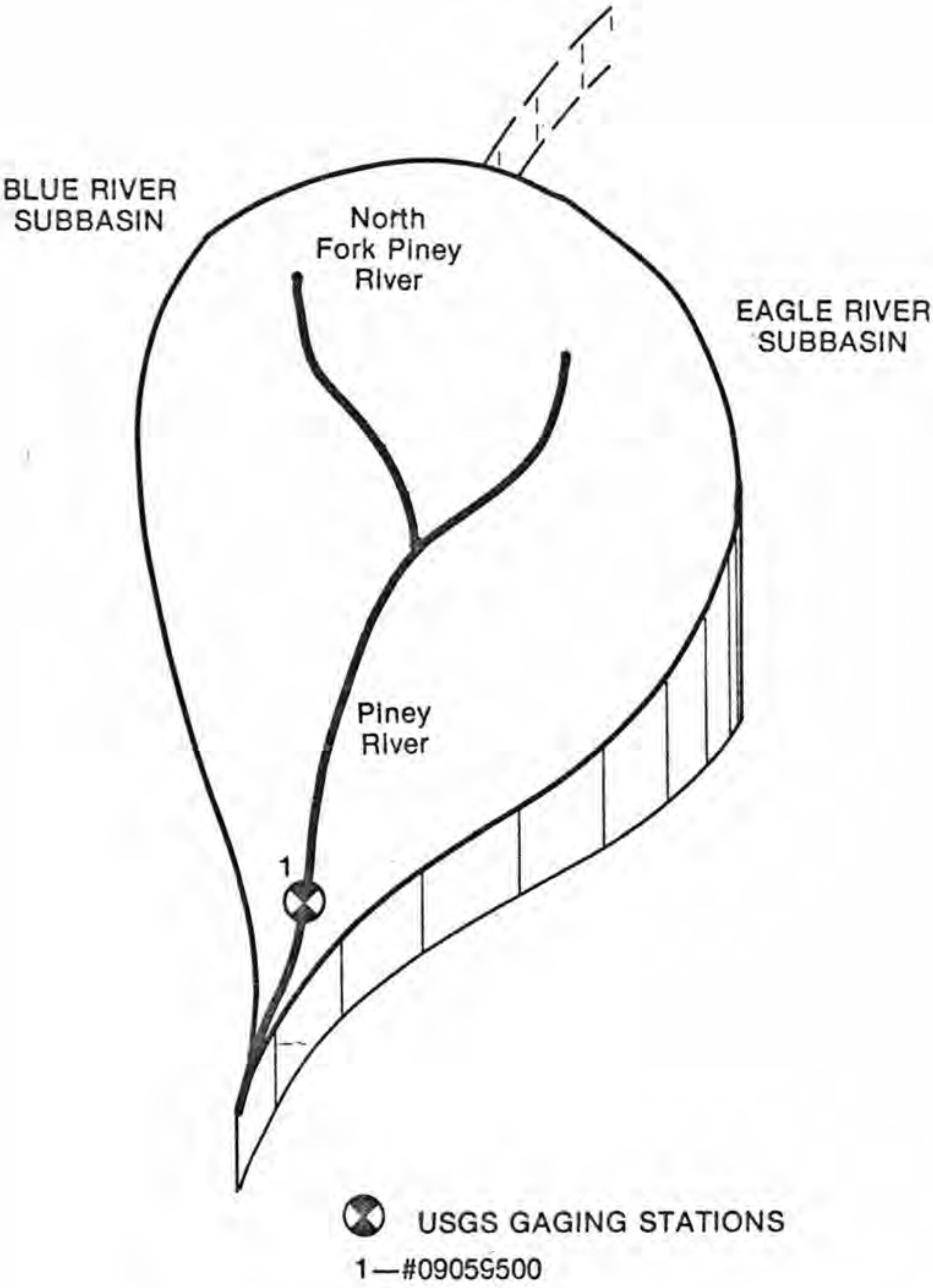


Figure 8-20: Schematic of the Piney River Subbasin

The native surface water supply of this sub-basin can be estimated from the flows recorded at the USGS gagin station #09059500, "Piney River near State Bridge, Colorado," these records are compiled in Table C2-5. The average annual native surface water supply of the Piney River sub-basin is estimated from Table A2-13 to be 55,136 acre-feet per year. The 1970 surface water supply of this sub-basin is estimated from Table A2-14 to have been 65,360 acre-feet or 118.54% of average.

The native surface water supply during the 1952-1956 four year drought period averaged 38,805 acre-feet per year, or 70.38% of the average; computations are shown in Table A2-15.

8.6.2 *Transbasin Diversion Structures* - There are presently no transbasin diversion structures operating in this sub-basin.

8.7 The Eagle River Sub-basin

8.7.1 *Surface Water Supply* - The drainage area of the Eagle River sub-basin, above gagin station #09070000, "Eagle River below Gypsum, Colorado," is 944 square miles. This gaging station is located approximately seven miles upstream from the confluence of the Eagle River with the main stem of the Colorado River.

The Eagle River originates on the western edge of the Continental Divide across from the Arkansas River Basin. From elevations exceeding 13,000 feet, the Eagle River flows North and then west through this sub-basin for approximately 60 miles losing more than 6,500 feet in altitude. The major headwater tributaries of the Eagle River are the Gore Creek and Homestake Creek.

There are approximately 17,000 acres of irrigated land in the sub-basin (USGS, 1974). Four major diversion structures export native surface flows of this sub-basin. All deliver water to the Arkansas River

Basin, with one supplying water to be further diverted to the South Platte River Basin. No water is imported to this sub-basin nor are there any major reservoirs. Figure 8-21 is a schematic drawing of this sub-basin.

The precipitation in the headwaters area of the Eagle River averages 32 inches per year, dropping to about 16 inches per year in its lower elevations (National Ocean and Atmospheric Administration, 1974). As with all the high mountain west slope river drainages, the surface water supply is mostly from snowmelt with the major runoff occurring during the period May through July.

The native surface water supply of this sub-basin can be estimated from the flows recorded at the USGS Gaging Station, #09070000, "Eagle River below Gypsum, Colorado;" Table C2-6 summarizes the available records. The average native surface water supply available to the Eagle River sub-basin is estimated from Table A2-16 to be 445,432 acre-feet per year. The 1970 surface water supply of this sub-basin is estimated to have been 529,480 acre-feet of 118.87% of average (Table A2-17). The native surface water supply available to this sub-basin during the 1952-1956 four year drought period is estimated from Table A2-18 to have averaged 347,838 acre-feet per year, or 78.09% of the long term average.

8.7.2 *Transbasin Diversion Structures* - Five diversion structures presently export native surface flows of the Eagle River sub-basin. Four of these transport water to the Arkansas River basin while one diverts water to the Blue River sub-basin. The latter carries water from Robinson Reservoir (capacity 2,520 acre-feet) to Ten Mile Creek for mining purposes. No records of flow are available.

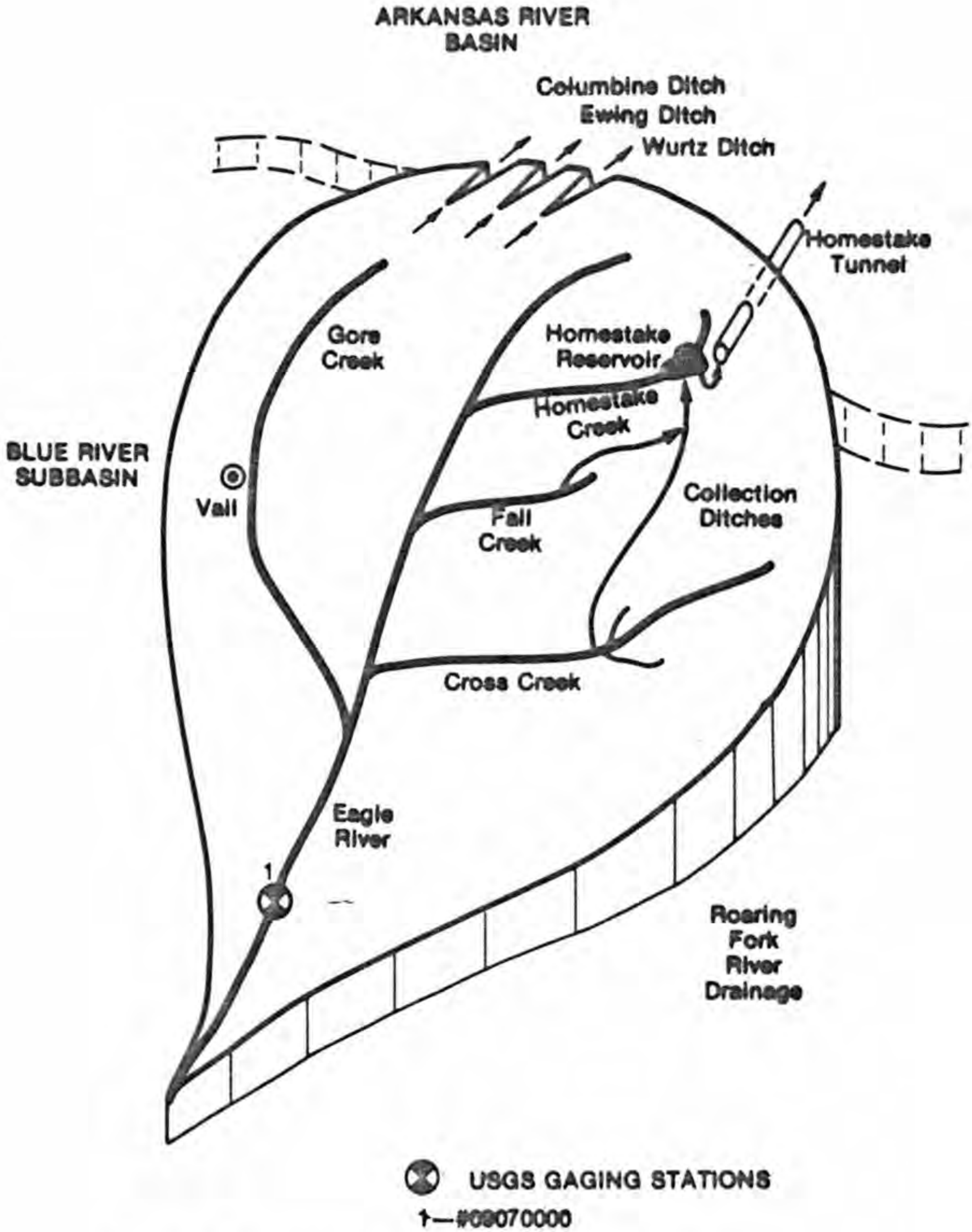


Figure 8-21: Schematic of the Eagle River Subbasin

The four transbasin diversion structures, Columbine Ditch, Ewing Ditch, Wurtz Ditch, and the Homestake Tunnel, all export water to the Arkansas River Basin. Of importance to the South Platte River basin is the Homestake Tunnel. A portion of its Eagle River sub-basin water exported to the Arkansas Basin is rediverted at a high elevation and brought to the South Platte River basin, via the Aurora-Homestake extension of the Homestake Pipeline. The other three diversion structures are important to the South Platte River basin in that their water rights are senior to those that will be exercised through the proposed additional collection facilities of the Homestake Tunnel.

The Columbine Ditch - This ditch diverts water from tributaries of the Eagle River at an elevation of 11,430 feet to Chalk Creek, a tributary of the East Fork of the Arkansas River. All available records of the yearly diversions through the Columbine Ditch, which begin with the 1931 water year are shown in Appendix B, Table B4-2. To date, these exports have averaged 1,202 acre-feet per year.

The Ewing Ditch - This ditch diverts water at an altitude of 10,500 feet from Piney Creek, a tributary of the Eagle River, to Tennessee Creek, a tributary of the Arkansas River. All available records of the yearly diversions through the Ewing Ditch, which begin with the 1909 water year are shown in Appendix B, Table B4-3. To date these exports have averaged 1,176 acre-feet per year. The first diversions through the Ewing Ditch were made for mining. Since 1912 the water has been used for irrigation within the Arkansas River Basin (USGS, 1954).

The Wurtz Ditch - This ditch diverts water from tributaries of the Eagle River at 10,570 feet to Tennessee Creek, a tributary of the Arkansas River. All available records of the yearly diversions through the Wurtz Ditch, which began in the 1932 water year, are shown in Appendix B, Table B4-2. To date these exports have averaged 2,270 acre-feet per year.

The Homestake Tunnel and Project

Project Description. The project was developed by the East Slope cities of Aurora and Colorado Springs. Present facilities include Homestake Reservoir on Homestake Creek, and diversion structures on Fancy, French, Sopris, and Missouri Creeks and on the East Fork of the Homestake Creek. Water diverted from these tributaries is stored with water from Homestake Creek in Homestake Reservoir which has a capacity of 45,000 acre-feet.

The Homestake Tunnel delivers water of the Eagle River sub-basin from Homestake Reservoir to Lake Fork Creek, above Turquoise Lake, in the Arkansas River-Mountains sub-basin. The City of Aurora has an agreement with the United States Bureau of Reclamation to lease up to 15,000 acre-feet of storage in Turquoise Reservoir, which is expected to be complete sometime in 1977 (Beck, 1974). Aurora will use this reservoir to provide some additional storage and regulation for her share of the yield of the Homestake Project.

Once in the Arkansas River Basin, imports through Homestake Tunnel comingle with the native runoff of the Arkansas and flow apprxoimately 25 miles downstream to the intake structure of the Homestake Pipeline. This is located just below Granite, Colorado and just above the confluence of Clear Creek with the Arkansas River. The water then proceeds by gravity to the Otero Pumping Plant where it is forced through Little Annie, and Goddard Tunnels, and then under Trout Creek Pass to the South Platte River basin. A turnout from the Homestake Pipeline, called the Aurora-Homestake Pipeline delivers Aurora's share of this water to Elevenmile Canyon Reservoir on the mainstem of the Upper South Platte River. The remainder of the water continues through the Homestake Pipeline and is brought back to the Arkansas River Basin and to Colorado Springs. Figure 8-22 shows the layout of the project features. The Homestake Tunnel has recently been reopened after having been closed for nearly one year for repairs during the period 1976-1977.

Project Yields. The initial diversion through the Homestake Tunnel was in June of 1967. Exports have averaged 30,620 acre-feet per year to date. All records of the yearly diversions through the Homestake Tunnel are shown in Appendix B, Table B4-5. Aurora began turnouts through the Aurora-Homestake Pipeline on August 24, 1967 and these are shown also in Appendix B, Table B4-5.

While aurora and Colorado Springs each own one-half of the Homestake projects water yield (15,310 acre-feet) Aurora has been able to use an average of only 6,831 acre-feet per year thus far. She has been giving the excess of her additional allotment of 8,479 acre-feet per year to Colorado Springs until her demands require more (Miskel, 1976).

Proposed Expansion-Homestake Collection System Extension and Eagle-Arkansas Division. Expansion of the existing Homestake collection system involves the development of Cross, Fall, Peterson, and Whitney Creeks and several unnamed tributaries within the Homestake Creek drainage of the Eagle River sub-basin. Present plans as described in a recent report on the project by Black and Veatch Consulting Engineers (1973), envision construction of Iron Mountain Reservoir on Homestake Creek, downstream of the existing Homestake Reservoir, together with

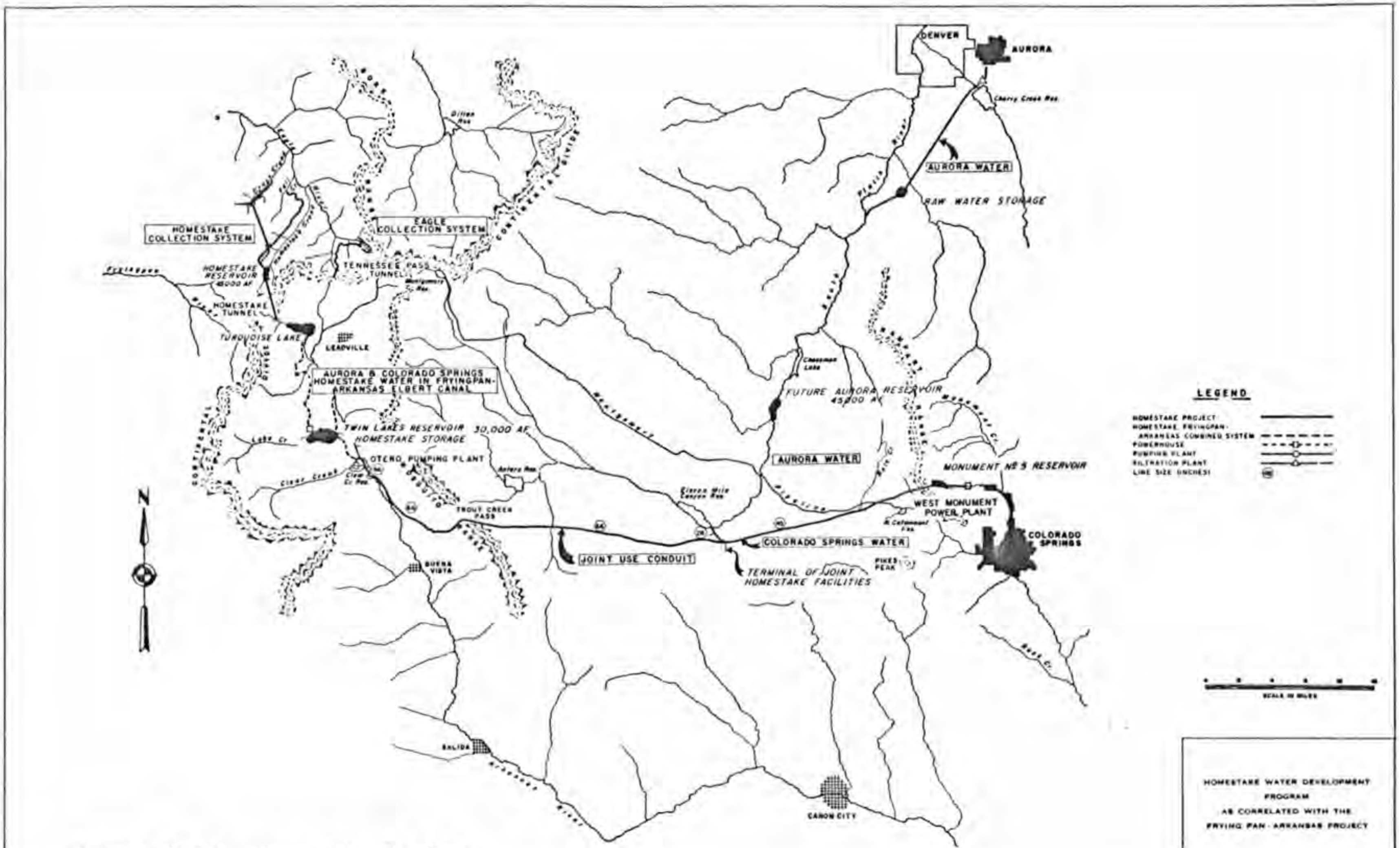


Figure 8-22: Homestake Project

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related facilities for pumping project water up to Homestake Reservoir for diversion through Homestake Tunnel.

The Eagle-Arkansas division of the Homestake Project would be located on the upper drainage area of the Eagle River. Three transbasin diversion ditches (Wurtz, Columbine, and Ewing) have decrees senior to the rights associated with this expansion of the Homestake collection system. The Columbine and Ewing Ditches divert water from areas above and tributary to the proposed collection facilities of the Homestake Eagle-Arkansas system. As originally conceived, water from the Eagle-Arkansas Diversion would be diverted through a proposed Tennessee Pass Tunnel into Tennessee Creek. There, these flows would be picked up downstream at the inlet to the Homestake delivery pipeline. However, recent studies conducted for the Homestake Project Steering Committee, composed of representatives of Aurora and Colorado Springs (Beck, 1974), have recommended that, instead, a diversion structure be constructed on the Eagle River below Camp Hale and that the Eagle-Arkansas Division water be diverted into the proposed Iron Mountain Reservoir for storage and conveyance to Homestake Reservoir. Present project scheduling indicates that the Homestake Collection System expansion and the Eagle-Arkansas divisions could be operational for the year 1982 (Beck, 1974). According to Mr. Ed Bailey, Water Resources Engineer for the City of Colorado Springs (1976), these proposed projects are expected to be on line no later than 1986. Black and Veatch (1973) estimate the average annual yield of both of these projects to be 41,030 acre-feet. One-half of this, or 20,515 acre-feet per year would be available to the City of Aurora.

8.8 The Little Snake River Sub-basin

8.8.1 *Surface Water Supply* - This sub-basin includes the upper most reach of the Little Snake River from its headwaters on the western edge of the Continental Divide to the USGS Gaging Station #09253000, "Little Snake River Near Slater, Colorado." The Little Snake drains an area of 285 square miles above this gaging station, portions of which lie both within Colorado and Wyoming.

From elevations in excess of 11,000 feet, the Little Snake River flows west for approximately 30 miles, losing more than 4,000 feet in altitude. It then veers southwest to meet the Yampa River, a major tributary of the Green River. The Green River flows into the Colorado River just above Lake Powell. The major tributaries of the Little Snake are the North, Middle, and South Forks of the Little Snake River and King Solomon Creek, Roaring Fork Creek, and Battle Creek.

The most intensive use of water within this sub-basin is for the irrigation of approximately 2,000 acres of land (USGS, 1974). There is one diversion structure, the Cheyenne Tunnel, that exports water from the sub-basin. It transports this water to the North Platte River-Mountains sub-basin in the North Platte River basin where it is exchanged for that sub-basin water, which is then diverted to the South Platte River basin. The sub-basin has several small reservoirs, and there are no diversion structures importing water. Figure 8-23 is a schematic of the Little Snake River Sub-basin.

The precipitation available to the headwaters of this sub-basin average 40 inches per year and to its lower elevations approximately 1,640 inches per year (National Oceanic and Atmospheric Administration, 1974). Similar to the other Colorado River sub-basins, the surface water supply

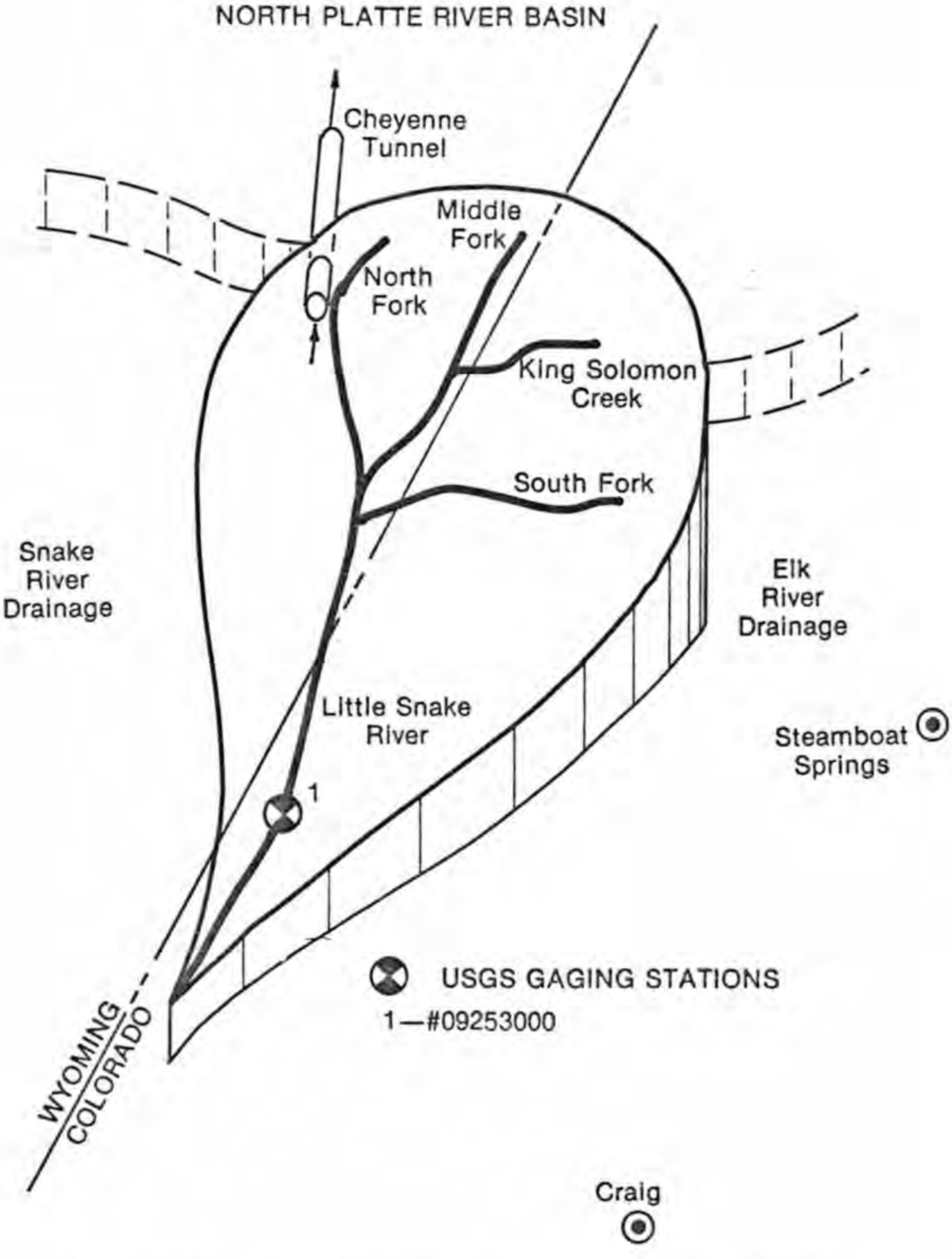


Figure 8-23: Schematic of the Little Snake River Subbasin

of this sub-basin is derived principally from snowmelt, the bulk appearing May through July.

The native surface water supply of this sub-basin can be estimated from the flows recorded at USGS Gaging Station #09253000, "Little Snake near Slater, Colorado," which are summarized in Table C2-7.

The average native surface water supply of the Little Snake sub-basin is estimated from Table A2-19 to be 168,733 acre-feet per year. The 1970 native surface water supply of this sub-basin was 218,529 acre-feet, or 129.51% of average; computations are seen in Table A2-20. The native surface water supply of this sub-basin during the 1952-1956 four year drought period averaged 121,049 acre-feet per year, or 71.74% of the long term average; computations are seen in Table A2-21.

8.8.2 *Transbasin Diversion Structures* - The Cheyenne Tunnel is the only transbasin diversion structure exporting water from the Little Snake River sub-basin. The water supply system of the City of Cheyenne Spans four major river drainages. Colorado River water (i.e., the Little Snake) is exchanged for North Platte River water; this water is imported across the Laramie River Drainage to Crow Creek, and then to Cheyenne. Crow Creek is a sub-basin of the South Platte River basin.

There are no imports of water to the Little Snake River sub-basin from other drainage areas.

The Cheyenne Tunnel - Cheyenne developed her outside water supply system in 1961. A pipeline diverts water from Douglas Creek, in the North Platte River drainage, where regulation and storage is provided by Rob Roy Reservoir. The pipeline then crosses the Laramie River drainage, where regulation is provided by the Owens Surge Reservoir; it then discharges into Crow Creek above Cheyenne.

Replacement water is furnished to North Platte River water users by Colorado River Basin water imported through the Cheyenne Tunnel. This tunnel collects water from Green, Tinker, Ted and the North Fork of Little Snake Creeks as well as other minor tributaries within the Little Snake River sub-basin. It brings this water under the Continental Divide to Hog Park Reservoir for regulation and storage. This reservoir is located on Hog Park Creek, a tributary to Encampment Creek which is a tributary to the North Platte River. Figure 8-24 is a schematic diagram of the system involved.

The initial diversions through this sytem occurred in the 1965 water year and have averaged 7,316 acre-feet per year. All the yearly diversions through the Cheyenne Pipeline (which must be met with equal releases from Hog Park Reservoir which in turn must come through the Cheyenne Tunnel) are shown in Appendix B, Table B2-1. Tables 8-6 and 8-7 lists Cheyenne's first stage (activity using), second stage (pursuing to use) and third stage (filing for future potential use) water right permits involved with both this tunnel and pipeline. The Cheyenne Pipeline is limited in its diversions from Douglas Creek to the amount that can be diverted from the collection system of the Cheyenne Tunnel.

The drainage basin tributary to the existing collection facilities of the Cheyenne Tunnel has a total area of 3,800 acres (Banner, 1974). The average annual diversion yield has been 1.9 acre-feet per acre.

A diversion-replacement scheduling program that would maximize yields from Cheyenne's existing facilities could possible increase average annual diversions from 5 to 10% (Banner, 1974). In 1973,

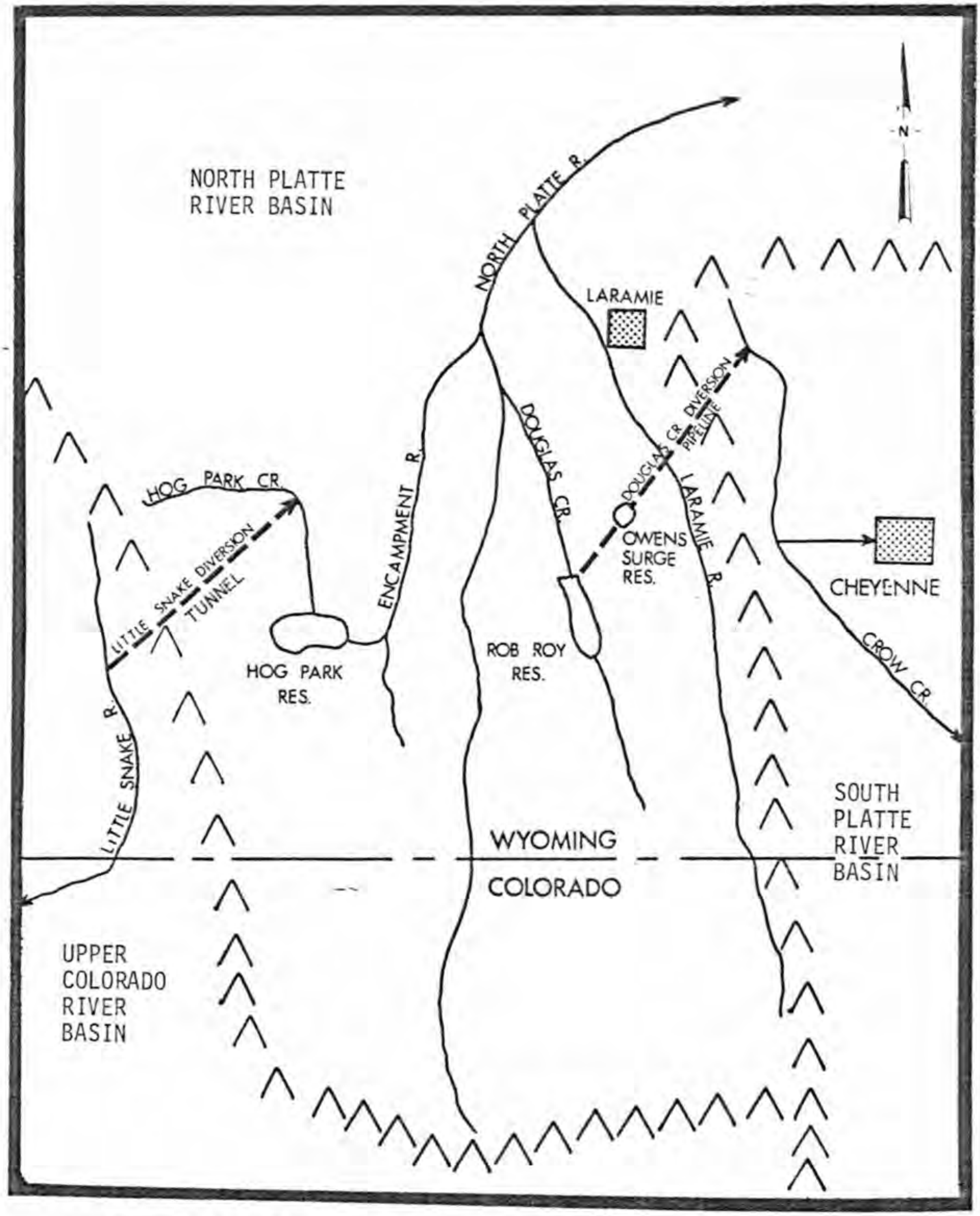


Figure 8-24: Schematic of Cheyennes Exogenons Water Supply System.

Table 8-6 City of Cheyenne Water Rights (First Stage Permits).

Location of Water Right	River Basin	Amount	Permit No.	Priority Date	Notes
Dale Creek	Colorado		22123	3/12/1954	
N. Fork Little Snake River	Colorado	54.43 cfs	22117	3/12/1954	1/4/
Ellis Creek	Colorado		22124	3/12/1954	
Rodine Creek	Colorado		22125	3/12/1954	
Happy Creek	Colorado		22126	3/12/1954	
Ted Creek	Colorado	40.70 cfs	22122	3/12/1954	2/4/
Tinker Creek	Colorado	7.46 cfs	22128	3/12/1954	3/4/
Green Timber Creek	Colorado		22127	3/12/1954	
Douglas Creek	North Platte	N.A.	22094	3/12/1954	5/
Spring Creek	North Platte	N.A.	22101	3/12/1954	5/
Horse Creek	North Platte	22.96	22115	3/2/1961	5/

Notes: N.A. means information not available.

1/This water is all diverted from the North Fork of the Little Snake River to Hog Park Creek via the Little Snake Diversion Pipeline. The capacity of the pipeline at its point of diversion is 54.43 cfs.

2/The Ted Creek pickup line diverts water from Ted Creek (permit no. 22122) to the Little Snake Diversion Pipeline. The capacity of the pickup line is 40.70 cfs.

3/The Green Timber Creek pickup line diverts water from Green Timber Creek (Permit no. 22127) and Tinker Creek (Permit no. 22128) and Granite Gulch, Quartz Gulch, and Madre Gulch (new applications) to the Little Snake Diversion Pipeline. The capacity of the pickup line is 7.46 cfs.

4/Source: "Petition for Change of Points of Diversion of the First Phase of the Little Snake Diversion Pipeline," before the State Engineer, Cheyenne, Wyoming, signed April 2, 1964.

5/Source: "Petition for Change of Points of Diversion of the First Phase of the Douglas Creek Diversion Pipeline," before the State Engineer, Cheyenne, Wyoming, signed April 2, 1964.

Table 8-7 City of Cheyenne (Second and Third State Permits).

Permit No.	Description
22095	Douglas Creek Diversion Pipe Line, from West Branch Muddy Creek, trib. Muddy Creek.
22096	Douglas Creek Diversion Pipe Line, from Nugget Gulch Branch, trib. Beaver Creek.
22097	Douglas Creek Diversion Pipe Line, from Podunk Creek, trib. Douglas Creek.
22098	Douglas Creek Diversion Pipe Line, from Gold Crater Creek, trib. Beaver Creek.
22099	Douglas Creek Diversion Pipe Line, from Spring Branch, trib. Beaver Creek.
22100	Douglas Creek Diversion Pipe Line, from Beaver Creek, trib. Douglas Creek.
22102	Douglas Creek Diversion Pipe Line, from Camp Creek, trib. Muddy Creek.
22103	Douglas Creek Diversion Pipe Line, from Middle Branch Camp Creek, trib. Camp Creek.
22104	Douglas Creek Diversion Pipe Line, from East Branch Camp Creek, trib. Camp Creek.
22105	Lake Creek to Laramie River Diversion Canal No. 2, from Lake Creek, trib. Douglas Creek.
22106	Lake Creek to Laramie River Diversion Canal No. 2, from Hay Creek, trib. Lake Creek.
22107	Lake Creek to Laramie River Diversion Canal No. 2, from East Branch Hay Creek, trib. Hay Creek.
22108	Lake Creek to Laramie River Diversion Canal No. 2, from West Branch Hay Creek, trib. Hay Creek.
22109	Lake Creek to Laramie River Diversion Canal No. 1, from Lincoln Gulch Creek, trib. Lake Creek.
22110	Lake Creek to Laramie River Diversion Canal No. 1, from Joe Creek, trib. Banner Creek.
22111	Lake Creek to Laramie River Diversion Canal No. 1, from Banner Creek, trib. Lake Creek.
22112	Lake Creek to Laramie River Diversion Canal No. 1, from H.T. Creek, trib. Lincoln Gulch Creek.
22113	Keystone Creek Extension to Douglas Creek Diversion Pipe Line, from Nelson Branch, trib. Keystone Creek.
22114	Keystone Creek Extension to Douglas Creek Diversion Pipe Line, from Keystone Creek, trib. Douglas Creek.
22118	Little Snake Diversion Pipe Line, from Deadman Creek, trib. North Fork Little Snake River.
22119	Little Snake Diversion Pipe Line, from First Creek, trib. North Fork Little Snake River.
22120	Little Snake Diversion Pipe Line, from Second Creek, trib. North Fork Little Snake River.
22121	Little Snake Diversion Pipe Line, from Third Creek, trib. North Fork Little Snake River.

Table 8-7 Continued.

Permit No.	Description
22129	Little Snake Diversion Pipe Line, from Rose Creek, trib. North Fork Little Snake River.
22130	Little Snake Diversion Pipe Line, from Harrison Creek, trib. North Fork Little Snake River.
22131	Little Snake Diversion Pipe Line, from Solomon Creek, trib. North Fork Little Snake River.
22132	Little Snake Diversion Pipe Line, from East Branch Solomon Creek, trib. Solomon Creek.
22133	(West Branch Extension to) Little Snake Diversion Pipe Line, from West Fork of North Fork, trib. North Fork Little Snake River.
22134	Little Snake Diversion Pipe Line, from Rabbit Creek, trib. West Fork North Fork.
22135	Battle Creek to Jack Creek Diversion Canal, from Battle Creek, trib. Little Snake River.
22136	Battle Creek to Jack Creek Diversion Canal, from Smith Creek, trib. Battle Creek.
22137	Battle Creek to Jack Creek Diversion Canal, from Haskins Creek, trib. Battle Creek.
22138	Battle Creek to Jack Creek Diversion Canal, from Lost Creek, trib. Haggerty Creek.
22139	Battle Creek to Jack Creek Diversion Canal, from Haggerty Creek, trib. West Fork Battle Creek.
22140	Battle Creek to Jack Creek Diversion Canal, from Mill Creek, trib. Big Sandstone Creek.
22141	Battle Creek to Jack Creek Diversion Canal, from South Branch Big Sandstone Creek, trib. Big Sandstone Creek.
22142	Battle Creek to Jack Creek Diversion Canal, from North Branch Big Sandstone Creek, trib. Big Sandstone Creek.
22143	Battle Creek to Jack Creek Diversion Canal, from Douglas Creek, trib. Big Sandstone Creek.
22144	Battle Creek to Jack Creek Diversion Canal, from Deep Creek, trib. Big Sandstone Creek.

because Rob Roy and Hog Park Reservoirs were full, the system lost divertable spring runoff over the spillways.

In June of 1977, preliminary surveying should start for the expansion of Hog Park Reservoir to allow increased yields from the Cheyenne Tunnel-Pipeline. Its present capacity of 3,000 acre-feet will be increased to 56,000 acre-feet (Sherard, 1976).

Cheyenne presently has permits for an additional 30,000 acre-feet of Colorado River basin water alloted to Wyoming (Herman Noe, 1976). She will use this water for exchange with water from the North Platte River Drainage.

8.9 Other Proposed Projects to Export Colorado River Basin Water to the South Platte River Basin

According to Mr. Roland Rischer of the Colorado River Water Conservation District, there is only one other proposed project, in addition to those mentioned, that would divert water from the Colorado River basin to the South Platte basin. This is the Four Counties Water Association Project, recently under the direction of a firm called Sproule, which would divert waters from the Yampa River, and by exchanges upstream in the Colorado River Basin via existing transbasin collection systems, it would deliver approximately 40,000 acre-feet per year to the South Platte River basin (Roland Fischer, 1976). There seems to be no strong activity on the project at the present time, however.

8.10 Conclusions

Diversions from the Colorado River Basin within Colorado to the South Platte River basin within Colorado presently averaged 338,753 acre-feet per year (i.e., for the latest period of time subsequent to any expansions). Diversions from the Colorado River Basin in Wyoming to the South Platte River basin in Wyoming recently have averaged 7,316 acre-feet per year.

In looking towards the future from the vantage point of the present, it appears that no new transbasin diversion structures will be built to import additional water from this basin. It seems probable, however, that the collection systems for the existing facilities will be expanded, as long as there is water available (i.e., in terms of the seniority of one's water right, and in terms of what has already been diverted relative to the total supply).

Table 8-8 shows projected future average annual imports to the Colorado portion of the South Platte River basin from the Colorado portion of the Colorado River Basin. The estimates were obtained compiling the envisaged expansion plans of the controlling interests of the presently existing transbasin diversion structures. By 2020, the amount imported from the Colorado River would be 704,798 acre-feet per year according to Table 8-8, or 110.1% more than the amount presently imported.

Table 8-9 shows estimates of Colorado River depletions in Colorado, projected by several groups. These include the Colorado River Basin Salinity Forum, the Pacific Southwest Interagency Committee, and the Committee of Fourteen (representing the seven Colorado River Basin States), the Department of the Interior's Energy Report, and the Colorado Water Conservation Board.

Of the 1970 total exports from the Colorado River Basin within Colorado, transfers to the South Platte River Basin accounted for approximately 72 percent (Table 8-1). If this is true in the future,

Table 8-8 The Historical and Future Average Annual Imports of Colorado River Basin Water to the Colorado Portion of the South Platte River Basin.

Diversion Structure	Pre 1975 Historical Annual Average Diversion (acre-feet)	Future Annual Average Diversions (acre-feet)					
		1975	1980	1990	2000	2020	Date Uncertain
Grand River Ditch	17,523 1/	21,523 2/	21,523	21,523	21,523	21,523	? 3/
Eureka Ditch	82	82	82	82	82	82	0
Alva B. Adams Tunnel	227,626 4/	227,626	281,626 5/	281,626	281,626	281,626	0
Moffat Tunnel	54,322 6/	59,322 7/	59,322	77,322 8/	77,322	77,322	0
Berthoud Pass Ditch	615	615	615	615	615	615	0
Vidler Tunnel	48	48	48	48	48	48	365,000 9/
Harold D. Roberts	28,654	28,654	28,654	28,654	28,654	287,654 10/	0
Boreas Pass Ditch	103	103	103	103	103	103	0
Aurora-Homestake Pipeline	6,450	6,450	6,450	35,825 11/	35,825	35,825	0
Four Counties	-	-	-	-	-	-	40,000 12/
Total imports from the Colorado to the South Platte River Basin	335,423	344,423	398,423	445,798	445,798	704,798	405,000
Increase over the historical annual average	-	2.7	18.8	32.9	32.9	110.1	-

1/ Annual average diversion subsequent to the enlargement of the main intercepting canal in 1930 (Table B3-1).
2/ The 1975 increase in storage capacity of Long Draw Reservoir will provide an additional 4,000 acre-feet per year through the Grand River Ditch (U.S. Department of the Interior, 1973).
3/ Further enlargement of Long Draw Reservoir is possible and would allow increased average annual diversions through the Grand River Ditch without the acquisition of additional water rights. When this might be done and how much it would yield is uncertain.
4/ Annual average was taken between 1953 and 1974 excluding the first 6 years which were not representative of the systems potential (Table B3-3).
5/ Windy Gap Project to come on line in 1980 (NCWCD, 1975) and provide an additional 54,000 acre-feet per year (Engineering Consultants, Inc., 1974).
6/ Annual average was taken subsequent to the addition of the Jones Pass-Vasquez Tunnel infrastructure to the Moffat Collection System in 1959.
7/ Englewoods Development of their Ranch Creek Collection System in 1975 will provide an additional 5,000 acre-feet per year through the Moffat Tunnel (Denver Water Department, 1975).
8/ Expansion of the Williams Fork collection system will provide an additional 18,000 acre-feet per year through the Moffat Tunnel by 1986 at the latest (Robert Fischer, 1976).
9/ The Vidler Tunnel Corporation has filed with the courts to deliver 365,000 acre-feet per year to the South Platte River Basin (Roland Fischer, 1976). This project has not acquired any water rights or land and its feasibility has yet to be assessed. Therefore, the date of initial diversion is uncertain.
10/ The expansion of the Harold D. Roberts Collection system will at least be on line by 2020 with the proposed projects contributing the following amounts; (Robert Fischer, 1976). Straight Creek 9,000, East Gore 70,000, Eagle-Piney 100,000, Eagle-Colorado 80,000, Total 259,000.
11/ The Homestake Project Collection System expansion (including the Eagle-Arkansas Division) is to be on line by 1982 providing Aurora with an additional 20,515 acre-feet per year through the Aurora-Homestake Pipeline (Beck, 1974). Also includes presently unused share of existing yield, 8860 acre-feet.
12/ The Four Counties Water Association Project recently under the direction of a firm called Sproule, would deliver to the South Platte River Basin 40,000 acre-feet per year (Roland Fischer, 1976). When this project will start diversions and how they will get to the South Platte River Basin is uncertain at this time.

Table 8-9 Estimated Future Annual Colorado River Depletion in Colorado (From Laren D. Morrils' Personal Files, 1976).

1980

Colorado River Depletions in Colorado by Use (In Thousands of acre-feet per year)1/	Colorado Water Conservation Board	Pacific Southwest Interagency Committee	Committee of 14	U.S. Department of the Interior Energy Report	Salinity Forum		
					Low	Moderate	High
Out of Basin Export	672	682	630	606	605	650	680
(To the South Platte River Basin, 72)	(484)	(491)	(454)	(436)	(436)	(468)	(490)
In Basin Agricultural Use	1,245	-	1,248	-	1,245	1,245	1,250
In Basin Coal Development	53	55	55	54	35	40	50
In Basin Oil Shale	20	20	15	45	15	20	45
Other In Basin Uses	41	43	22	-	24	34	44
Total	2,031	-	1,970	-	1,924	1,989	2,069

1985

Colorado River Depletions in Colorado by Use (In Thousands of acre-feet per year)1/	Colorado Water Conservation Board	Pacific Southwest Interagency Committee	Committee of 14	U.S. Department of the Interior Energy Report	Salinity Forum		
					Low	Moderate	High
Out of Basin Export	713	723	665	643	640	680	715
(To the South Platte River basin, 72')	(513)	(521)	(479)	(463)	(461)	(490)	(515)
In Basin Agricultural Use	1,342	1,342	1,264	-	1,255	1,295	1,345
In Basin Coal Development	56	47	56	32	40	55	55
In Basin Oil Shale	60	45	25	45	25	50	60
Other In Basin Uses	67	46	37	-	39	54	69
Total	2,238	2,206	2,047	-	1,999	2,134	2,244

1990

Colorado River Depletions in Colorado by Use (In Thousands of acre-feet per year)1/	Colorado Water Conservation Board	Pacific Southwest Interagency Committee	Committee of 14	U.S. Department of the Interior Energy Report	Salinity Forum		
					Low	Moderate	High
Out of Basin Export	728	-	700	725	700	730	730
(To the South Platte River Basin, 72)	(524)	(-)	(504)	(522)	(504)	(526)	(526)
In Basin Agricultural Use	1,384	-	1,337	1,492	1,335	1,365	1,495
In Basin Coal Development	64	-	106	119	65	105	120
In Basin Oil Shale	125	-	95	108	95	110	125
Other In Basin Uses	88	-	42	-	39	69	89
Total	2,389	-	2,280	-	2,234	2,379	2,559

1/ Does not include Colorado's pro rata share of evaporation from main stem reservoirs (51.75% of 520,000 or 269,100 acre-feet per year).
Does not include Colorado's share of Mexican water treaty obligations.

then the South Platte River Basin will receive 524,000 acre-feet per year by 1990 according to the Colorado Water Conservation Board. The Salinity Forum, in Table 8-9, estimates that it should receive no less than 504,000 but no more than 526,000 acre-feet per year by 1990. These estimates represent a 55% and a 49% and 56% respectively over the present annual average.

The United States Department of the Interior, in their 1975 Westwide study estimate that the annual maximum diversions from the Colorado River Basin to the South Platte River basin will be 935,000 acre-feet per year (Figure 8-7). This represents a 177% increase of approximately 600,000 additional acre-feet per year over the historical annual average.

Diversions from the Wyoming portion of the Colorado River Basin to the Wyoming portion of the South Platte River basin presently average 7,316 acre-feet per year. This water is exported by the Cheyenne Tunnel-Pipeline Project. As presently envisioned, these diversions will increase to approximately 37,000 acre-feet per year as Cheyenne's demand for this water grows.

8.11 The Colorado Intrastate Controversy Over Colorado River Water

The amount of presently unused water available from the Colorado River within Colorado is estimated to range between 1,321,650 and 348,750 acre-feet per year (Figures 8-5 and 8-6). However, water use within other river basins within Colorado, i.e., the South Platte River basin, the Arkansas River basin, already is in excess of their respective native supplies.

Barring weather modification and drastic climatic changes, this presently unused Colorado River Water, the remains of the Colorado portion of that basins alloted endogenous supplies, represents the final unappropriated source of exogenous water available to other river basins within Colorado.

Once this water is absolutely decreed, there will be no more unappropriated endogenous water left for the Colorado portion of the Colorado River basin and there will be no more unappropriated exogenous water left for other basins in Colorado. Realizing this fact, interests seeking this water for uses within that basin, and without have secured conditional decrees worth several times the amount in question. Obviously, somebody who wants this water is not going to get it.

This state of affairs, the rumbling of which were heard as early as the 1950's, is rapidly approaching a head.

Prevailing sentiment in the Colorado portion of the Colorado River basin is that future transbasin diversions would seriously hamper, if not prevent, the development of western Colorado.

The eastern slope counters with the observation that their development is an accomplished fact and that their pace is increasing. They ask should the growth in this area, the center of the states economy, be cut short by the lack of water in order to await future developments on the western slope?

The Colorado River Basins Routt County Regional Planning Commission, in answer to the Federal Power Commissions request for comments on the Sheephorn Project, listed the following objections to its transbasin diversion plans (Steamboat Pilot, 1976):

1. Increase in the salinity of western streams.
2. Damage to the cold water fisheries.
3. Increase of the cancerous growth along the east slope of the Rockies.
4. Environmental damage of the project and its results.

5. Economic damage to the western slope and loss of water needed to develop coal resources.
6. Damage to agriculture in western Colorado.
7. Damage to the Colorado River compacts with western states and Mexico.

In 1975 the Denver Water Department argued for increased imports by stating that, based on dry year estimates of water demands and yields, even allowing for reservoir carry-over, Denver and most of the other independent water supplies in the Metropolitan area will be hard pressed to meet their obligations in 15 years.

CHAPTER 9

THE ARKANSAS RIVER BASIN

The Arkansas River heads on the Continental Divide and drains the Front Range Mountains in Colorado South of the south Platte River Basin to about the New Mexico state line. The stream also drains the plains east from the Front Range Mountains, which extend into Kansas. Only a portion of this basin, called here the Arkansas River-Mountains sub-basin, is considered herein. This sub-basin is defined as that portion of the drainage area of the main stem Arkansas River above Buena Vista, Colorado. The area is 611 square miles. Figure 9-1 shows the essential characteristics of the sub-basin. The average annual runoff from this drainage area is about 309,049 acre-feet per year (Table A3-1).

The water supplies of the sub-basin are very important to the cities and agriculture of the Arkansas River basin and for that reason there is virtually no water available to the South Platte. However, there are some interactions which warrant mention. The native water supply of the sub-basin is not sufficient to satisfy in-basin demands and so there has been a history of water importation from the Colorado River. The latest activity is the Fryingpan-Arkansas Project of the United States Bureau of Reclamation.

9.1 The Arkansas River-Mountains Sub-basin

9.1.1 *Surface Water Supply* This sub-basin includes the upper most reach of the Arkansas River, from its headwaters on the eastern edge of the Continental Divide to the USGS gaging station #07087200, "Arkansas River at Buena Vista, Colorado." The Arkansas river above this gaging station drains an area of 611 square miles. The Arkansas River orginates

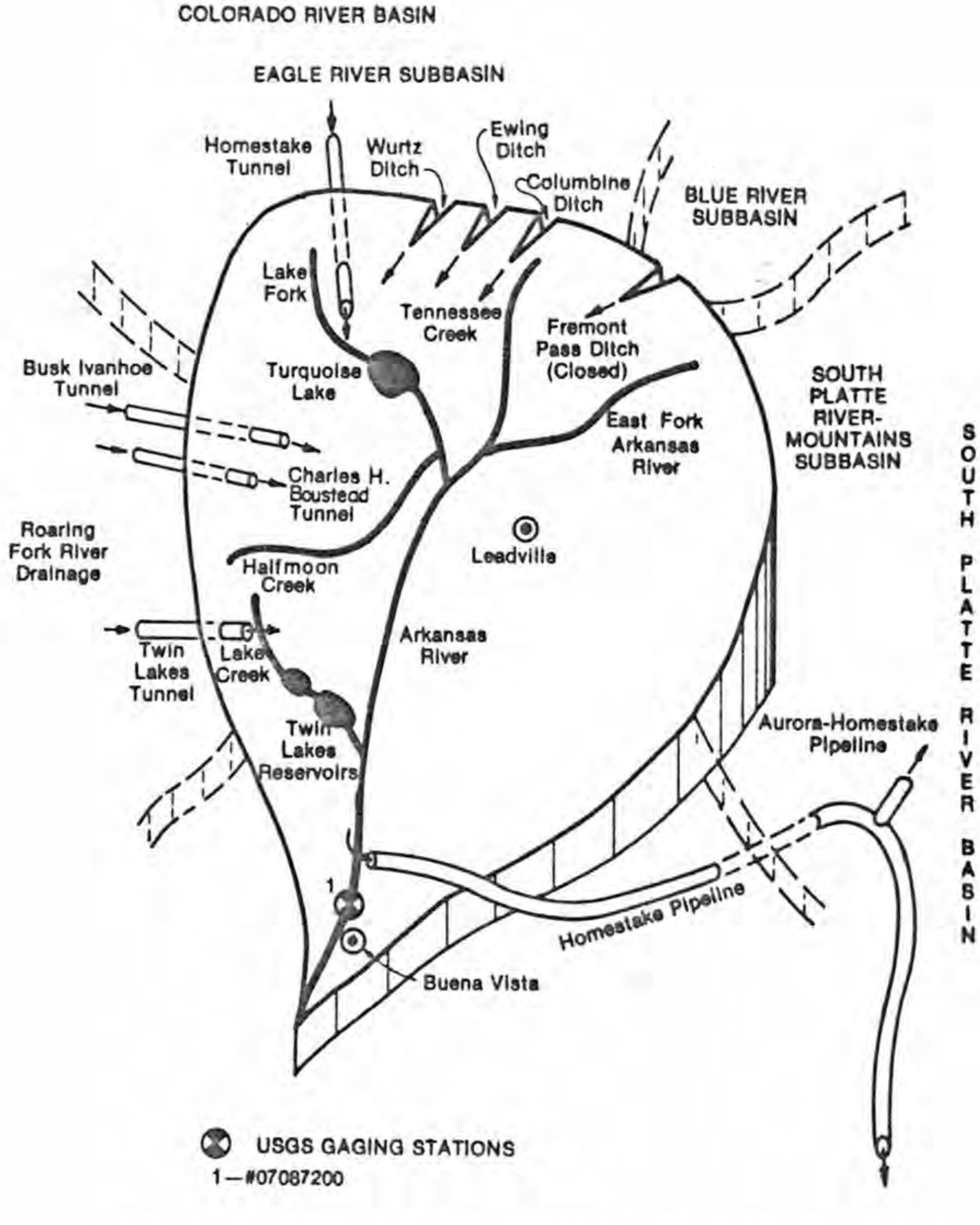


Figure 9-1: Schematic of the Arkansas River-Mountains Subbasin

on the eastern edge of the Continental Divide at elevations of greater than 14,000 feet. This sub-basin shares boundaries with the Colorado River basin to the north and west and with the South Platte River basin to the north and east.

From its headwaters the Arkansas River flows south for approximately 40 miles to Buena Vista, losing more than 6,000 feet in altitude. Below Buena Vista at Salida it veers east through Colorado, Kansas, and Oklahoma finally reaching the Mississippi River in the State of Arkansas. The principal tributaries within this sub-basin are Clear, Lake, Halfmoon, Lake Fork, and Tennessee Creeks and the East Fork of the Arkansas River.

The most intensive use of water in this sub-basin is made through the irrigation of approximately 7,400 acres of land in its lower valleys, (USGS, 1975). There are nine diversion structures importing water to this sub-basin from the Colorado River basin. There is one diversion structure which exports water from this sub-basin, delivering water both to the South Platte and Arkansas River basin below this sub-basin. Several large reservoirs are located within the sub-basin which provide storage for native flows and imports. Their aggregate capacity is 193,900 acre-feet (USGS, 1975).

The precipitation in the headwaters area average 32 inches per year and about ten inches per year in the lower elevations (National Oceanic and Atmospheric Administration, United States Department of Commerce, 1974). The principal form of precipitation in this sub-basin during the winter is snow derived from moisture moving eastward from the Pacific Ocean. However, this sub-basin lies in the "rain shadow" to the east of the Continental Divide. Generally these winter storms produce less snow here than to the west due to the orographic effect of the high mountains.

The surface water supply of the sub-basin is derived principally from the resulting winter snow pack as it melts in the spring. Summer rainfall is usually insufficient to produce significant runoff (McCain, Jarrett, 1976).

The native surface water supplies of this sub-basin can be estimated from the flows recorded at the USGS Gaging Station #07087200, "Arkansas River at Buena Vista, Colorado." The records of annual runoff gaged at this station are given in Table C3-1. From these data, adjusted as seen in Table A3-1, the average native surface water supply available to the Arkansas River-Mountains Sub-basin is estimated to be 309,049 acre-feet per year. The 1970 native surface water supply of this sub-basin was 385,432 acre-feet, or 124.72% of average; computations are shown in Table A3-2. The native surface water supply of this sub-basin during the 1953-1956 four year drought period is estimated to have averaged 235,001 acre-feet per year, or 76.04% of the long term average; computations are seen in Table A3-3.

9.1.2 *Legal Constraints* - There are no interstate compacts, decrees, or agreements which specifically limit exports from this river basin. The Arkansas River Compact (Appendix D, Section D-3) apportions equitably the flows of this river to both Colorado and Kansas and relinquishes jurisdiction over this water to the respective states. Exports from this basin within Colorado therefore are constrained only by Colorado water laws. These state that if the water of a drainage area is unappropriated, they may be freely exported provided no harm is done to downstream appropriators. If the water is appropriated, changes in place of use is a well-recognized right and the water may be purchased.

However, only the average annual historical consumptive use may be exported as downstream users have a vested right to the return flows.

9.1.3 *Transbasin Diversion Structures* - Seven transbasin diversion structures presently import water to the Arkansas River-Mountains sub-basin. They all bring water in from the Colorado River Drainage.

The use of Freemont Pass Ditch, which imported water from the Blue River, was discontinued in 1943. Four of the presently operating trans-basin diversion structures, the Combine, Ewing, and Wurtz Ditches and the Homestake Tunnel, import water from the Blue River sub-basin. The remaining three, the Busk-Ivanhoe, the Charles H. Boustead, and the Twin Lakes Tunnels, import water from the Roaring Fork Drainage.

The Homestake Tunnel-Homestake Pipeline is the only one of these projects which interacts directly with the South Platte River basin. The pipeline picks up all of the tunnel imports and delivers the water to Aurora in the South Platte basin and Colorado Springs in the Arkansas River basin. The flow in the pipeline may be supplemented on occasion by native flows from the Arkansas River. This was a joint project of the cities of Aurora and Colorado Springs, with each city owning half interest.

The other six projects are of interest only from the standpoint of their significance with respect to whether the Arkansas River-Mountains sub-basin could be a source of water for users in the South Platte River basin. The very existence of these diversion structures are evidence that the waters of the Arkansas River basin are already overappropriated indicating water could not be available for export except perhaps by purchase of existing senior water rights.

The Freemont Pass Ditch - This ditch is described in section 8.7.2.

The Columbine Ditch - This ditch is described in section 8.7.2.

The Ewing Ditch - This ditch is described in section 8.7.2.

The Wurtz Ditch - This ditch is described in section 8.7.2.

The Homestake Tunnel - This tunnel, and the overall Homestake Project, are described in section 8.7.2.

The Busk Ivanhoe Tunnel - This tunnel diverts water at an altitude of 10,950 feet from Ivanhoe Lake on Ivanhoe Creek, a tributary to the Fryingpan River, which is a tributary to the Roaring Fork River. It delivers water to Busk Creek, in the Arkansas River Drainage, a tributary to Lake Fork.

The complete records of the yearly diversions through this tunnel, which began in the 1925 water years, are shown in Appendix B, Table B4-6. To date, these imports have averaged 4,878 acre-feet per year.

The Charles H. Bousted Tunnel - This tunnel diverts water from collection ditches which intercept the main stem and tributaries of the Fryingpan River, a tributary to the Roaring Fork River. The water is delivered to Lake Fork. The complete records of the yearly diversions through this tunnel, which began in May of 1972, are shown in Appendix B, Table B4-7. To date these imports have averaged 34,837 acre-feet. This tunnel and Turquoise Lake are part of the USBR's Fryingpan-Arkansas Project.

The Twin Lakes Tunnel - This tunnel diverts water at an altitude of 10,500 feet from headwater tributaries of the Roaring Fork River to Lake Creek. The complete records of the yearly diversions through this tunnel, which began on May 24, 1935, are shown in Appendix B, Table B4-8. To date these imports have averaged 39,495 acre-feet per year.

The Homestake Pipeline - A description of the Homestake project can be found in section 8.7.2. Of interest here is the use of the Homestake pipeline for the exportation of native Arkansas River Basin water.

Aurora is presently the only South Platte Basin water user who has rights to the native water of this sub-basin. This water is comingled in the Homestake Pipeline with water brought over via the Homestake Tunnel from the Eagle River sub-basin. In the South Platte River basin the Homestake Pipeline branches with the Aurora-Homestake Pipeline delivering water to Aurora, while the main pipeline continues to Colorado Springs.

The city of Aurora is actively engaged also in increasing its interest in water rights in the Arkansas River headwaters. The city owns shares in the Twin Lakes Reservoir and Canal Company, which owns direct flow and storage rights to Arkansas River water. However, its primary source of water is from the Roaring Fork River, a tributary of the Colorado River, which the company imports through the Twin Lakes Tunnel. In 1973 Aurora realized 40 acre-feet from her shares in this company (Beck, 1974). Table 9-1 shows Aurora's aquisition schedule of shares in the Twin Lakes Reservoir and Canal Company and their yields.

Table 9-1 Aurora Twin Lakes Water Acquisition Schedule (Beck, 1974).

Year	Shares Acquired	Acre-feet per year
1973-1977	37.015	40.7165
1978-1981	582.655	640.9205
1982-1985	1636.655	1800.3205
1986-	2344.655	2579.1205

In 1975 Aurora purchased the Burroughts Estate water rights. This water was previously used to irrigate land within the Arkansas River-Mountains sub-basin, in Lake County, west of Leadville, Colorado. The historical average annual consumptive use of this right was determined to have been 341 acre-foot (Rice, 1971). Because downstream appropriators in the Arkansas River Basin have a vested right to the Burroughs Estate historical return flows, only the consumptive use associated with this right is available to Aurora for diversion to the South Platte River. Table 9-2 shows the yield availability pattern of this right, which is equal to the consumptive use associated with the Burrough's right.

The first diversion through the Homestake Pipeline occurred in 1966. This was prior to the initial deliveries by the Homestake Tunnel in June of 1967. This use of Arkansas River water was made by Colorado Springs. The first turnout through the Aurora-Homestake pipeline was made by Aurora on August 24, 1967. These latter diversions, however, were from the Blue River brought over through the Homestake Tunnel. It was not until 1973, that Aurora used water from the upper Arkansas River.

Table 9-2 The Yield Availability Pattern of the Burroughs Estate Water Right (Beck, 1971).

Month	% of Annual Yield	Monthly Yield (acre-feet)[1/]
May	35	119
June	35	119
July	20	68
August	10	35
Total	100%	341

9.1.4 *Conclusions* - Water users within the Arkansas River basin are faced with much the same situation as water users in the South Platte River basin. They lie in the "rain shadow" of the Continental Divide and are similarly confronted with the pressures of rapid growth along the Front Range. Endogenous surface water supplies have been appropriated to the point where they too must look elsewhere for water. This has led them also to the Colorado River basin where most, if not all, of the unappropriated water in the State of Colorado is to be found.

Because of all of the endogenous water supplies of the Arkansas River basin have been appropriated, the only water that is legally available for import to the South Platte River basin is that amount of a particular right that is consumptively used. Historical return flows of water rights must remain in the basin of origin.

So far, the only South Platte River basin water users that has looked to the Arkansas River basin for water is the City of Aurora. She has purchased a water right to the endogenous supplies of this basin that had been used for irrigation. She exports only the historical consumptive use of the right purchased. Aurora has also purchased, and is scheduling to acquire more, shares in the exogenous water supplies that are being developed by Arkansas River Basin water interests (Twin Lakes Reservoir and Canal Company). Aurora imports this water through an exchange with Colorado Springs for it's exogenous water supplies. In this manner, the return flows of the Twin Lakes Reservoir and Canal Companies water are returned to the Arkansas River by Colorado Springs sewage treatment plant.

Other South Platte River basin water users seeking Arkansas River basin water may proceed as Aurora has. However, this may be economically prohibitive as appropriate importation facilities must be built, the water must be purchased from its present owners, and then only the historical consumptive use may be diverted. Of course, they may set up an agreement for use of the existing Homestake Project facilities, but the amount of imports will be limited also by the capacity of the Homestake Pipeline.

CHAPTER 10

OTHER RIVER BASINS

The Columbia, Missouri, Mississippi and Mackenzie are a few of the rivers that have been proposed in the past as sources of more water for the arid west. The transfer of water from these basins to the South Platte River basin, among others, is technically feasible. However, there are a host of complex ramifications associated with such projects, any one of these could render it unfeasible. Eleven of the inter-regional transfer proposals made since 1963 are shown in Figure 10-1.

10.1 NAWAPA

The NAWAPA plan (North American Water and Power Alliance) proposed by the Ralph M. Parsons Company of Los Angeles and originally conceived by Hillman Hansen (Smith, 1968), is one of the best known and most gradiose plans of this nature. Backed up with considerable documentation in a preliminary study, the proposal caught the attention of the Senate Committee on Public Works which established the sub-committee on Western Water Development, chaired by Senator Mass of Utah, to study the plan to ascertain whether a larger study was warranted.

The description of the NAWAPA plan which follows is taken from Vlachos and Hendricks in Technology Assessment for Water Supplies (1977).

The NAWAPA plan is outlined here very briefly because it represents one type of thinking about water supply alternatives - that new supplies can always be developed by being sufficiently bold and imaginative. Although little discussed after 1970, the NAWAPA plan or a less grand Columbia River water transfer project could be a serious proposal if the Southwest finds it still cannot live within its constraints of limited

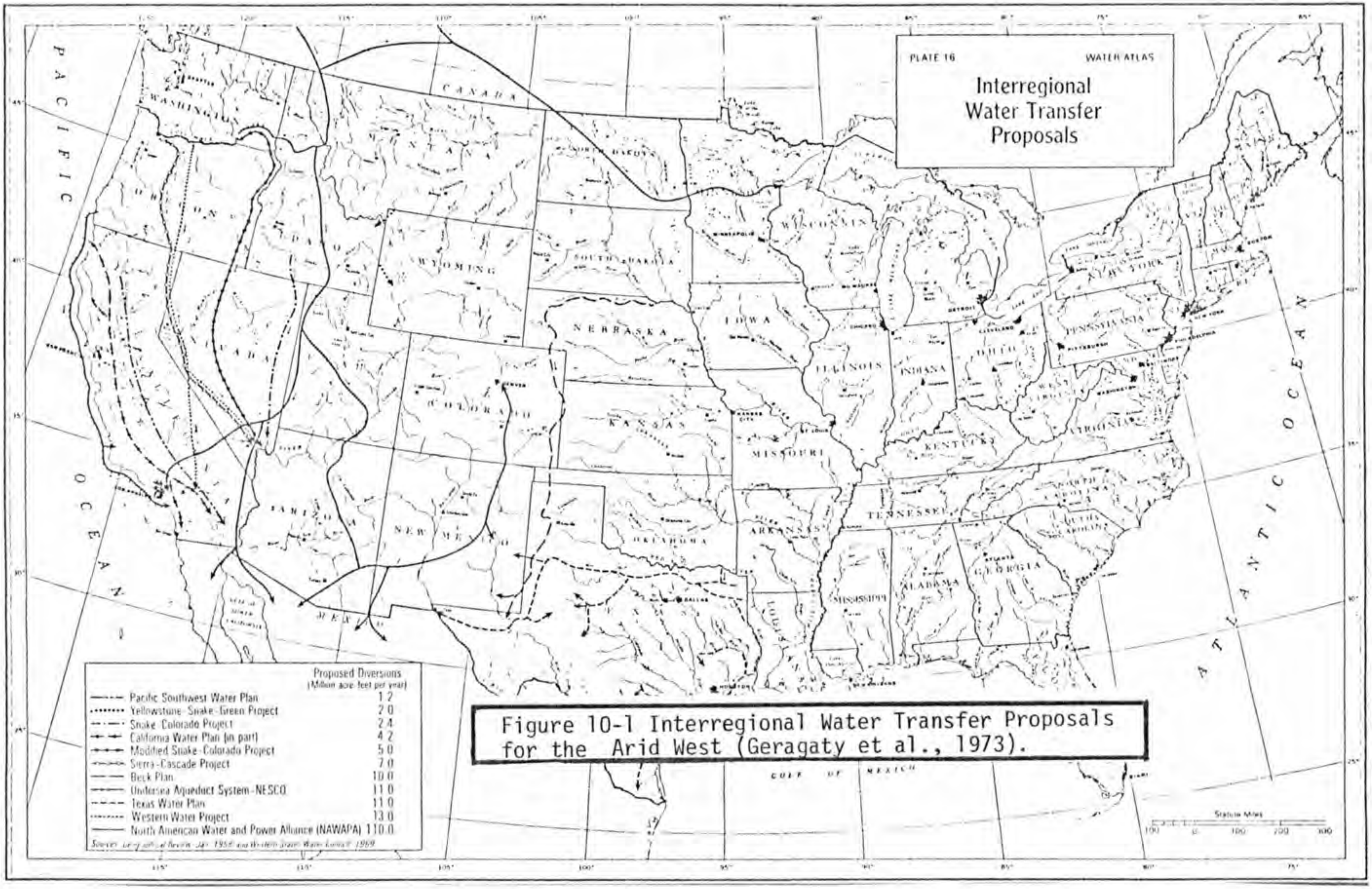


Figure 10-1 Interregional Water Transfer Proposals for the Arid West (Geragaty et al., 1973).

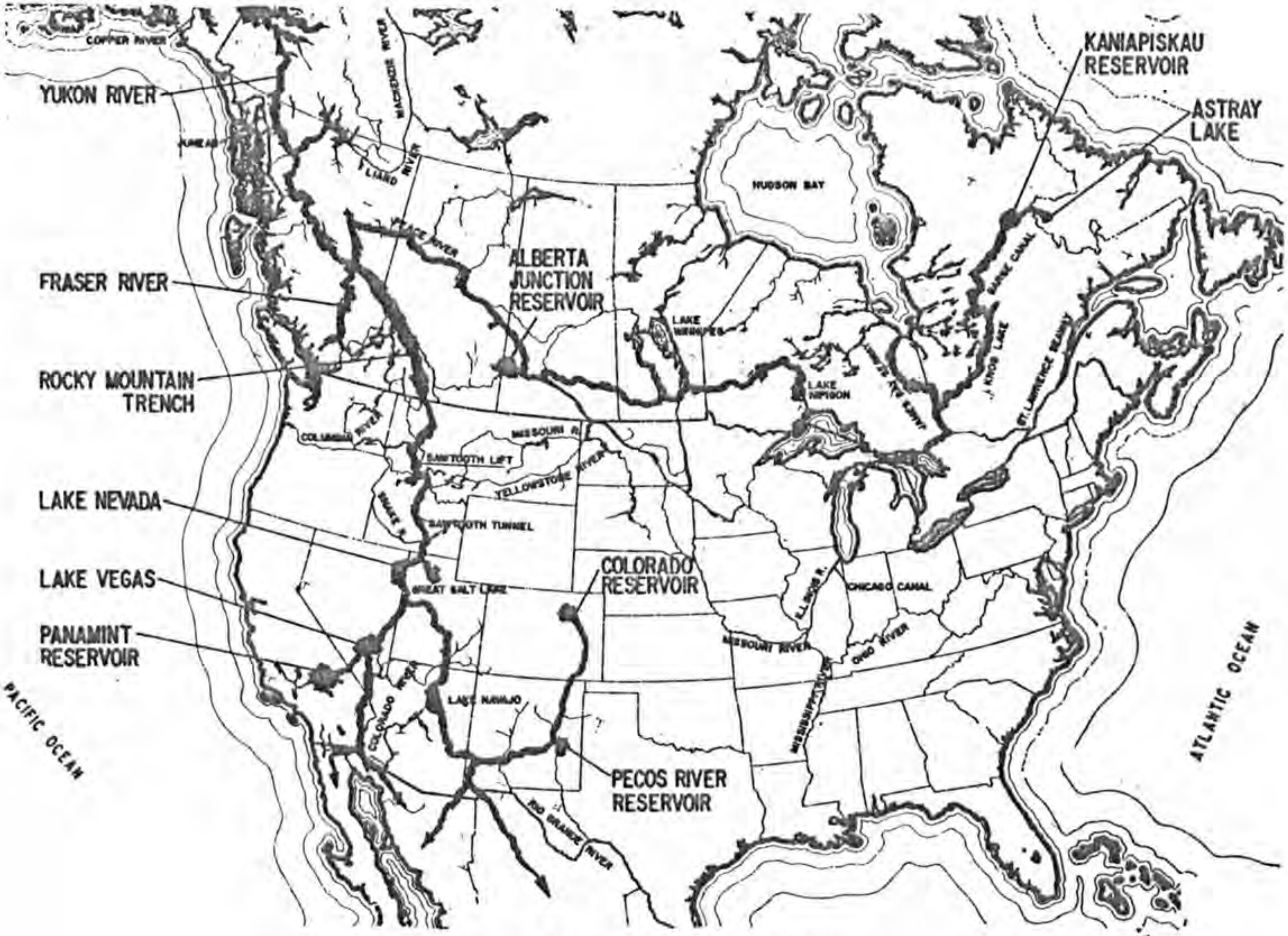
water. It would seem that the political opposition to any such plan would certainly be more formidable than anything experienced to date for any other project.

The Project - Briefly, NAWAPA would collect surplus waters from the Fraser, Yukon, Peace, Athabasca, and other rivers of Alaska, British Columbia, and Yukon Territory, and distribute these to water scarce areas of Canada, the western and midwestern United States, and Northern Mexico. The drainage area of the NAWAPA collection system is about 1,300,000 square miles having a mean annual precipitation of about 40 inches and an average annual runoff of about 663 million acre-feet.

The NAWAPA project would divert about ten million acre-feet and would deliver this water mostly to the western United States (with 20 million acre-feet for northern Mexico). Figure 10-2 is a NAWAPA system map indicating the grand nature of the concept. The NAWAPA concept would comprise 369 projects consisting of reservoirs, irrigation systems, and navigation channels. Table 10-1 summarizes the NAWAPA projects by category and by location. The total construction cost is estimated to be about 80 billion dollars.

Some of the key features of the NAWAPA plan which give a further perspective on the magnitude of the concept include:

1. A dam 1700 feet high to impound flows of the Copper River in Alaska.
2. A 500 mile long storage reservoir at 3000 foot elevation in Canada on the west side of Banff and Jasper National Parks in a location known as the Rocky Mountain trench.
3. A navigable waterway from Vancouver, B.C. to Lake Superior.
4. Canals as wide as 630 feet.



NAWAPA SYSTEM MAP

Figure 10-2: NAWAPA System Map (U. S. Senate, Committee on Public Works, 1964).

Table 10-1 Summary of NAWAPA Projects (U.S. Senate, Committee on Public Works, 1964).

	Number of Projects	Storage	Installed Capacity	Acres Irrigated	Total Construction Cost
		Acre-feet	Thousand kilowatt-hours		
Reservoirs	240	4,338,509,000	99,788	----------	$37,881,820,000
Irrigation systems	112	-------------	---------	35,940,000	41,773,180,000
Navigation channels	17	-------------	---------	----------	340,000,000
Total	369	4,338,509,000	99,788	35,940,000	80,000,000,000

Reservoirs

	Number of Projects	Storage Capacity	Installed Capacity	Total Construction Cost
		Acre-feet	Thousand kilowatts	
United States:				
Alaska	3	1,486,400,000	1,119.0	$ 1,441,000,000
Colorado	26	20,772,000	11,623.0	1,985,880,000
Columbia	18	29,330,000	27,100.0	16,908,000,000
Great Basin	1	7,312,000	---------	46,000,000
Missouri	8	-------------	837.0	67,100,000
Rio Grande-Gulf	5	-------------	2,976.0	1,210,000,000
Total, United States	61	1,543,814,000	43,655.0	21,657,980,000
Canada	179	2,794,695,000	56,133.0	16,223,840,000
Total reservoirs	240	4,338,509,000	99,788.0	37,881,820,000

Irrigation Aqueducts and Distribution Systems

	Number of Projects	Acres Irrigated	Total Construction Cost
Alaska	10	(1)	$ 555,000,000
Colorado	16	7,000,000	6,250,000,000
Columbia	8	(1)	180,000,000
Great Basin	15	2,000,000	11,300,000,000
Missouri	2	1,000,000	720,000,000
Rio Grande-Gulf	13	11,000,000	5,672,000,000
Total, United States	64	21,000,000	24,677,000,000
Canada	37	9,000,000	15,030,000,000
Mexico	11	5,940,000	2,071,180,000
Total irrigation systems	112	35,940,000	41,778,180,000

(1) Not available.

Navigation Channels

	Number of Projects	Total Construction Cost
United States: Missouri	2	(1)
Canada	15	(2)$340,000,000
Total navigation channels	17	340,000,000

(1) Included in cost of irrigation system.
(2) Cost of 1 project, other costs included in irrigation systems.

5. Six pumping plants to lift 85,000 cubic feet per second of water 2,360 feet from Flathead Lake to the proposed Upper Salmon Reservoir.

The unit cost of NAWAPA water is of interest for comparison purposes. As a rough estimate assume a 50 year amortization period with an interest rate of seven percent; this gives an annual cost, on an 80 billion dollar principal, of 5.7968 billion dollars per year. Assume also an annual operating cost of one billion dollars per year (this is an arbitrary figure); this gives an annual cost of 6.7968 billion dollars per year (keep in mind that income is neglected and the total capital cost is assigned to water production). For 110 million acre-feet of project produced water the unit cost would be 61.79 dollars per acre foot.

Problems - Such a project would literally change the face of western Canada and the western United States and provide a tremendous new growth potential for the western states. The feasibility of such a project is questionable on economic, financial, materials and environmental grounds. The project would upset capital markets and cause materials shortages and affect the national economies of both Canada and the United States. The environmental perturbations of such a project would also be inestimabel and would be sure to generate political opposition at a level heretofore unknown. And finally there is the question of social desirability of such a project. Current attitudes in many western states seem to rejct the idea of further population growth and development. While such attitudes are not measurable they are evident empirically by the political expressions of the electorate of several states in choosing congressional delegations, governors, and in deciding on referendum issues (e.g., the rejection of the 1976 Winter Olympics by Colorado Voters).

10.2 Other Projects

Another concept, the Western States Water Augmentation Concept envisioned water collection and distribution systems similar in scope and magnitude of the NAWAPA plan. However, it is more definitive as to source areas and distribution arms within the United States. In addition, this proposal made rough comparisons of costs of water transfers from various alternative basins.

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APPENDIX A

DETERMINATION OF NATIVE SURFACE WATER RUNOFF OF THE SUBBASINS WITHIN THE SOUTH PLATTE AND ADJACENT RIVER BASINS

<u>SECTION A3</u> -- Arkansas River Basin

<u>SECTION A4</u> -- South Platte River Basin

INTRODUCTION

Contained within this appendix are the estimations of the long term average annual, 1970 and 4-year drought period native surface water runoff of the designated subbasins of the South Platte and adjacent river basins.

The general methodology used in estimating these subbasins' average annual native surface water supply is as follows. The drainage area of the gaging station located at the subbasins' mouth (Appendix C) defines the subbasin boundaries. The published records of the yearly flows recorded at this gaging station were averaged. This value was then adjusted for the consumptive use of the subbasins' demand sectors and for any water resources development upstream which have perturbated the natural system and affected the flows recorded at the gaging station. Table A-1 lists the major man-caused effects considered, and their subsequent influence on the flows recorded at a gaging station with respect to its drainage areas naturally occurring runoff. Because of the lack of data, some perturbations could not be addressed, specifically the consumptive use of surface water supplies by municipalities and industries on the west slope and in the mountainous portions of the South Platte Basin. However, their effects are known to be fairly insignificant, generally using less than the error induced due to the accuracy of the gaging stations flow measurements. In addition, shrinkage losses of water imported to a drainage area, between the point of entry and measurement by the gaging station, were neglected.

Reservoirs only serve to prolong the inevitableness of water flowing past the gaging station. Over the long term, the regulation

TABLE A-1: Major Considerations in Estimating the Native Surface Water Runoff of a Gaging Station's Drainage Area from its Flow Records

Upstream Man-Caused Effects	Subsequent Influence on a Gaging Station's Recorded Flow With Respect to its Drainage Areas' Native Surface Supplies	
	Increases	Decreases
Surface water return flows from ground water pumpage in the gaging station drainage area	X	
Consumptive use of the native surface supplies by agriculture, municipalities, industries, or reservoirs and conveyance facilities		X
Exports of the native surface water supplies to outside the gaging station's drainage area		X
Imports of water from outside the gaging station's drainage area that are not consumptively used before reaching the gaging station	X	
Reservoir storage of the native surface supplies occurring during the study period		X
Reservoir releases of the native surface water supplies stored prior to the study period and not consumptively used before reaching the gaging station	X	
Reservoir releases of water imported from outside the gaging station's drainage area that are not consumptively used before reaching the gaging station	X	

effects of these storage facilities can be assumed negligable (however, evaporation cannot).

Consideration of upstream man-caused effects in the analysis that are not shown are either negligable or do not apply.

The procedure for estimating these subbasins' 1970 native surface water supply was the same as above except that instead of average annual values, 1970 data was used.

The procedure for estimating these subbasins' native surface water supply during a drought was a variation of the above analysis. 1953-56 average annual values of runoff were used. The 1953-56 period is the most severe drought period where the gaging station records of these subbasins are the most complete. A four year period was chosen to place the most stress on the reservoirs in the South Platte Basin and on the west slope storage facilities that supply several of the transbasin diversion structures exporting water to the South Platte River Basin. In the drought analysis perturbations caused by the consumptive use of agriculture, municipalities and industries were not corrected for. While these amounts were not known for the 1953-56 period, they can be assumed to have been less than average as only the most senior water right holders would receive water during drought runoff conditions. In addition, the evaporation from reservoirs were not corrected for. These would have been depressed from average due to the lesser volume in storage and consequently decreased surface area.

The 1953-56 average annual recorded runoff was corrected only for perturbations caused by storage changes in reservoirs and the exports and imports of water to the subbasin. This value, termed "adjusted runoff," was then compared to the corresponding "adjusted runoff" found under long term average conditions. The percent the drought "adjusted runoff" was of the average "adjusted runoff" was applied to that subbasin's long term average native surface water supply to arrive at its native surface water supply under drought conditions.

The difference between a subbasin's computed native surface water during a drought and its drought "adjusted runoff" was, therefore, assumed to have been the consumptive use available to agriculture, municipalities, industries, and reservoirs during the drought.

NOTE: Not included in this Appendix is the water supply analysis of the subbasin's contained within the South Platte Basin Subbasin Grouping Number 4, "The South Platte River Plains and its Emphemeral Tributaries". Information regarding the native surface water runoff of these five subbasins during the long term, 1970 water year, and the 1953-56 four year drought period can be found in Part II, Chapter 6 of the text.

SECTION A1

THE NORTH PLATTE RIVER BASIN

TABLE A1-1: Computation of Native Surface Water Runoff

Subbasin: North Platte River-Mountains
Supply Condition: Average Annual, Long Term
USGS Gaging Station(s) and Period: #06620000, 1916-75

Average Annual Upstream Man-Caused Effect	Influence (Acre-Feet)
A. Computation of the net influence of upstream man-caused effects on the gaging stations' recorded flow with respect to its drainage areas' native surface water runoff	
Consumptive use of surface water by irrigated agriculture	+169,000[1]
Export of surface water by the Michigan Ditch	+ 2,385[2]
Export of surface water by the Cameron Pass Ditch	+ 186[3]
NET INFLUENCE	+171,571
B. Computation of the native surface water runoff	
Average annual runoff as measured by the USGS gaging station(s)	315,755[4]
Average annual net influence of upstream man-caused effects	+171,571
Average annual native surface water runoff	487,326

[1] There are diversions for approximately 130,000 acres of irrigated hay meadows above the gaging station (USGS, 1975). It is assumed that the irrigation application rates in this subbasin roughly corresponding to those in the Cache La Poudre Subbasin of the South Platte River Basin where the growing season precipitation is similar. Therefore, on the average 2.78 acre-feet of water is applied to each acre of land of which about 1.3 acre-feet is consumptively used (Janonis and Gerlek, 1977). It is further assumed that ground water development in this subbasin is minor and that the irrigation demand is met exclusively by surface flows. Thus, the average consumptive use of surface water supplies by irrigation in this subbasin is approximately 169,000 acre-feet per year. The non-consumptively use portion of the applied irrigation water is assumed to infiltrate to the aquifer, and eventually accrue back to the stream as return flows. Therefore, over the long term this water need not be corrected for as it will show up as surface flows at a later date.

[2] Appendix B, Table B1-8.

TABLE A1-1: (continued)

[3] Appendix B, Table B1-7.

[4] Appendix C, Table C1-1.

TABLE A1-2: Computation of Native Surface Water Runoff

Subbasin: North Platte River-Mountsins
Supply Condition: 1970 Water Year
USGS Gaging Station(s) and Period: #06620000, 1970

1970 Upstream Man-Caused Effect	Influence (Acre-Feet)
A. Computation of the net influence of upstream man-caused effects on the gaging station's recorded flow with respect to its drainage areas' native surface water runoff	
Consumptive use of surface water by irrigated agriculture	+169,000[1]
Export of surface water by the Michigan Ditch	0[2]
Export of surface water by the Cameron Pass Ditch	0[3]
NET INFLUENCE	+169,000
B. Computation of the native surface water runoff	
1970 runoff as measured by the USGS gaging station(s)	386,000[4]
1970 net influence of upstream man-caused effects	+169,000
1970 native surface water runoff	555,000

[1] Assumed to be average depletion, see Footnote[1], Appendix A, Table A-1.

[2] Appendix B, Table B1-8.

[3] Appendix B, Table B1-7.

[4] Appendix C, Table C1-1.

TABLE A1-3: Computation of Native Surface Water Runoff

Subbasin: North Platte River-Mountains
Supply Condition: Average Annual, 4 Year Drought Period
USGS Gaging Station(s) and Period: #06620000, 1953-56

1953-56 Average Annual Upstream Man-Caused Effect	Influence (Acre-Feet)
A. Computation of the net influence of upstream man-caused effects on the gaging station's recorded flow with respect to its drainage areas' native surface water runoff (excluding the consumptive use of surface water by municipalities, agriculture, and industries, and reservoir evaporation)	
Export of surface water by the Michigan Ditch	+ 827[1]
Export of surface water by the Cameron Pass Ditch	177[2]
NET INFLUENCE	+ 1,004
B. Computation of the native surface water "adjusted runoff"	
1953-56 average annual runoff as measured by the USGS gaging station(s)	183,755[3]
1953-56 average annual net influence of upstream man-caused effects	1,004
1953-56 average annual native surface water "adjusted runoff"	184,759

C. Computation of the native surface water runoff

$$\frac{\text{1953-56 Drought Period Average Annual "Adjusted Runoff"}}{\text{Long Term Average Annual "Adjusted Runoff"}} = \frac{\text{184,759 Acre-Feet}}{\text{318,326 Acre-Feet}^4} = 0.5804$$

Therefore, 58.04 percent of the long term average annual native surface water runoff of this subbasin is assumed to be the average annual native surface water runoff during a four year drought period, or,

[0.5804] [487,236 acre-feet[5]] = 282,844 Acre-Feet

[1] Appendix B, Table B1-8.

[2] Appendix B, Table B1-7.

[3] Appendix C, Table C1-1.

TABLE A1-3: (continued)

[4] Appendix A, Table A1-1. The average annual native surface water runoff of this subbasin minus the average annual surface water consumptive use of its agriculture.

[5] Appendix A, Table A1-1. The long term average annual native surface water runoff of this subbasin.

TABLE A1-4: Computation of Native Surface Water Runoff

Subbasin: Laramie River
Supply Condition: Average Annual, Long Term
USGS Gaging Station(s) and Period: #066585000, 1905, 1911-71

Average Annual Upstream Man-Caused Effect	Influence (Acre-Feet)
A. Computation of the net influence of upstream man-caused effects on the gaging station's recorded flow with respect to its drainage areas' native surface water runoff	
Consumptive use of surface water by irrigated agriculture	+ 6,032[1]
Export of surface water by the Skyline Ditch	+10,177[2]
Export of surface water by the Laramie-Poudre Tunnel	+10,383[3]
Export of surface water by the Wilson Supply Ditch	+ 2,469[4]
Export of surface water by the Bob Creek Ditch	+ 214[5]
Export of surface water by the Columbine Ditch	+ 70[6]
Export of surface water by the Lost Lake Outlet	+ 126[7]
NET INFLUENCE	+29,651
B. Computation of the native surface water runoff	
Average annual runoff as measured by the USGS gaging station(s)	116,227[8]
Average annual net influence of upstream man-caused effects	+29,651
Average annual native surface water runoff	145,878

[1] There are diversions for approximately 4,640 acres of irrigated hay meadows above the gaging station (United States Geological Survey, 1970b). The methodology for estimating the consumptive use of surface water supplies by irrigated acreage within the subbasin is the same as that used for the North Platte River-Mountains Subbasin (Footnote[1], Appendix A, Table A1-1).

[2] Appendix B, Table B1-5.

TABLE A1-4: (continued)

[3] The Laramie-Poudre Tunnel has been diverting water only since 1914 (Appendix B, Table B1-4). The value entered is the equivalent 1905, 1911-1971 annual diversion. This was computed by spreading out its 58-year 1914-71 diversions over the 62 years 1905, 1911-71 time period.

[4] Appendix B, Table B1-1.

[5] The Bob Creek Ditch only diverted water for the 37 year period, water years 1920-56 (Appendix B, Table B1-3). The value entered is the 1905, 1911-71 equivalent annual diversion. This was computed by spreading out its 37 years, 1920-56 diversions over the 62 year 1905, 1911-71 time period.

[6] The Columbine Ditch only diverted water for the 36 year period, water years 1921-56 (Appendix B, Table B1-2). The value entered is the equivalent 1905, 1911-71 annual diversion. This was computed by spreading out its 36 year 1921-56 diversions over the 62 year 1905, 1911-71 time period.

[7] The Lost Lake Outlet diverted water for a 52 year period, 1899 to 1950 (Appendix B, Table B1-6). The value entered is the equivalent 1905, 1911-71 annual diversion. This was computed by spreading out its 41 year 1905, 1911-50 diversions over the 62 year 1905, 1911-71 time period.

[8] Appendix C, Table C1-2.

TABLE A1-5: Computation of Native Surface Water Runoff

Subbasin: Laramie River
Supply Condition: 1970 Water Year
USGS Gaging Station(s) and Period: #06658500, 1970

1970 Upstream Man-Caused Effect	Influence (Acre-Feet)
A. Computation of the net influence of upstream man-caused effects on tha gaging station's recorded flow with respect to its drainage areas' native surface water runoff	
Consumptive use of surface water by irrigated agriculture	+ 6,032[1]
Export of usrface water by the Skyline Ditch	+ 1,550[2]
Export of surface water by the Laramie-Poudre Tunnel	+14,990[3]
Export of surface water by the Wilson Supply Ditch	+ 2,880[4]
NET INFLUENCE	+25,452
B. Computation of the native surface water runoff	
1970 runoff as measured by the USGS gaging station(s)	145,600[5]
1970 net influence of upstream man-caused effects	+25,452
1970 native surface water runoff	171,052

[1] Assumed to be the average depletion, see Footnote[1], Appendix A, Table A1-4.

[2] Appendix B, Table B1-5.

[3] Appendix B, Table B1-4.

[4] Appendix B, Table B1-1.

[5] Appendix C, Table C1-2.

TABLE A1-6: Computation of the Native Surface Water Runoff

Subbasin: Laramie River
Supply Condition: Average Annual, 4 Years Drought Period
USGS Gaging Station(s) and Period: #06658500, 1953-56

1953-56 Average Annual Upstream Man-Caused Effect	Influence (Acre-Feet)
A. Computation of the net influence of upstream man-caused effects on the gaging station's recorded flow with respect to its drainage areas' native surface water runoff (excluding the consumptive use of surface water by municipalities, agriculture and industries, and reservoir evaporation).	
Export of surface water by the Skyline Ditch	+ 3,915[1]
Export of surface water by the Laramie-Poudre Tunnel	+14,570[2]
Export of surface water by the Wilson Supply Ditch	+ 2,012[3]
Export of surface water by the Bob Creek Ditch	+ 372[4]
Export of surface water by the Columbine Ditch	+ 115[5]
NET INFLUENCE	+20,984
B. Computation of the native surface water "adjusted runoff"	
1953-56 average annual runoff as measured by the USGS gaging station(s)	68,900[6]
1953-56 average annual net influence of upstream man-caused effects	+20,984
1953-56 average annual native surface water "adjusted runoff"	89,884
C. Computation of the native surface water runoff	

$$\frac{\text{1953-56 Drought Period Average Annual "Adjusted Runoff"}}{\text{Long Term Average Annual "Adjusted Runoff"}} = \frac{\text{89,994 Acre-Feet}}{\text{139,846 Acre-Feet}^{7}} = 0.6427$$

Therefore, 64,27 percent of the long term average annual native surface water runoff of this subbasin is assumed to be the average annual native surface water runoff during a four year drought period, or,

[0.6427] [145,878 acre-feet[8]] = 93,756 Acre-Feet

TABLE A1-6: (continued)

[1] Appendix B, Table B1-5.

[2] Appendix B, Table B1-4.

[3] Appendix B, Table B1-1.

[4] Appendix B, Table B1-3.

[5] Appendix B, Table B1-2.

[6] Appendix C, Table C1-2.

[7] Appendix A, Table A1-4. The average annual native surface water runoff of this subbasin minus the average annual surface water consumptive use of its agriculture.

[8] Appendix A, Table A1-4. The average annual native surface water runoff of this subbasin.

SECTION A2

THE COLORADO RIVER BASIN

TABLE A2-1: Computation of Native Surface Water Runoff

Subbasin: Colorado River-Mountains
Supply Condition: Average Annual, Long Term
USGS Gaging Station(s) and Period: #09034500, 1905-46[1]

Average Annual Upstream Man-Caused Effect	Influence (Acre-Feet)
A. Computation of the net influence of upstream man-caused effects on the gaging station's recorded flow with respect to its drainage areas' native surface water runoff	
Consumptive use of surface water by irrigated agriculture	+ 6,500[2]
Export of surface water by the Grand River Ditch	+14,100[3]
Export of surface water by the Eureka Ditch	+ 16[4]
NET INFLUENCE	+20,616
B. Computation of the native surface water runoff	
Average annual runoff as measured by the USGS gaging station(s)	357,858[5]
Average annual net influence of upstream man-caused effects	+20,616
Average annual native surface water runoff	378,474

[1] Although this gaging station is still operating (Appendix C, Table C2-1), the average annual native surface water supply is estimated from the 42 water year period 1905-46. This was done to avoid correcting for the perturbations caused by Shadow Mountain and Grand Lake Reservoirs which began storage in April 1947, by Lake Granby which began flow regulation September 1949, and by the Alva B. Adams Tunnel which began exporting water August, 1947. The drainage area of this gaging station includes the Fraser River Subbasin as well as the Colorado River-Mountains Subbasin. In this analysis, Fraser River contributions, those recorded at gaging station #340 (Appendix C, Table C2-2), will be subtracted in order to estimate the average annual native surface water runoff of only the Colorado River Mountains Subbasin.

[2] There are approximately 13,000 acres of irrigated land above this gaging station, 8,000 of which are dependent on Fraser River surface flows (United States Geological Survey, 1954). It is assumed that the irrigation application rates in this subbasin roughly correspond to those in the Cache La Poudre River Subbasin of the South Platte River

TABLE A2-1: (continued)

Basin where the growing season precipitation is similar. Therefore, on the average, 2.78 acre-feet of water is applied to each acre of land of which about 1.3 acre-feet is consumptively used (Janonis and Gerlek, 1977). It is further assumed that groundwater development in this subbasin is minor and that the irrigation demand is met exclusively by surface flows. Thus, the average consumptive use of surface water supplies by irrigation in the Colorado River-Mountains Subbasin is 6,500 acre-feet per year. The non-consumptively used portion of the applied irrigation water is assumed to infiltrate to the aquifer, and eventually accrue back to the stream as return flows. Therefore, over the long term this water need not be corrected for as it will show up as surface flow at a later date.

[3] Appendix B, Table B3-1.

[4] The Eureka Ditch has been exporting water only since 1940 (Appendix B, Table B3-2). The value entered is the equivalent 1905-46 annual diversion. THis was computed by spreading out its 7 year 1940-46 diversions over the 42 year 1905-46 period.

[5] From Appendix C, Table C2-1. The 1905-46 average runoff at gaging station #09034500 is 483,005 acre-feet per year. The inflow from the Fraser River drainage (which was subtracted) is the recorded 1905-09, 1938-55 average at gaging station #340, 125,147 acre-feet per year (Appendix C, Table C2-2).

TABLE A2-2: Computation of Native Surface Water Runoff

Subbasin: Colorado River-Mountains
Supply Condition: 1970 Water Year
USGS Gaging Station(s) and Period: #09034500, 1970[1]

1970 Upstream Man-Caused Effect	Influence (Acre-Feet)
A. Computation of the net influence of upstream man-caused effects on the gaging station's recorded flow with respect to its drainage areas' native surface water runoff	
Consumptive use of surface water by irrigated agriculture	+ 6,500[2]
Storage change in Shadow Mt. Reservoir & Grand Lake	0[3]
Storage change in Lake Granby	+85,900[3]
Evaporation from Shadow Mountain Reservoir, Grand Lake and Lake Granby	+21,000[4]
Export of surface water by Alva B. Adams Tunnel	+204,600[5]
Export of surface water by the Eureka Ditch	+ 32[6]
Export of surface water by the Grand River Ditch	+12,830[7]
NET INFLUENCE	+330,862
B. Computation of the native surface water runoff	
1970 runoff as measured by the USGS gaging station(s)	88,881[8]
1970 net influence of upstream man-caused effects	+330,862
1970 native surface water runoff	419,743

[1] The drainage area of this gaging station includes the Fraser River Subbasin as well as the Colorado River-Mountains Subbasin. In this analysis, Fraser River contributions will be subtracted in order to estimate the 1970 surface water runoff of only the Colorado River-Mountains Subbasin.

[2] Assumed to be the average depletion, see Footnote[2], Appendix A, Table A2-1.

TABLE A2-2: (continued)

[3] USGS, 1970b.

[4] NCWCD, 1970, 75.

[5] Appendix B, Table B3-3.

[6] Appendix B, Table B3-2.

[7] Appendix B, Table B3-1.

[8] From Appendix C, Table C2-1. The 1970 runoff at gaging station #09034500 was 224,300 acre-feet. The inflow from the Fraser River drainage (which was subtracted) was estimated to be 135,419 acre-feet in 1970 (Appendix A, Table A2-5, Footnote[4]).

TABLE A2-3: Computation of Native Surface Water Runoff

Subbasin: Colorado River-Mountains
Supply Condition: Average Annual, 4 Year Drought Period
USGS Gaging Station(s) and Period: #09034500, 1953-56

1953-56 Average Annual Upstream Man-Caused Effect	Influence (Acre-Feet)
A. Computation of the net influence of upstream man-caused effects on the gaging station's recorded flow with respect to its drainage areas' native surface water runoff (excluding the consumptive use of surface water by municipalities, agriculture and industries, and reservoir evaporation).	
Storage change in Shadow Mountain Reservoir and Grand Lake	+ 170[1]
Storage change in Lake Granby	-64,225[2]
Export of surface water by the Grand River Ditch	+17,277[3]
Export of surface water by the Eureka Ditch	+ 57[4]
Export of surface water by the Alva B. Adams Tunnel	+237,350[5]
NET INFLUENCE	+190,629
B. Computation of the native surface water "adjusted runoff"	
1953-56 average annual runoff as measured by the USGS gaging station(s)	27,067[6]
1953-56 average annual net influence of upstream man-caused effects	+190,629
1953-56 average annual native surface water "adjusted runoff"	217,696
C. Computation of the native surface water runoff	

$$\frac{\text{1953-56 Drought Period Average Annual "Adjusted Runoff"}}{\text{Long Term Average Annual "Adjusted Runoff"}} = \frac{217{,}696 \text{ Acre-Feet}}{350{,}974 \text{ Acre-Feet}^{7}} = 0.6203$$

Therefore, 62.03 percent of the long term average annual native surface water runoff of this subbasin is assumed to be the average annual native surface water runoff during a four year drought period, or,

[0.6203] [378,474 acre-feet[8]] = 234,767 Acre-Feet

TABLE A2-3: (continued)

[1] The drainage area of this gaging station includes the Fraser River Subbasin as well as the Colorado River-Mountains Subbasin. In this analysis, Fraser River contributions, those recorded at USGS gaging station #340 (Appendix C, Table C2-2), will be subtracted in order to estimate the native surface water runoff of only the Colorado River-Mountains Subbasin.

[2] USGS, 1964b.

[3] Appendix B, Table B3-1.

[4] Appendix B, Table B3-2.

[5] Appendix B, Table B3-3.

[6] From Appendix C, Table C2-1. The 1953-56 average annual runoff at gaging station #09034500 was 122,492 acre-feet. The inflow from the Fraser River drainage (which was subtracted) was estimated to average 95,425 acre-feet per year over this period (Appendix A, Table A2-6, Footnote[3]).

[7] Appendix A, Table A2-1; the average annual native surface water runoff of this subbasin (378,474 acre-feet) minus the average annual surface water consumptive use of its agriculture (6,500 acre-feet) minus the average annual evaporation from Grand Lake, Shadow Mountain Reservoir, and Lake Granby (21,000 acre-feet, NCWCD, 1970, 1975).

[8] Appendix A, Table A2-1; the average annual native surface water runoff of this subbasin.

TABLE A2-4: Computation of Native Surface Water Runoff

Subbasin: Fraser River
Supply Condition: Average Annual, Long Term
USGS Gaging Station(s) and Period: #340, 1905-09, 1938-55

Average Annual Upstream Man-Caused Effect	Influence (Acre-Feet)
A. Computation of the net influence of upstream man-caused effects on the gaging station's recorded flow with respect to its drainage areas' native surface water runoff	
Consumptive use of surface water by irrigated agriculture	+12,620[1]
Export of surface water by the Berthoud Pass Ditch	+ 426[2]
Export of surface water by the Moffat Water Tunnel	+22,951[3]
NET INFLUENCE	+35,997
B. Computation of the native surface water runoff	
Average annual runoff as measured by the USGS gaging station(s)	125,147[4]
Average annual net influence of upstream man-caused effects	+35,997
Average annual native surface water runoff	161,144

[1] There are diversions above the gaging station for the irrigation of about 6,500 acres above the station and about 1,500 acres below (United States Geological Survey, 1964a). The methodology for estimating the comsumptive use of surface water supplies by the irrigated acreage with the subbasin is the same as that used for the Colorado River-Mountains Subbasin (Footnote[2], Table A2-1). The diversions for irrigation below the gaging station are the entire application rate (2.78 acre-feet per acre). The return flows from this acreage will accrue below the gaging station.

[2] The Berthoud Pass Ditch has only been exporting water since 1910 (Appendix B, Table B3-5). The value entered is the equivalent 1905-09, 1938-55 annual diversion. This was computed by spreading out its 18 year 1938-55 diversions over the 23 year 1905-09, 1938-55 period.

[3] The Moffat Water Runnel has been exporting water only since 1936 (Appendix B, Table B3-4). The value entered is the equivalent 1905-09,

TABLE A2-4: (continued)

1938-55 annual diversion. This was computed by spreading out its 18 year 1938-55 diversions over the 23 year 1905-09, 1938-55 period.

[4] Appendix C, Table C2-2.

TABLE A2-5: Computation of Native Surface Water Runoff

Subbasin: Fraser River
Supply Condition: 1970 Water Year
USGS Gaging Station(s) and Period: #340, 1970[1]

1970 Upstream Man-Caused Effect	Influence (Acre-Feet)
A. Computation of the net influence of upstream man-caused effects on the gaging station's recorded flow with respect to its drainage areas' native surface water runoff	
Consumptive use of surface water by irrigated agriculture	+12,620[2]
Export of surface water by the Berthoud Pass Ditch	+ 29[3]
Export of surface water by the Moffat Water Tunnel	+41,874[4]
NET INFLUENCE	+54,785
B. Computation of the native surface water runoff	
1970 runoff as measured by the USGS gaging station(s)	135,419[5]
1970 net influence of upstream man-caused effects	+54,785
1970 native surface water runoff	190,204

[1] Gaging station #340 was discontinued in December of the 1956 water year, (Appendix C, Table C2-2). A correlation study was performed to determine the 1970 water year runoff at the site of this gaging station.

[2] Assumed to be the average depletion, see Footnote[1], Appendix A, Table A2-4.

[3] Appendix B, Table B3-5.

[4] Appendix B, Table B3-4 (includes imports from the Williams Fork River Subbasin, which arrives through the Vasquez and Jones Pass Tunnels).

[5] A correlation study was performed to determine the 1970 water year runoff at the site of this gaging station. The combined flows recorded at gaging stations #09026500, "Saint Louis Creek near Fraser, Colorado;" #09032000, "Ranch Creek near Fraser, Colorado;" #0902400, "Fraser River near Winter Park, Colorado," and #09025000, "Vasquez

TABLE A2-5: (continued)

Creek near Winter Park, Colorado," were found to average 67,216 acre-feet per year over a 26 year period, 1935-60 (United States Geological Survey, 1954, 1964b). These gaging stations are located on the Fraser River major headwater tributaries and their flows were not corrected for the exports of their drainage area's surface water supplies by the Moffat Water Tunnel and the Berthoud Pass Ditch, or for the consumptive use of agriculture. By subtraction from the average recorded runoff at gaging station #340 (Supporting Appendix C, Table C2-2), the average amount of surface water accruing to the Fraser River below these gaging stations and above gaging station #340 was found to be 57,931 acre-feet per year. The only significant perturbations to the surface water supplies in this reach of the Fraser River subbasin where these waters accrue is the consumptive use of irrigation.

During the 1970 water year these upstream gaging stations recorded a combined runoff of 69,470 acre-feet. Adjusted for exports from their drainage areas, their combined 1970 native runoff was 111,635 acre-feet, or 113.84 percent above their average 1935-60 native surface water supplies which were found to be 98,064 acre-feet per year (Average actual flows of 67,216 acre-feet corrected for 1935-60 upstream perturbations). It is assumed, therefore, that if gaging station #340 was recording flows during the 1970 water year, it would have measured the actual 1970 runoff of the upstream gaging stations (69,470 acre-feet) plus 113.84 percent of the average inflow between (1.1384 X 57,931 acre-feet = 65,949 acre-feet), for a total of 135,419 acre-feet.

A spot check of several years when gaging station #340 was operating shows the computed runoff to be ± 5 to 10 percent of the recorded runoff. This validates the methodology with respect to the accuracy of the data and to the overall intent of this analysis with respect to this study.

TABLE A2-6: Computation of Native Surface Water Runoff

Subbasin: Fraser River
Supply Condition: Average Annual, 4 Year Drought Period
USGS Gaging Station(s) and Period: #340, 1953-56

1953-56 Average Annual Upstream Man-Caused Effect	Influence (Acre-Feet)
A. Computation of the net influence of upstream man-caused effects on the gaging station's recorded flow with respect to its drainage area's native surface water runoff (excluding the consumptive use of surface water by municipalities, agriculture, and industries, and reservoir evaporation).	
Export of surface water by the Berthoud Pass Ditch	+ 416[1]
Export of surface water by the Moffat Water Tunnel	+36,265[2]
NET INFLUENCE	+36,681
B. Computation of the native surface water "adjusted runoff"	
1953-56 average annual runoff as measured by the USGS gaging station(s)	95,425[3]
1953-56 average annual net influence of upstream man-caused effects	+36,681
1953-56 average annual native surface water "adjusted runoff"	132,106

C. Computation of the native surface water runoff

$$\frac{\text{1953-56 Drought Period Average Annual "Adjusted Runoff"}}{\text{Long Term Average Annual "Adjusted Runoff"}} = \frac{\text{132,106 Acre-Feet}}{\text{148,524 Acre-Feet}^{4}} = 0.8895$$

Therefore, 88.95 percent of the long term average annual native surface water runoff of this subbasin is assumed to be the average annual native surface water runoff during a four year drought period, or,

[0.8895] [161,144 acre-feet[5]] = 143,338 acre-feet

[1] Appendix B, Table B3-5.

[2] Appendix B, Table B3-4.

[3] Gaging station #340 was discontinued in December of the 1956 water year. A correlation study, the same as that used to estimate the 1970

TABLE A2-6: (continued)

runoff (Footnote[5], Table A2-5), was performed to determine the 1956 water year runoff at the site of this gaging station. During the 1956 water year, the four upstream gaging stations recorded a combined runoff of 52,470 acre-feet. Adjusted for exports from their drainage areas, their combined native runoff was 106,296 acre-feet, or 108.39 percent above their average 1935-60 native surface water supplies which were found to be 98,064 acre-feet per year. It is assumed, therefore, that if gaging station #340 was recording flow during the 1956 water year, it would have measured the actual runoff of the four upstream gaging stations (52,470 acre-feet) plus 108.39 percent of the average inflow between (1.0839 X 57.931 acre-feet = 62,791 acre-feet) for a total of 115,261 acre-feet. The 1953-55 yearly records of gaging station #340 are found in Appendix C, Table C2-2.

[4] Appendix A, Table A2-4. The average annual native surface water runoff of this subbasin minus the average annual surface water consumptive use of its agriculture.

[5] Appendix A, Table A2-4. The average annual native surface water runoff of this subbasin.

TABLE A2-7: Computation of Native Surface Water Runoff

Subbasin: Williams Fork River
Supply Condition: Average Annual, Long Term
USGS Gaging Station(s) and Period: #09037500, 1905-24, 1934-74

Average Annual Upstream Man-Caused Effect	Influence (Acre-Feet)
A. Computation of the net influence of upstream man-caused effects on the gaging station's recorded flow with respect to its drainage areas' native surface water runoff	
Consumptive use of surface water by irrigated agriculture	+ 8,640[1]
Export of surface water by the Jones Pass Tunnel	+ 3,066[2]
NET INFLUENCE	+11,706
B. Computation of the native surface water runoff	
Average annual runoff as measured by the USGS gaging station(s)	98,203[3]
Average annual net influence of upstream man-caused effects	+11,706
Average annual native surface water runoff	109,909

[1] There are diversions above the gaging station for the irrigation of about 1,300 acres above the station and about 2,500 acres below (United States Geological Survey, 1974). The methodology for estimating the consumptive use of surface water supplies by the irrigated acreage within the subbasin is the same as that used for the Colorado River-Mountains Subbasin (Footnote[2], Table A2-1). The diversions for irrigation below the gaging station are the entire application rate (2.78 acre-feet per acre). The return flows from this acreage will accrue below the gaging station.

[2] The Jones Pass Tunnel has been exporting the native surface flows of this subbasin only since 1940 (Appendix B, Table B3-6). The value entered is the equivalent annual 1905-24, 1934-74 annual diversion. This was computed by spreading out its 35 year 1940-74 diversion over the 61 year 1905-24, 1934-74 period.

[3] Appendix C, Table B2-3.

TABLE A2-8: Computation of Native Surface Water Runoff

Subbasin: Williams Fork River
Supply Condition: 1970 Water Year
USGS Gaging Station(s) and Period: #09037500, 1970

1970 Upstream Man-Caused Effect	Influence (Acre-Feet)
A. Computation of the net influence of upstream man-caused effects on the gaging station's recorded flow with respect to its drainage area's native surface water runoff	
Consumptive use of surface water by irrigated agriculture	+ 8,640[1]
Export of surface water by the Jones Pass Tunnel	+ 2,112[2]
NET INFLUENCE	+10,752
B. Computation of the native surface water runoff	
1970 runoff as measured by the USGS gaging station(s)	103,700[3]
1970 net influence of upstream man-caused effects	+10,752
1970 native surface water runoff	114,452

[1] Assumed to be the average depletion, see Footnote[1], Table A2-7.

[2] Appendix B, Table B3-6.

[3] Appendix C, Table C2-3.

TABLE A2-9: Computation of Native Surface Water Runoff

Subbasin: Williams Fork River
Supply Condition: Average Annual, 4 Year Drought Period
USGS Gaging Station(s) and Period: #09037500, 1953-56

1953-56 Average Annual Upstream Man-Caused Effect	Influence (Acre-Feet)
A. Computation of the net influence of upstream man-caused effects on the gaging station's recorded flow with respect to its drainage area's native surface water runoff (excluding the consumptive use of surface water by municipalities, agriculture, and industries, and reservoir evaporation).	
Export of surface water by the Jones Pass Tunnel	+8,020[1]
NET INFLUENCE	+8,020
B. Computation of the native surface water "adjusted runoff."	
1953-56 average annual runoff as measured by the USGS gaging station(s)	57,002[2]
1953-56 average annual net influence of upstream man-caused effects	+8,020
1953-56 average annual native surface water "adjusted runoff"	65,022

C. Computation of the native surface water runoff.

$$\frac{\text{1953-56 Drought Period Average Annual "Adjusted Runoff"}}{\text{Long Term Average Annual "Adjusted Runoff"}} = \frac{65{,}022 \text{ Acre-Feet}}{101{,}269 \text{ Acre-Feet}^{3}} = 0.6421$$

Therefore, 64.21 percent of the long term average annual native surface water runoff of this subbasin is assumed to be the average annual native surface water runoff during a four year drought period, or,

[0.6421] [109,909 acre-feet[4]] = 70,573 Acre-Feet

(continued)

TABLE A2-9 (continued)

[1] Appendix B, Table B3-6.

[2] Appendix C, Table C2-3.

[3] Appendix A, Table A2-8, the average annual native surface water runoff of this subbasin minus the average annual surface water consumptive use of its agriculture.

[4] Appendix A, Table A2-8, the average annual native surface water runoff of this subbasin.

TABLE A2-10: Computation of Native Surface Water Runoff

Subbasin: Blue River
Supply Condition: Average Annual, Long Term
USGS Gaging Station(s) and Period: #09053500, 1944-63[1]

Average Annual Upstream Man-Caused Effect	Influence (Acre-Feet)
A. Computation of the net influence of upstream man-caused effects on the gaging station's recorded flow with respect to its drainage area's native surface water runoff.	
Consumptive use of surface water by irrigated agriculture	+ 5,200[2]
Export of surface water by the Boreas Pass Ditch	+ 128[3]
Export of surface water by the Hoosier Pass Tunnel	+ 4,213[4]
NET INFLUENCE	+ 9,541
B. Computation of the native surface water runoff.	
Average annual runoff as measured by the USGS gaging station(s)	313,940[5]
Average annual net influence of upstream man-caused effects	+ 9,541
Average annual native surface water runoff	323,481

[1] Although this gaging station was operated until the 1971 water year (Appendix C, Table C2-4), the average annual native surface water runoff is estimated from the 20 water year period 1944-63. This was done to avoid correcting for the perturbations caused by Dillon Reservoir which began storage at the end of the 1963 water year.

[2] There are diversions for approximately 4,000 acres of irrigated land above the gaging station (USGS, 1971). The methodology for estimating the consumptive use of surface water supplies by the irrigated acreage within this subbasin is the same as that used for the Colorado River-Mountains Subbasin (Footnote [2], Table A2-1).

[3] Appendix B, Table B3-9.

[4] The Hoosier Pass Tunnel has only been exporting water since 1953 (Appendix B, Table B3-11). The value entered is the equivalent 1944-63 annual diversion. This was computed by spreading out its 12-year 1952-63 diversions over the 1944-63 20 year period.

[5] Appendix C, Table C2-4.

TABLE A2-11: Computation of Native Surface Water Runoff

Subbasin: Blue River
Supply Condition: 1970 Water Year
USGS Gaging Station(s) and Period: #09053500, 1970

1970 Upstream Man-Caused Effect	Influence (Acre-Feet)
A. Computation of the net influence of upstream man-caused effects on the gaging station's recorded flow with respect to its drainage area's native surface water runoff.	
Consumptive use of surface water by irrigated agriculture	+ 5,200[1]
Storage change in Dillon Reservoir	+ 7,300[2]
Evaporation from Dillon Reservoir	+ 2,600[3]
Export of surface water by the Harold D. Roberts Tunnel	+10,212[4]
Export of surface water by the Boreas Pass Ditch	0[5]
Export of surface water by the Hoosier Pass Tunnel	+ 6,100[6]
NET INFLUENCE	+31,412
B. Computation of the native surface water runoff.	
1970 runoff as measured by the USGS gaging station(s)	368,100[7]
1970 net influence of upstream man-caused effects	+31,412
1970 native surface water runoff	399,512

[1] Assumed to be the average depletion, see footnote [2], Table A2-10.

[2] USGS, 1970b.

[3] During the 1970 water year the average contents of Dillon Reservoir was 243,000 acre-feet (USGS, 1970). This corresponds to a surface area of about 3,120 acres (International Engineering Company, Inc., et al., 1973). The mean annual precipitation minus the mean annual evaporation of the region around Dillon Reservoir is about -10 inches (Meyer, 1942). Therefore, the 1970 evaporation loss of Dillon Reservoir is estimated to be approximately 2,600 acre-feet.

[4] Appendix B, Table B3-8.

[5] Appendix B, Table B3-9.

[6] Appendix B, Table B3-11.

[7] Appendix C, Table C2-4.

TABLE A2-12: Computation of Native Surface Water Runoff

Subbasin: Blue River
Supply Condition: Average Annual, 4 Year Drought Period
USGS Gaging Station(s) and Period: #09053500, 1953-56

1953-56 Average Annual Upstream Man-Caused Effects	Influence (Acre-Feet)
A. Computation of the net influence of upstream man-caused effects on the gaging station's recorded flow with respect to its drainage area's native surface water runoff (excluding the consumptive use of surface water by municipalities, agriculture, and industries, and reservoir evaporation).	
Export of surface water by the Boreas Pass Ditch	+ 234[1]
Export of surface water by the Hoosier Pass Tunnel	+ 6,032[2]
NET INFLUENCE	+ 6,266
B. Computation of the native surface water "adjusted runoff."	
1953-56 average annual runoff as measured by the USGS gaging station(s)	261,150[3]
1953-56 average annual net influence of upstream man-caused effects	+ 6,266
1953-56 average annual native surface water "adjusted runoff"	267,416

C. Computation of the native surface water runoff.

$$\frac{\text{1953-56 Drought Period Average Annual "Adjusted Runoff"}}{\text{Long Term Average Annual "Adjusted Runoff"}} = \frac{\text{267,416 Acre-Feet}}{\text{318,281 Acre-Feet}^{4}} = 0.8402$$

Therefore, 84.02 percent of the long term average annual native surface water runoff of this subbasin is assumed to be the average annual native surface water runoff during a four year drought period, or,

[0.8402] [323,481 acre-feet[5]] = 271,789 Acre-Feet

(continued)

TABLE A2-12 (continued)

[1] Appendix B, Table B3-9.

[2] Appendix B, Table B3-11.

[3] Appendix C, Table C2-4.

[4] Appendix A, Table A2-10, the average native surface water runoff of this subbasin minus the average annual surface water consumptive use of its agriculture.

[5] Appendix A, Table A2-10, the average native surface water runoff of this subbasin.

TABLE A2-13: Computation of Native Surface Water Runoff

Subbasin: Piney River
Supply Condition: Average Annual, Long Term
USGA Gaging Station(s) and Period: #09059500, 1945-24

Average Annual Upstream Man-Caused Effect	Influence (Acre-Feet)
A. Computation of the net influence of upstream man-caused effects on the gaging station's recorded flow with respect to its drainage area's native surface water runoff.	
Consumptive use of surface water by irrigated agriculture	+520[1]
NET INFLUENCE	+520
B. Computation of the native surface water runoff.	
Average annual runoff as measured by the USGS gaging station(s)	54,616[2]
Average annual net influence of upstream man-caused effects	+520
Average annual native surface water runoff	55,136

[3] There are diversions for approximately 400 acres of irrigated hay meadows above the gaging station (USGS, 1974). The methodology for estimating the consumptive use of surface water supplies by the irrigated acreage within this subbasin is the same as that used for the Colorado River-Mountains Subbasin (Footnote [2], Table A2-1).

[2] Appendix C, Table C2-5.

TABLE A2-14: Computation of Native Surface Water Runoff

Subbasin: Piney River
Supply Condition: 1970 Water Year
USGS Gaging Station(s) and Period: #09059500, 1970

1970 Upstream Man-Caused Effect	Influence (Acre-Feet)
A. Computation of the net influence of upstream man-caused effects on the gaging station's recorded flow with respect to its drainage area's native surface water runoff.	
Consumptive use of surface water by irrigated agriculture	+520[1]
NET INFLUENCE	+520
B. Computation of the native surface water runoff.	
1970 runoff as measured by the USGS gaging station(s)	64,840[2]
1970 net influence of upstream man-caused effects	+520
1970 native surface water runoff	65,360

[1] Assumed to be the average depletion, see footnote [1], Appendix A, Table A2-13.

[2] Appendix C, Table C2-5.

TABLE A2-15: Computation of Native Surface Water Runoff

Subbasin: Piney River
Supply Condition: Average Annual, 4 Year Drought Period
USGS Gaging Station(s) and Period: #09059500, 1953-56

1953-56 Average Annual Upstream Man-Caused Effect	Influence (Acre-Feet)
A. Computation of the net influence of upstream man-caused effects on the gaging station's recorded flow with respect to its drainage area's native surface water runoff (excluding the consumptive use of surface water by municipalities, agriculture, and industries, and reservoir evaporation).	
NET INFLUENCE	0
B. Computation of the native surface water "adjusted runoff."	
1953-56 average annual runoff as measured by the USGS gaging station(s)	38,440[1]
1953-56 average annual net influence of upstream man-caused effects	0
1953-56 average annual native surface water "adjusted runoff"	38,440
C. Computation of the native surface water runoff.	

$$\frac{\text{1953-56 Drought Period Average Annual "Adjusted Runoff"}}{\text{Long Term Average Annual "Adjusted Runoff"}} = \frac{38{,}440 \text{ Acre-Feet}}{54{,}616 \text{ Acre-Feet}^{2}} = 0.7038$$

Therefore, 70.38 percent of the long term average annual native surface water runoff of this subbasin is assumed to be the average annual native surface water runoff during a four year drought period, or,

[0.7038] [55,136 acre-feet[3]] = 38,805 Acre-Feet

[1] Appendix C, Table C2-5.

[2] Appendix A, Table A1-13, the average annual native surface water runoff of this subbasin minus the average annual surface water consumptive use by its agriculture.

[3] Appendix A, Table A2-13, the average annual native surface water runoff of this subbasin.

TABLE A2-16: Computation of Native Surface Water Runoff

Subbasin: Eagle River
Supply Condition: Average Annual, Long Term
USGS Gaging Station(s) and Period: #09070000, 1947-74

Average Annual Upstream Man-Caused Effect	Influence (Acre-Feet)
A. Computation of the net influence of upstream man-caused effects on the gaging station's recorded flow with respect to its drainage area's native surface water runoff.	
Consumptive use of surface water by irrigated agriculture	+22,100[1]
Export of surface water by the Columbine Ditch	+ 1,241[2]
Export of surface water by the Erving Ditch	+ 1,027[3]
Export of surface water by the Wurtz Ditch	+ 2,378[4]
Export of surface water by the Homestake Tunnel	+ 6,768[5]
NET INFLUENCE	+33,514
B. Computation of the native surface water runoff.	
Average annual runoff as measured by the USGS gaging station(s)	411,918[6]
Average annual net influence of upstream man-caused effects	+33,514
Average annual native surface water runoff	445,432

[1] There are approximately 17,000 acres of irrigated land above the gaging station (estimated from land use maps published by the U.S. Soil Conservation Service). The methodology for estimating the consumptive use of surface water supplies by the irrigated acreage within this subbasin is the same as that used for the Colorado River-Mountains Subbasin (Footnote [2], Table A2-1).

[2] Appendix B, Table B4-2.

[3] Appendix B, Table B4-3.

[4] Appendix B, Table B4-4.

[5] The Homestake Tunnel has been exporting water only since 1967 (Appendix B, Table B4-5). The value entered is the equivalent 1947-74 annual diversion. This was computed by spreading out its 18 year 1967-74 diversions over the 28 year 1947-74 year period.

[6] Appendix C, Table C2-6.

TABLE A2-17: Computation of Native Surface Water Runoff

Subbasin: Eagle River
Supply Condition: 1970 Water Year
USGS Gaging Station(s) and Period: #09070000, 1970

1970 Upstream Man-Caused Effect	Influence (Acre-Feet)
A. Computation of the net influence of upstream man-caused effects on the gaging station's recorded flow with respect to its drainage area's native surface water runoff.	
Consumptive use of surface water by irrigated agriculture	+22,100[1]
Export of surface water by the Columbine Ditch	+ 2,160[2]
Export of surface water by the Erving Ditch	+ 1,340[3]
Export of surface water by the Wurtz Ditch	+ 3,870[4]
Export of surface water by the Homestake Tunnel	+23,010[5]
NET INFLUENCE	+52,480
B. Computation of the native surface water runoff.	
1970 runoff as measured by the USGS gaging station(s)	477,000[6]
1970 net influence of upstream man-caused effects	+52,480
1970 native surface water runoff	529,480

[1] Assumed to be the average depletion, see footnote [1], Table A2-16.

[2] Appendix B, Table B4-2.

[3] Appendix B, Table B4-3.

[4] Appendix B, Table B4-4.

[5] Appendix B, Table B4-5.

[6] Appendix C, Table C2-6.

TABLE A2-18: Computation of Native Surface Water Runoff

Subbasin: Eagle River
Supply Condition: Average Annual, 4 Year Drought Period
USGS Gaging Station(s) and Period: #09070000, 1953-56

1953-56 Average Annual Upstream Man-Caused Effect	Influence (Acre-Feet)
A. Computation of the net influence of upstream man-caused effects on the gaging station's recorded flow with respect to its drainage area's native surface water runoff (excluding the consumptive use of surface water by municipalities, agriculture and industries, and reservoir evaporation).	
Export of surface water by the Columbine Ditch	+ 1,108[1]
Export of surface water by the Erving Ditch	788[2]
Export of surface water by the Wurtz Ditch	+ 1,714[3]
NET INFLUENCE	+ 3,610
B. Computation of the native surface water "adjusted runoff."	
1953-56 average annual runoff as measured by the USGS gaging station(s)	326,975[4]
1953-56 average annual net influence of upstream man-caused effects	+ 3,610
1953-56 average annual native surface water "adjusted runoff"	330,585
C. Computation of the native surface water runoff.	

$$\frac{\text{1953-56 Drought Period Average Annual "Adjusted Runoff"}}{\text{Long Term Average Annual "Adjusted Runoff"}} = \frac{\text{330,585 Acre-Feet}}{\text{423,332 Acre-Feet}^{5}} = 0.7809$$

(continued)

TABLE A2-18 (continued)

Therefore, 78.09 percent of the long term average annual native surface water runoff of this subbasin is assumed to be the average annual native surface water runoff during a four year drought period, or,

[0.7809] [445,432 acre-feet[6]] = 347,838 Acre-Feet

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[1] Appendix B, Table B4-2.

[2] Appendix B, Table B4-3.

[3] Appendix B, Table B4-4.

[4] Appendix C, Table C2-6.

[5] Appendix A, Table A2-16, the average annual native surface water runoff of this subbasin minus the average annual surface water consumptive use of its agriculture.

[6] Appendix A, Table A2-16, the average annual native surface water runoff of this subbasin.

TABLE A2-19: Computation of Native Surface Water Runoff

Subbasin: Little Snake River
Supply Condition: Average Annual, Long Term
USGS Gaging Station(s) and Period: #09253000, 1943-47
1951-74

1943-47, 1951-74 Average Annual Upstream Man-Caused Effect	Influence (Acre-Feet)
A. Computation of the net influence of upstream man-caused effects on the gaging stations recorded flow with respect to its drainage areas native surface water runoff	
Consumptive use of surface water by irrigated agriculture	+2,600[1]
Export of surface water by the Cheyenne Tunnel	+2,497[2]
NET INFLUENCE	+5,097
B. Computation of the native surface water runoff	
1943-47, 1951-74 average annual runoff as measured by the USGS gaging station(s)	163,636[3]
1943-47, 1951-74 average annual net influence of upstream man-caused effects	+5,097
1943-47, 1951-74 average annual native surface water runoff	168,733

[1] There are diversions for approximately 2000 acres of irrigated land above the gaging station (United States Geological Survey, 1974). The mothodology for estimating the consumptive use of surface water supplies by irrigated acerage within this subbasin is the same as that used for the Colorado River-Mountains subbasin, (Footnote [2], Table A2-1).

[2] The Cheyenne Pipeline has been exporting water only since 1965. (Appendix B, Table B2-1). The value entered is the equivalent 1943-47, 1951-74 annual diversion. This was computed by spreading out its 10 years 1965-74 diversions over the 29 year 1943-47, 1951-74 time period.

[3] Appendix C, Table C2-7.

TABLE A2-20: Computation of Native Surface Water Runoff

Subbasin: Little Snake River
Supply Condition: 1970 Water Year
USGS Gaging Station(s) and Period: #09253000, 1970

1970 Upstream Man-Caused Effect	Influence (Acre-Feet)
A. Computation of the net influence of upstream man-caused effects on the gaging stations recorded flow with respect to its drainage areas native surface water runoff	
Consumptive use of surface water by irrigated agriculture	+2,600[1]
Export of surface water by the Cheyenne Tunnel	+8,229[2]
NET INFLUENCE	+10,829
B. Computation of the native surface water runoff	
1970 Runoff as measured by the USGS Gaging Station(s)	207,700[3]
1970 net influence of upstream man-caused effects	+10,829
1970 native surface water runoff	218,529

[1] Assumed to be the average depletion, see Footnote[1], Table A2-19.

[2] Appendix B, Table B2-1.

[3] Appendix C, Table C2-7.

TABLE A2-21: Computation of Native Surface Water Runoff

Subbasin: Little Snake River
Supply Condition: Average Annual, 4 Year Drought Period
USGS Gaging Station(s) and Period, #09253000, 1953-56

1953-56 Average Annual Upstream Man-Caused Effect	Influence (Acre-Feet)
A. Computation of the net influence of upstream man-caused effects on the gaging stations recorded flow with respect to its drainage areas native surface water runoff (excluding the consumptive use of surface water by municipalities, agriculture, and industries, and reservoir evaporation)	
NET INFLUENCE	0
B. Computation of the native surface water "adjusted runoff"	
1953-56 average annual runoff as measured by the USGS Gaging Station(s)	119,177[1]
1953-56 average annual net influence of upstream man-caused effects	0
1953-56 average annual native surface water "adjusted runoff"	119,177
C. Computation of the native surface water runoff	

$$\frac{\text{1953-56 Drought Period Average Annual "Adjusted Runoff"}}{\text{Long Term Average Annual "Adjusted Runoff"}} = \frac{119{,}177 \text{ Acre-Feet}}{166{,}133 \text{ Acre-Feet}^{2}} = 0.7174$$

Therefore, 71.74 percent of the long term average annual native surface water runoff of this subbasin is assumed to be the average annual native surface water runoff during a four year drought period, or,

[0.7174] [168,733 acre-feet[3]] = 121,049 Acre-feet

[1] Appendix C, Table C2-7.

[2] Appendix A, Table A2-19, the average annual native surface water runoff of this subbasin minus the average annual consumptive use of its agriculture.

[3] Appendix A, Table A2-19, the average annual native surface water runoff of this subbasin.

SECTION A3

THE ARKANSAS RIVER BASIN

TABLE A3-1: Computation of Native Surface Water Runoff

Subbasin: Arkansas River-Mountains
Supply Condition: Average annual, long term
USGS Gaging Station(s) and Period: #07087200, 1965-75

1965-75 Average Annual Upstream Man-Caused Effect	Influence (Acre-Feet)
A. Computation of the net influence of upstream man-caused effects on the gaging stations recorded flow with respect to its drainage areas native surface water runoff	
Consumptive use of surface water by irrigated agriculture	+9,620[1]
Import of surface water by the Homestake Tunnel	-22,671[2]
Import of surface water by the Columbine Ditch	-1,714[3]
Import of surface water by the Ewing Ditch	-1,048[4]
Import of surface water by the Wurtz Ditch	-2,849[5]
Import of surface water by the Twin Lakes Tunnel	-48,955[6]
Import of surface water by the Charles H. Boustead Tunnel	-12,668[7]
Import of surface water by the Busk-Ivanhoe Tunnel	-6,332[8]
Export of surface water by the Homestake Pipeline	+16,966[9]
NET INFLUENCE	-69,651
B. Computation of the native surface water runoff	
1965-75 average annual runoff as measured by the USGS Gaging Station(s)	378,700[10]
1965-75 average annual net influence of upstream man-caused effects	-69,651
1965-75 average annual native surface water runoff	309,049

[1] There are diversions for approximately 7,400 acres of irrigated land above the gaging station, (United States Geological Survey, 1975). It is assumed that the irrigation application rates in this subbasin roughly correspond to those in the Cache La Poudre River subbasin of

TABLE A3-1: (continued)

the South Platte River Basin where the growing season precipitation is similar. Therefore, on the average, 2.78 acre-feet of water is applied to each acre of land of which about 1.3 acre-feet is consumptively used (Janonis and Gerlek, 1977). It is further assumed that ground water development in this subbasin is minor and that the irrigation demand is met exclusively by surface flows. Thus, the average consumptive use of surface water supplies by irrigation in this subbasin is approximately 9,620 acre-feet per year. The non-consumptively used portion of the applied irrigation water is assumed to infiltrate to the aquifer, and eventually accrue back to the stream as return flows. Therefore, over the long term this water need not be corrected for, as it will show up as surface flows at a later date.

[2] The Homestake Tunnel has been importing water only since 1967 (Appendix B, Table B4-5). The value entered is the equivalent 1965-75 annual diversion. This was computed by spreading out its 9 year 1967-75 diversions over the 1965-75 11 year period.

[3] Appendix B, Table B4-2.

[4] Appendix B, Table B4-3.

[5] Appendix B, Table B4-4.

[6] Appendix B, Table B4-8.

[7] The Charles H. Boustead Tunnel has been importing water since 1972, (Appendix B, Table B4-7). The value entered is the equivalent 1965-75 annual diversion. This was computed by spreading out its 4 year 1972-75 diversions over the 11 year 1965-75 time period.

[8] Appendix B, Table B4-6.

[9] The Homestake Pipeline has been exporting water only since 1966, (Appendix B, Table B4-5). The value entered is the equivalent 1965-75 annual diversion. This was computed by spreading out its 10 year 1966-75 diversions over the 11 year 1965-75 time period.

[10] Appendix C, Table C3-1.

TABLE A3-2: Computation of Native Surface Water Runoff

Subbasin: Arkansas River-Mountains
Supply Condition: 1970 Water Year
USGS Gaging Station(s) and Period: #07087200, 1970

1970 Upstream Man-Caused Effect	Influence (Acre-Feet)
A. Computation of the net influence of upstream man-caused effects on the gaging stations recorded flow with respect to its drainage areas native surface water runoff	
Consumptive use of surface water by irrigated agriculture	+9,620[1]
Import of surface water by the Homestake Tunnel	-23,010[2]
Import of surface water by the Columbine Ditch	-2,160[3]
Import of surface water by the Ewing Ditch	-1,340[4]
Import of surface water by the Wurtz Ditch	-3,870[5]
Import of surface water by the Twin Lakes Tunnel	-62,020[6]
Import of surface water by the Busk-Ivanhoe Tunnel	-7,910[7]
Export of surface water by the Homestake Pipeline	-22,822[2]
NET INFLUENCE	-67,868
B. Computation of the native surface water runoff	
1970 runoff as measured by the USGS Gaging Station(s)	453,300[8]
1970 net influence of upstream man-caused effects	-67,868
1970 native surface water runoff	385,432

[1] Assumed to be the average depletion, see Footnote[1], Table A3-1.

[2] Appendix B, Table B4-5.

[3] Appendix B, Table B4-2.

TABLE A3-2: (continued)

[4] Appendix B, Table B4-3.

[5] Appendix B, Table B4-4.

[6] Appendix B, Table B4-8.

[7] Appendix B, Table B4-6.

[8] Appendix C, Table C3-1.

TABLE A3-3: Computation of Native Surface Water Runoff

Subbasin: Arkansas River-Mountains
Supply Condition: Average annual, 4 Year Drought Period
USGS Gaging Station(s) and Period: #07087200, 1953-56[1]

1953-56 Average Annual Upstream Man-Caused Effect	Influence (Acre-Feet)
A. Computation of the net influence of upstream man-caused effects on the gaging stations recorded flow with respect to its drainage areas native surface water runoff (excluding the consumptive use of surface water by municipalities, agriculture, and industries, and reservoir evaporation)	
Import of surface water by the Columbine Ditch	-1,108[2]
Import of surface water by the Ewing Ditch	- 788[3]
Import of surface water by the Wurtz Ditch	-1,714[4]
Import of surface water by the Twin Lakes Tunnel	-34,817[5]
Import of surface water by the Busk-Ivanhoe Tunnel	-4,487[6]
NET INFLUENCE	-42,914
B. Computation of the native surface water "adjusted runoff"	
1953-56 average annual runoff as measured by the USGS Gaging Station(s)	270,614[7]
1953-56 average annual net influence of upstream man-caused effects	-42,914
1953-56 average annual native surface water "Adjusted Runoff"	227,700
C. Computation of the native surface water runoff	

$$\frac{\text{1953-56 Drought Period Average Annual "Adjusted Runoff"}}{\text{Long Term Average Annual "Adjusted Runoff"}} = \frac{\text{227,700 Acre-Feet}}{\text{299,429 Acre-Feet}^{8}} = 0.7604$$

Therefore, 76.04 percent of the long term average annual native surface water runoff of this subbasin is assumed to be the average annual native surface water runoff during a four year drought period, or,

TABLE A3-3: (continued)

[0.7604] [309,040 acre-feet[9]] = 235,001 Acre-Feet

[1] Gaging station #07087200 has been operating only since 1965. A correlation study was performed to estimate the 1953-56 flows at the site of this gaging station.

[2] Appendix B, Table B4-2.

[3] Appendix B, Table B4-3.

[4] Appendix B, Table B4-4.

[5] Appendix B, Table B4-8.

[6] Appendix B, Table B4-6.

[7] Gaging station #07087200, "Arkansas River at Buena Vista, Colorado", has been in operation only since 1965. Gaging station #07086000, "Arkansas River at Granite, Colorado" is located about 16 miles upstream and has been in operation consistantly since the 1911 water year. The amount of water accruing to the Arkansas River between these gaging stations averaged 53,825 acre-feet per year between 1965-75 when their operations coincided. The only significant perturbations of the surface water supplies in the drainage area between these gaging station sites during the 1953-56 was the consumptive use of about 700 acres of irrigated land, (United States Geological Survey, 1964-75). During the 1953-56 water years, the gaging station at Granite recorded an average annual runoff of 226,025 acre-feet. Gaging Station #07086500, "Clear Creek above Clear Creek Reser voir, Colorado" is located on the major tributary contributing to the surface flows of the drainage area between the two gaging station sites on the Arkansas River. Perturbations to the surface water supplies above this gaging station are negligible and its 1953-56 average annual runoff was 82.84 percent of its 28 year 1947-75 period of record, (USGS, 1964c). It is therefore assumed that if gaging station #07087200, "Arkansas River at Buena Vista, Colorado" was recording flows during the 1953-56 water years, its 4 year average for this period would have been approximately the 1953-56 average recorded at Granite (226,025 Acre-Feet) plus 82.84 percent of the average inflow between (.8284 x 53,825 acre-feet = 44,589 acre-feet) for a total of 270,614 acre-feet.

[8] Appendix A, Table A3-1, the average annual surface water runoff of this subbasin minus the average annual consumptive use of surface water by agriculture.

[9] Appendix A, Table A3-1, the average annual surface water runoff of this subbasin.

SECTION A4

THE SOUTH PLATTE RIVER BASIN

TABLE A4-1: Computation of Native Surface Water Runoff

Subbasin: South Platte River-Mountains
Supply Condition: Average annual, long term
USGS Gaging Station(s) and Period: #06707000, 1914-75[1]

1914-74 Average Annual Upstream Man-Caused Effect	Influence (Acre-Feet)
A. Computation of the net influence of upstream man-caused effects on the gaging stations recorded flow with respect to its drainage areas native surface water runoff	
Consumptive use of surface water by irrigated agriculture	+39,169[2]
Consumptive use of surface water by municipalities	+ 90[3]
Net evaporation from reservoirs	+7,974[4]
Import of surface water by the Boreas Pass Ditch	- 71[5]
Import of surface water by the East and West Hoosier Pass Ditches	- 40[6]
Import of surface water by the Aurora-Homestake Pipeline	- 992[7]
NET INFLUENCE	+46,130
B. Computation of the native surface water runoff	
1914-75 average annual runoff as measured by the USGS Gaging Station(s)	155,081[8]
1914-75 average annual net influence of upstream man-caused effects	+46,130
1914-75 average annual native surface water runoff	201,211

[1] The long term average annual native surface water runoff of this subbasin was estimated from the flows recorded at USGS gaging station #06707000, "South Platte River at South Platte, Colorado". This gaging station is located about 8 miles upstream from the subbasins mouth and just below the confluence of the North Fork of The South River. It was found that by using this gaging station instead of the one at the subbasins mouth, perturbations in the small drainage area between whos long term records were not available (exports out of the subbasin by several structures diverting near the mouth of the Platte Canyon), would not have to be corrected for. It was assumed that the surface water runoff accruing to this 24 square mile drainage area of the subbasin excluded from the analysis was negligible.

TABLE A4-1: (continued)

[2] Janonis and Gerlek, 1977. It was assumed that the consumptive use of surface water in this subbasin by agriculture was constant over the study period and equal to the value found for the 1970 water year.

[3] Janonis, 1977. It was assumed that the consumptive use of surface water in this subbasin by municipalities was constant over the study period and equal to the value found for the 1970 water year.

[4] Antero, Elevenmile, and Cheesman Reservoirs are the major storage facilities located in this subbasin and in aggregate they provide the bulk of its storage capacity. Only the consumptive use of the subbasins surface water runoff by evaporation from these reservoirs were considered.

A. Antero Reservoir began storage in 1909 and therefore has been operational over the entire 62 year, 1914-75, study period. This reservoirs' average surface area between January 1962 - December 1971 was 1,788 acres, (International Engineering Company, Inc. et al, 1973). This was assumed to be the average surface area over the study period. The 1970 relationship between evaporation loss minus precipitation gain and surface area for Antero Reservoir was 1.31 acre-feet per acre (Britten, 1976). It was assumed that the climatic conditions influencing evaporation rates and precipitation amounts were average during the 1970 water year. Furthermore, it was assumed that a linear relationship exists between net evaporation loss (evaporation minus precipitation) and surface areas. Therefore, the average annual net evaporation loss of Antero Reservoir was estimated to be 2,342 acre-feet, (1.31 acre-feet per acre x 1,788 acres).

B. Elevenmile Canyon Reservoir began storage in 1932 and thus has been operational for only 44 years of the 62 years study period. The procedure for determining the average annual net evaporation loss for this reservoir was the same as that used for Antero Reservoir. The average surface area between October 1965 - September 1970 was 3,264 acres, (International Engineering Company, Inc., et al, 1973). The 1970 net evaporation loss was 2.03 acre-feet per acre, (Britten, 1976). Therefore, the average annual net evaporation loss of Elevenmile Canyon Reservoir was estimated to be 6,626 acre-feet. However, this reservoir was not in existence during the first 18 years of the study period. Therefore, an equivalent annual net evaporation loss was used in the analysis. This was computed by spreading out its total 1932-75 net evaporation loss over the 1914-75 period.
[(6,626 acre-feet per year x 44 years) ÷ 62 years = 4,702 acre-feet per year]

Table A4-1: (continued)

C. Cheesman Lake began storage in 1905 and therefore has been operational over the entire study period. The procedure for determining the average annual net evaporation loss for this reservoir was also the same as that used for Antero Reservoir. The average surface area between October 1965 - September 1970 was 669 acres, (International Engineering Company, Inc., et al, 1973). The 1970 net evaporation loss was 1.39 acre-feet per acre, (Britten, 1976). Therefore, the average annual net evaporation loss of Cheesman Lake was estimated to be 930 acre-feet.

[5] The Boreas Pass Ditch has been importing surface water to this subbasin only since 1933, (Appendix B, Table B3-9). The value entered is the equivalent 1914-75 annual import. This was computed by spreading out its 43 year, 1933-75, imports over the 62 year, 1914-75, study period.

[6] The East and West Hoosire Pass Ditches imported surface water only in water years 1935 through 1940 and 1939, respectively, (Appendix B, Table B3-10). The value entered is the equivalent 1914-75 annual import. This was computed by spreading out their short period of imports over the 62 year, 1914-75, study period.

[7] The Homestake has been importing surface water to this subbasin only since 1967, (Appendix B, Table B4-5). The value entered is the 1914-75 equivalent annual import. This was computed by spreading out its 9 year, 1967-75, imports over the 62 year, 1914-75, study period.

[8] Gaging station #06707500, "South Platte at South Paltte, Colorado" is located below the confluence of the North Fort of the South Platte River. Therefore, it was necessary to subtract the surface water flows entering this subbasin through the mouth of the North Fork of the South Platte River Subbasin. These flows are measured at USGS gaging station #06707000, "North Fork South Platte River at South Platte, Colorado". Information on both of these gaging stations and their published records of yearly runoff can be found in Appendix C, Tables C4-2 and C4-1, respectively.

TABLE A4-2: Computation of Native Surface Water Runoff

Subbasin: South Platte River-Mountains
Supply Condition: 1970 Water Year
USGS Gaging Station(s) and Period: #06707000, 1970[1]

1970 Upstream Man-Caused Effect	Influence (Acre-Feet)
A. Computation of the net influence of upstream man-caused effects on the gaging stations recorded flow with respect to its drainage areas' native surface water runoff	
Consumptive use of surface water by irrigated agriculture	+39,169[2]
Consumptive use of surface water by municipalities	+ 90[3]
Net Evaporation from Reservoirs	+10,657[4]
Storage Change in Reservoirs	+6,189[5]
Import of surface water through the Boreas Pass Ditch	0[6]
Import of surface water through the Aurora-Homestake Pipeline	-3,370[7]
NET INFLUENCE	+52,735
B. Computation of the native surface water runoff	
1970 runoff as measured by the USGS Gaging Station(s)	349,500[8]
1970 net influence of upstream man-caused effects	+52,735
1970 native surface water runoff	402,235

[1] The 1970 native surface water runoff of this subbasin was estimated from the flows recorded at USGS gaging station #06707000, "South Platte River at South Platte, Colorado". This gaging station is located about 8 miles upstream from the subbasins mouth and just below the confluence of the North Fork of the South River. It was found that by using this gaging station instead of the one at the subbasins mouth, perturbations in the small drainage area between whos long term records were not available (exports out of the subbasin by several structures diverting near the mouth of the Platte Canyon), would not have to be corrected for. It was assumed that the surface water runoff accruing to this 24 square mile drainage area of the subbasin excluded from the analysis was negligible.

[2] Janonis and Gerlek, 1977.

TABLE A4-2: (continued)

[3] Janonis, 1977.

[4] Antero, Elevenmile, and Cheesman Reservoirs are the major storage facilities located in this subbasin and in aggregate they provide the bulk of its storage capacity. Only the consumptive use of the subbasin surface water supplies by evaporation from these reservoirs were considered. During the 1970 water year their individual net evaporation losses were, (Britten, 1976):

Antero	2,547 acre-feet
Elevenmile Canyon	6,925 acre-feet
Cheesman	1,185 acre-feet
TOTAL	10,657 acre-feet

[5] The storage changes in only the major reservoirs of this subbasin were considered. The individual changes in reservoir contents during the 1970 water year were as follows, (Britten, 1976):

Antero	- 19 acre-feet
Elevenmile Canyon	+ 336 acre-feet
Cheesman	+5,872 acre-feet
TOTAL	+6,189 acre-feet

[6] Appendix B, Table B3-9.

[7] Appendix B, Table B4-5.

[8] Gaging station #06707500, "South Platte at South Platte, Colorado" is located below the confluence of the North Fork of the South Platte River. Therefore, it was necessary to subtract the surface water flows entering this subbasin through the mouth of the North Fork of the South Platte River Subbasin. These flows are measured at USGS gaging station #06707000, "North Fork South Platte River at South Platte, Colorado". Information on both of these gaging stations and their published records of yearly runoff can be found in Appendix C, Tables C4-2 and C4-1 respectively.

TABLE A4-3: Computation of Native Surface Water Runoff

Subbasin: South Platte River-Mountains
Supply Condition: Average Annual, 4 Year Drought Period
USGS Gaging Station(s) and Period: #06707000, 1953-56[1]

1953-56 Average Annual Upstream Man-Caused Effect	Influence (Acre-Feet)
A. Computation of the net influence of upstream man-caused effects on the gaging stations recorded flow with respect to its drainage areas native surface water runoff (excluding the consumptive use of surface water by municipalities, agriculture, and industries, and reservoir evaporation)	
Storage change in reservoirs	-23,703[2]
Surface water import through the Boreas Pass Ditch	- 234[3]
NET INFLUENCE	-23,937
B. Computation of the native surface water "adjusted runoff"	
1953-56 average annual runoff as measured by the USGS Gaging Station(s)	104,563
1953-56 average annual net influence of upstream man-caused effects	-23,937
1953-56 average annual native surface water "adjusted runoff"	80,626
C. Computation of the native surface water runoff	

$$\frac{\text{1953-56 Drought Period Average Annual "Adjusted Runoff"}}{\text{Long Term Average Annual "Adjusted Runoff"}} = \frac{\text{80,626 Acre-Feet}}{\text{153,978 Acre-Feet}^{5}} = 0.5236$$

Therefore, 52.36 percent of the long term average annual native surface water runoff of this subbasin is assumed to be the average annual native surface water runoff during a four year drought period, or,

[0.5236] [201,211 acre-feet][6] = 105,354 Acre-Feet

[1] The drought period average annual native surface water runoff of this subbasin was estimated from the flows recorded at USGS gaging station #06706000, "South Platte River at South Platte, Colorado". This gaging station is located about 8 miles upstream from the subbasins mouth and just below the confluence of the North Fork of the South River. It was found that by using this gaging station instead

TABLE A4-3: (continued)

of the one at the subbasins mouth, perturbations in the small drainage area between whos long term records were not available (exports out of the subbasin by several structures diverting near the mouth of the Platte Canyon), would not have to be corrected for. It was assumed that the surface water runoff accruing to this 24 square mile drainage area of the subbasin excluded from the analysis was negligible.

[2] The storage changes in only the major reservoirs of this subbasin were considered. The individual average annual storage changes during the 1953-56 period were as follows, (USGS, 1964a):

Antero	not available
Elevenmile Canyon	-13,583 acre-feet
Cheesman	-10,120 acre-feet
Total	-23,703 acre-feet

[3] Appendix B, Table B3-9.

[4] Gaging station #06707500, "South Platte at South Platte, Colorado" is located below the confluence of the North Fork of the South Platte River. Therefore, it was necessary to subtract the surface water flows entering this subbasin through the mouth of the North Fork of the South Platte River Subbasin. These flows are measured at USGS gaging station #06707000, "North Fork South Platte River at South Platte, Colorado". Information on both of these gaging stations and their published records of yearly runoff can be found in Appendix C, Tables C4-2 and C4-1, respectively.

[5] Appendix A, Table A4-1, the long term average annual surface water runoff of this subbasin minus the long term average annual comsumptive use of surface water by its municipalities, agriculture, and evaporation from its reservoirs.

[6] Appendix A, Table A4-1, the long term average annual surface water runoff of this subbasin.

TABLE A4-4: Computation of Native Surface Water RUnoff

Subbasin: North Fork of the South Platte River
Supply Condition: Average annual, long term
USGS Gaging Station(s) and Period: #06706000, 1914-75

1914-75 Average Annual Upstream Man-Caused Effect	Influence (Acre-Feet)
A. Computation of the net incluence of upstream man-caused effects on the gaging stations recorded flow with respect to its drainage areas native surface water runoff	
Import of surface water by the Harold D. Roberts Tunnel	-6,113[1]
NET INFLUENCE	-6,113
B. Computation of the native surface water runoff	
1914-75 average annual runoff as measured by the USGS Gaging Station(s)	118,717[2]
1914-75 average annual net influence of upstream man-caused effects	-6,113
1914-75 average annual native surface water runoff	112,604

[1] The Harold D. Roberts Tunnel has been importing water to this subbasin only since the 1964 water year, (Appendix B, Table B3-8). The value entered is the equivalent 1914-75 annual import. This was computed by spreading out its 12 year, 1964-75 imports over the 62 year, 1914-75, study period.

[2] Appendix C, Table C4-1.

TABLE A4-5: Computation of Native Surface Water Runoff

Subbasin: North Fork of the South Platte River
Supply Condition: 1970 Water Year
USGS Gaging Station(s) and Period: #06707000, 1970

1970 Upstream Man-Caused Effects	Influence (Acre-Feet)
A. Computation of the net influence of upstream man-caused effects on the gaging stations recorded flow with respect to its drainage areas native surface water runoff	
Import of surface water by the Harold D. Roberts Tunnel	-10,620[1]
NET INFLUENCE	-10,620
B. Computation of the native surface water runoff	
1970 runoff as measured by the USGS Gaging Station(s)	209,300[2]
1970 net influence of upstream man-caused effects	-10,620
1970 native surface water runoff	198,680

[1] Appendix B, Table B3-8.

[2] Appendix C, Table C4-1.

TABLE A4-6: Computation of Native Surface Water Runoff

Subbasin: North Fork of the South Platte
Supply Condition: Average Annual, 4 Year Drought Period
USGS Gaging Station(s) and Period: #06707000, 1953-56

1953-56 Average Annual Upstream Man-Caused Effect	Influence (Acre-Feet)
A. Computation of the net influence of upstream man-caused effects on the gaging stations recorded flow with respect to its drainage areas native surface water runoff (excluding the consumptive use of surface water by municipalities, agriculture, and industries, and reservoir evaporation)	
NET INFLUENCE	0
B. Computation of the native surface water "adjusted runoff"	
1953-56 average annual runoff as measured by the USGS Gaging Station(s)	64,287[1]
1953-56 average annual net influence of upstream man-caused effects	0
1953-56 average annual native surface water "adjusted runoff"	64,287
C. Computation of the native surface water runoff	

$$\frac{\text{1953-56 Drought Period Average Annual "Adjusted Runoff"}}{\text{Long Term Average Annual "Adjusted Runoff"}} = \frac{64{,}287 \text{ Acre-Feet}}{112{,}604 \text{ Acre-Feet}^{2}} = 0.5709$$

Therefore, 57.09 percent of the long term average annual native surface water runoff of this subbasin is assumed to be the average annual native surface water runoff during a four year drought period. Or,

[0.5709] [112,604 acre-feet[3]] = 64,287 Acre-Feet

[1] Appendix C, Table C4-1.

[2] Appendix A, Table A4-4. The long term average annual native surface water runoff of this subbasin minus the long term average annual consumptive use of surface water by agriculture, municipalities, and industries, and reservoir evaporation.

[3] Appendix A, Table A4-4. The long term average annual native surface water runoff of this subbasin.

TABLE A4-7: Computation of Native Surface Water Runoff

Subbasin: Cherry Creek
Supply Condition: Average Annual, Long Term
USGS Gaging Station(s) and Period: #6-7153, 1943-56[1]

1943-56 Average Annual Upstream Man-Caused Effect	Influence (Acre-Feet)
A. Computation of the net influence of upstream man-caused effects on the gaging stations recorded flow with respect to its drainage areas native surface water runoff	
Consumptive use of surface water by irrigated agriculture	+5,100[2]
NET INFLUENCE	+5,100
B. Computation of the native surface water runoff of Cherry Creeks entire hydrological drainage area	
1943-56 average annual runoff as measured by the USGS Gaging Station(s)	13,276[3]
1943-56 average annual net influence of upstream man-caused effects	+5,100
1943-56 average annual native surface water runoff	18,376
C. Computation of the native surface water runoff of the Cherry Creek Subbasin	
1943-56 average annual native surface water runoff of the entire Cherry Creek drainage	18,376
1943-56 average minus the annual native surface water runoff accruing to the portion of Cherry Creek drainage within the South Platte River - Transition subbasin	-7,301[4]
1943-56 average annual native surface water supply of the Cherry Creek Subbasin	11,075

[1] Gaging station #6-7135 is located at the mouth of the Cherry Creek drainage area; encompassing 24 more square miles than the designated Cherry Creek Subbasin. In this analysis, once the native surface water supply of the entire Cherry Creek drainage is found, water naturally accruing to its drainage within the South Platte River - Transition Subbasin is subtracted to find the native surface water supply of just the Cherry Creek Subbasin. While gaging station #6-7135 was operated until the 1969 water year, the 1943-56 water years will be used in this analysis. This was done to avoid correcting for upstream perturbations caused by Cherry Creek Lake which began permanent storage on May 15, 1957. Cherry Creek Lake was

TABLE A4-7: (continued)

completed in June of 1950, however, it was initially operated as a dry reservoir. This does not appreciably affect runoff records as flood water is released as soon as possible after it occurs.

[2] Janonis and Gerlek, 1977. The only irrigated area within the Cherry Creek drainage is above Cherry Creek Lake, lying within the Cherry Creek Subbasin.

[3] Appendix C, Table C4-9.

[4] Between 1958 and its last recording in 1969, gaging station #6-7135 recorded an average annual runoff of 10,136 (supporting Appendix C, Table C4-9). Also during this 12 year time period, Cherry Creek Lake released an average of 2,835 acre-feet per year (gaging station #06713000, supporting Appendix C, Table C4-8). It is assumed that the difference between these values (7,301 acre-feet per year) is the runoff naturally accruing to the lower portion of Cherry Creeks' drainage, within the South Platte River - Transition Subbasin.

TABLE A4-8: Computation of Native Surface Water Runoff

Subbasin: Cherry Creek
Supply Condition: 1970 Water Year

A correlation study was performed to estimate the 1970 native surface water runoff of the Cherry Creek Subbasin. The USGS gaging station #0671200, "Cherry Creek near Franktown, Colorado" recorded an average annual runoff of 6,480 acre-feet over its 35 years of record, 1939-75. (USGS, 1970b). This gaging station is located approximately in the middle of Cherry Creeks hydrological drainage and above most of the irrigation. The 1970 discharge of Cherry Creek near Franktown was 3,580 acre-feet or 55.25 percent of the long term average annual.

It was therefore assumed that the 1970 native surface water runoff of the Cherry Creek Subbasin was 55.25 percent of average or 6,119 acre-feet. (Table A4-7 shows the computations involved in estimating the long term average native surface water runoff of the Cherry Creek Subbasin; this was found to be 11,075 acre-feet/year). Furthermore, the 1970 surface water runoff of that portion of Cherry Creeks drainage within the South Platte River - Transition Subbasin was also assumed to have been 55.25 percent of average or 4,034 acre-feet. (Table A4-7, Footnote [4], shows the computations involved in estimating the longterm average native surface water runoff of this portion of the Cherry Creek drainage; this was found to be 7,301 acre-feet/year).

TABLE A4-9: Computation of Native Surface Water Runoff

Subbasin: Cherry Creek
Supply Condition: Average Annual, 4 Year Drought Period

A correlation study was performed to estimate the average annual native surface water runoff of the Cherry Creek subbasin during a 4 year drought period. The USGS gaging station #0671200, "Cherry Creek near Franktown, Colorado" recorded an average annual runoff of 6,480 acre-feet over its 35 years of record, 1939-75 (USGS, 1970b). This gaging station is located approximately in the middle of Cherry Creeks' hydrological drainage area and above most of the irrigation. The 1953-56 average yearly discharge of Cherry Creek near Franktown was 2,695 acre-feet/year or 41.59 percent of the long term average annual.

It was therefore assumed that the 1953-56 average annual native surface water runoff of the Cherry Creek Subbasin was 41.59 percent of the long term average annual or 4,606 acre-feet. (Table A4-7 shows the computations involved in estimating the long term average annual native surface water runoff of the Cherry Creek Subbasin; this was found to be 11,075 acre-feet). Furthermore, the 1953-56 average annual native surface water runoff of Cherry Creeks' drainage within the South Platte River - Transition Subbasin was also assumed to have been 41.59 percent of the long term average or 3,036 acre-feet (Table A4-7, Footnote[4] shows the computations involved in estimating the long term average native surface water runoff of this portion of the Cherry Creek Subbasin; this was found to be 7,301 acre-feet/year).

TABLE A4-10: Computation of Native Surface Water Runoff

Subbasin: Plum Creek
Supply Condition: Average Annual, Long Term
USGS Gaging Station(s) and Period: #06709500, 1948-75

1948-75 Average Annual Upstream Man-Caused Effects	Influence (Acre-Feet)
A. Computation of the net influence of upstream man-caused effects on the gaging stations recorded flow with respect to its drainage areas native surface water runoff	
Consumptive use of surface water by irrigated agriculture	+2,200[1]
NET INFLUENCE	+2,200
B. Computation of the native surface water runoff	
1948-75 average annual runoff as measured by the USGS Gaging Station(s)	20,589[2]
1948-75 average annual net influence of upstream man-caused effects	+2,200
1948-75 average annual native surface water runoff	22,789

[1] Janonis and Gerlek, 1977. While this figure was determined for conditions existing during the 1970 water year, it was assumed to be representative of the long term.

[2] Appendix C, Table C4-7.

TABLE A4-11: Computation of Native Surface Water Runoff

Subbasin: Plum Creek
Supply Condition: 1970 Water Year
USGS Gaging Station(s) and Period: #06709500, 1970

1970 Upstream Man-Caused Effect	Influence (Acre-Feet)
A. Computation of the net influence of upstream man-caused effects on the gaging stations recorded flow with respect to its drainage areas native surface water runoff	
Consumptive use of surface water by irrigated agriculture	+2,200[1]
NET INFLUENCE	+2,200
B. Computation of the native surface water runoff	
1970 runoff as measured by the USGS Gaging Station(s)	+29,240[2]
1970 net influence of upstream man-caused effects	+2,200
1970 native surface water runoff	31,440

[1] Janonis and Gerlek, 1977.

[2] Appendix C, Table C4-7.

TABLE A4-12: Computation of Native Surface Water Runoff

Subbasin: Plum Creek
Supply Condition: Average Annual, 4 Year Drought Period
USGS Gaging Station(s) and Period: #06709500, 1953-56

1953-56 Average Annual Upstream Man-Caused Effect	Influence (Acre-Feet)
A. Computation of the net influence of upstream man-caused effects on the gaging stations recorded flow with respect to its drainage areas native surface water runoff (Excluding the consumptive use of surface water by municipalities, agriculture, and industries, and reservoir evaporation)	
NET INFLUENCE	0
B. Computation of the native surface water "adjusted runoff"	
1953-56 average annual runoff as measured by the USGS Gaging Station(s)	6,452[1]
1953-56 average annual net influence of upstream man-caused effects	0
1953-56 average annual native surface water "adjusted runoff"	6,452

C. Computation of the native surface water runoff

$$\frac{\text{1953-56 Drought Period Average Annual "Adjusted Runoff"}}{\text{Long Term Average Annual "Adjusted Runoff"}} = \frac{6{,}452 \text{ Acre-Feet}}{20{,}589 \text{ Acre-Feet}^{2}} = 0.3134$$

Therefore, 31.34 percent of the long term average annual native surface water runoff of this subbasin is assumed to be the average annual native surface water runoff during a four year drought period. Or,

[0.3134] [22,789 acre-feet[3]] = 7,142 Acre-Feet

[1] Appendix C, Table C4-7.

[2] Appendix A, Table A4-10. The average annual native surface water runoff of this subbasin minus the average annual consumptive use of surface water by agriculture.

[3] Appendix A, Table A4-10. The average annual native surface water runoff of this subbasin.

TABLE A4-13: Computation of Native Surface Water Runoff

Subbasin: Bear
Supply Condition: Average Annual, Long Term
USGS Gaging Station(s) and Period: #06710500, 1920-75
#7110, 1930-49

Average Annual Upstream Man-Caused Effect	Influence (Acre-Feet)
A. Computation of the net influence of upstream man-caused effects on the gaging stations recorded flow with respect to its drainage areas native surface water runoff	
Consumptive use of surface water by irrigated agriculture	+ 453[1]
Consumptive use of surface water by municipalities	+ 630[2]
NET INFLUENCE	+ 1,083
B. Computation of the native surface water runoff	
Average annual runoff as measured by the USGS Gaging Station(s)	43,844[3]
Average annual net influence of upstream man-caused effects	+ 1,083
Average annual native surface water runoff	44,927

[1] Janonis and Gerlek, 1977. While this figure was determined for conditions existing during the 1970 water year, it was assumed to be representative of the long term.

[2] Janonis, 1977.

[3] The 1920-75 average annual surface water runoff recorded by USGS gagion station #067105000, "Bear Creek at Morrison, Colorado" was 38,744 acre-feet, (Appendix C, Table C4-4). USGS gaging station #7110, "Turkey Creek near Morrison, Colorado" was only operated during water years 1943-46, 1948-53. For this 10 year period of record, the average annual recorded runoff was 3,079 acre-feet, (Appendix C, Table C4-5). The USBR (1959) has correlated the flow past this gaging station with nearby gaging stations for years of missing record between 1930 and 1949. They estimated that the average annual discharge of Turkey Creek at this site during this 20 year period was 5,100 acre-feet. This figure was considered more representative of Long Term Conditions and therefore, was used in this analysis.

TABLE A4-14: Computation of Native Surface Water Runoff

Subbasin: Bear Creek
Supply Condition: 1970 Water Year
USGS Gaging Station(s) and Period: #067105000, 1970
#7110, 1970

1970 Upstream Man-Caused Effect	Influence (Acre-Feet)
A. Computation of the net influence of upstream man-caused effects on the gaging stations recorded flow with respect to its drainage areas native surface water runoff	
Consumptive use of surface water by irrigated agriculture	+ 453[1]
Consumptive use of surface water by municipalities	+ 630[2]
NET INFLUENCE	+ 1,083
B. Computation of the native surface water runoff	
1970 runoff as measured by the USGS Gaging Station(s)	75,161[3]
1970 net influence of upstream man-caused effects	+ 1,083
1970 native surface water runoff	76,244

[1] Janonis and Gerlek, 1977.

[2] Janonis, 1977.

[3] The 1970 surface water runoff recorded by the USGS gaging station #067105000, "Bear Creek at Morrison, Colorado" was 66,420 acre-feet, (Appendix C, Table C4-4). This was 171.4 percent of the long term average annual recorded runoff at this gaging station. Gaging station #7110, "Turkey Creek near Morrison, Colorado" was discontinued in September of 1953, after only 10 full water years of operation, (Appendix C, Table C4-5). It was assumed that if this gaging station was operating during the 1970 water year, it too would have recorded a runoff that was 171.4 percent of its long term average annual runoff. The USBR (1959) has correlated the flow of this gaging station with nearby gaging stations for years of missing record between 1930 and 1949. They estimated that the average annual discharge of Turky Creek for this 20 year period was 5,100 acre-feet. This was the figure considered more representative of long term conditions and therefore, 171.49 percent of it, or 8,741 acre-feet, was used in this analysis.

TABLE A4-15: Computation of Native Surface Water Runoff

Subbasin: Bear Creek
Supply Condition: Average Annual, 4 Year Drought Period
USGS Gaging Station(s) and Period: #06710500, 1953-56
#7100, 1953-56

1953-56 Average Annual Upstream Man-Caused Effect	Influence (Acre-Feet)
A. Computation of the net influence of upstream man-caused effects on the gaging stations recorded flow with respect to its drainage areas native surface water runoff (excluding the consumptive use of surface water by municipalities, agriculture, and industries, and reservoir evaporation)	
NET INFLUENCE	0
B. Computation of the native surface water "adjusted runoff"	
1953-56 average annual runoff as measured by the USGS Gaging Station(s)	19,339[1]
1953-56 average annual net influence of upstream man-caused effects	0
1953-56 average annual native surface water "adjusted runoff"	19,339
C. Computation of the native surface water runoff	

$$\frac{\text{1953-56 Drought Period Average Annual "Adjusted Runoff"}}{\text{Long Term Average Annual "Adjusted Runoff"}} = \frac{\text{19,339 Acre-Feet}}{\text{43,844 Acre-Feet}^{2}} = 0.4411$$

Therefore, 44.11 percent of the long term average annual native surface water runoff of this subbasin is assumed to be the average annual native surface water runoff during a four year drought period, or,

[0.4411] [44,927 acre-feet[3]] = 19,817 Acre-Feet

[1] The 1953-56 average annual surface water runoff recorded by USGS gaging station #067105000, "Bear Creek at Morrison, Colorado" was 17,100 acre-feet, (Appendix C, Table C4-4). This was 43.9 percent of the long term average annual runoff recorded at this gaging station. USGS gaging station #7110, "Turkey Creek near Morrison, Colorado" was discontinued in September of 1953 after only 10 full water years of operation. (Appendix C, Table C4-5). It was assumed that if this gaging station was operating during the 1953-56 water years, it too would have recorded an average annual runoff that was 43.9 percent of its long term average annual runoff. The USBR (1959) has correlated

TABLE A4-15: (continued)

the flow of this gaging station with nearby gaging stations for years of missing record between 1930 and 1949. They estimated that the average annual discharge of Turkey Creek for this 20 year period was 5,100 acre-feet. This was the figure considered more representative of Long Term Conditions and therefore, 45.99 percent of it, or 2,239 acre-feet was used in this analysis.

[2] Appendix A, Table A4-13. The long term average annual native surface water runoff of this subbasin minus the long term average annual consumptive use of surface water by agriculture, municipalities, and industries, and reservoir evaporation.

[3] Appendix A, Table A4-13. The long term average annual native surface water runoff of this subbasin.

TABLE A4-16: Computation of Native Surface Water Runoff

Subbasin: Clear
Supply Condition: Average Annual, Long Term
USGS Gaging Station(s) and Period: #06719500, 1912-75

1912-75 Average Annual Upstream Man-Caused Effect	Influence (Acre-Feet)
A. Computation of the net influence of upstream man-caused effects on the gaging stations recorded flow with respect to its drainage areas native surface water runoff	
Consumptive use of surface water by municipalities	+ 660[1]
Import of surface water by the Jones Pass Tunnel	- 1,855[2]
Import of surface water by the Berthoud Pass Ditch	- 621[3]
Export of surface water by agricultural ditches	+ 4,644[4]
NET INFLUENCE	+ 2,828
B. Computation of the native surface water runoff	
Average annual runoff as measured by the USGS Gaging Station(s)	171,166[5]
Average annual net influence of upstream man-caused effects	+ 2,828
Average annual native surface water runoff	173,994

[1] Janonis, 1977. While this figure was determined for conditions existing during the 1970 water year, it was assumed to be representative of the long term.

[2] The Jones Pass Tunnel imported water to this subbasin only during water years 1940-57, (Appendix B, Table B3-6). The value entered is the equivalent 1912-75 annual import. This was computed by spreading out its 18 year 1940-57 imports over the 64 year, 1912-75 study period.

[3] Appendix B, Table B3-5.

[4] This figure was determined through an analysis of the 1930-49 water year flows recorded at USGS gaging station #06719500, "Clear Creek at Golden, Colorado", and the 1930-49 corrected flows of Clear Creek at this point given by the USBR, 1959. The agricultural ditches referred to here divert surface water just above the gaging station

TABLE A4-16: (continued)

and deliver it to agricultural lands downstream, in Clear Creeks' outlying valley highlands. The 1930-49 average annual export was assumed to be representative of the long term.

5 The long term average annual native surface water runoff of this subbasin was estimated from the flows recorded at USGS gaging station #06719500, "Clear Creek at Golden, Colorado" and from diversions from Ralston Creek above where it issues onto the plains. This gaging station is located near Cleak Creeks canyon mouth and this point on Ralston Creek is located at its canyon mouth. The drainage area above these locations defines this subbasin. The 1912-75 average annual surface water runoff recorded by USGS gaging #06719500, "Clear Creek at Golden, Colorado" was 165,567 acre-feet, (Appendix C, Table C4-10). There has never been a USGS gaging station on Ralston Creek. Therefore, it was necessary to determine its' average annual contribution to the surface water runoff of this subbasin through other means. This was done by aggregating information on diversions from this creek. Denver is one of the major right holder to waters from Ralston Creek. Through its storage rights exercised by the Long Lakes reservoirs, Denver yielded an average of 4,580 acre-feet per year from this creek during 1958-75, (Denver Water Board, 1973-75). This was assumed to be representative of the long term yield of these reservoirs.

The amounts in storage during the 1970 water year of two other reservoirs with rights to Ralston Creek were available from the Colorado State Engineer. Through an analysis of this information, it was determined that they yielded 1,019 acre-feet from this creek in 1970. Since the 1970 precipitation in this area was near normal, and since Ralston Creeks' head waters usually have no carry over snow pack from prior years, the 1970 yield of these two reservoirs was assumed to be representative of the average annual long term yield. Therefore, it was assumed that the average annual long term yield of Ralston Creek was 5,599 acre-feet.

TABLE A4-17: Computation of Native Surface Water Runoff

Subbasin: Clear
Supply Condition: 1970 Water Year
USGS Gaging Station(s) and Period: #06719500, 1970

1970 Upstream Man-Caused Effect	Influence (Acre-Feet)
A. Computation of the net influence of upstream man-caused effects on the gaging stations recorded flow with respect to its drainage areas native surface water runoff	
Consumptive use of surface water by municipalities	+ 660[1]
Consumptive use of surface water by industries	+ 748[2]
Surface water return flows from ground water usage by industries	- 1,108[2]
Surface water imports through the Berthoud Pass Ditch	- 291[3]
Export of surface water by agricultural ditches	+ 4,644[4]
NET INFLUENCE	+ 4,653
B. Computation of the native surface water runoff	
1970 runoff as measured by the USGS Gaging Station(s)	220,709[5]
1970 net influence of upstream man-caused effects	+ 4,653
1970 native surface water runoff	225,362

[1] Janonis, 1977.

[2] Patterson, 1977.

[3] Appendix B, Table B3-5.

[4] This figure was determined through an analysis of the 1930-49 water year flows recorded at USGS gaging #06719500, "Clear Creek at Golden, Colorado", and the 1930-49 corrected flows of Clear Creek at this point given by the USBR, 1959. The agricultural ditches referred to here, divert surface water just above the gaging station and deliver it to agricultural lands downstream, in Clear Creeks outlying valley highlands. The 1930-49 average annual export was also assumed to be the 1970 export of these ditches.

TABLE A4-17: (continued)

[5] The 1970 water year native surface water runoff of this subbasin was estimated from the flows recorded at USGS gaging station #06719500, "Clear Creek at Golden, Colorado" and from diversions from Ralston Creek above where it issues onto the plains. This gaging station is located near Clear Creeks canyon mouth and this point on Ralston Creek is located at its canyon mouth. The drainage area above these locations defines this subbasin. The 1970 surface water runoff recorded by USGS gaging station #06719500, "Clear Creek at Golden, Colorado" was 211,400 acre-feet (Appendix C, Table C4-10). There has never been a USGS gaging station on Ralston Creek. Therefore, it was necessary to determine its 1970 contribution to the surface water runoff of this subbasin through other means. This was done by aggregating information on diversions from this creek. Denver is one of the major right holders to water from Ralston Creek. Through its storage rights exercised by the Long Lakes reservoirs, Denver yielded 8,290 acre-feet in 1970 from this creek, (Denver Water Board, 1970). The amounts in storage during the 1970 water year of two other reservoirs with rights to Ralston Creek were available from the Colorado State engineer. Through an analysis of this information it was determined that they yielded 1,019 acre-feet from this creek in 1970. Therefore, the 1970 surface water runoff of Ralston Creek was assumed to be 9,309 acre-feet.

TABLE A4-18: Computation of Native Surface Water Runoff

Subbasin: Clear Creek
Supply Condition: Average Annual, 4 Year Drought Period
USGS Gaging Station(s) and Period: #06719500, 1953-56

1953-56 Average Annual Upstream Man-Caused Effect	Influence (Acre-Feet)
A. Computation of the net influence of upstream man-caused effects on the gaging stations recorded flow with respect to its drainage areas native surface water runoff (excluding the consumptive use of surface water by municipalities, agriculture, and industries, and reservoir evaporation)	
Import of surface water by the Jones Pass Tunnel	- 8,020[1]
Import of surface water by the Berthoud Pass Ditch	- 416[2]
Export of surface water by agricultural ditches	+ 4,644[3]
NET INFLUENCE	- 3,792
B. Computation of the native surface water "adjusted runoff"	
1953-56 average annual runoff as measured by the USGS Gaging Station(s)	118,142[4]
1953-56 average annual net influence of upstream man-caused effects	- 3,792
1953-56 average annual native surface water "adjusted runoff"	114,350
C. Computation of the native surface water runoff	

$$\frac{\text{1953-56 Drought Period Average Annual "Adjusted Runoff"}}{\text{Long Term Average Annual "Adjusted Runoff"}} = \frac{\text{114,350 Acre-Feet}}{\text{173,334 Acre-Feet}^{5}} = 0.6597$$

Therefore, 65.97 percent of the long term average annual native surface water runoff of this subbasin is assumed to be the average annual native surface water runoff during a four year drought period, or,

[0.6597] [173,994 acre-feet[6]] = 114,784 Acre-Feet

[1] Appendix B, Table B3-6.

[2] Appendix B, Table B3-5.

TABLE A4-18: (continued)

[3] This figure was determined through an analysis of the 1930-49 water year flows recorded at USGS gaging #06719500, "Clear Creek at Golden, Colorado", and the 1930-49 corrected flows of Clear Creek at this point given by the USBR, 1959. The agricultural ditches referred to here, divert surface water just above the gaging station and deliver it to agricultural lands downstream, in Clear Creeks outlying valley highlands. The 1930-49 average annual export was assumed to be representative of the 1953-56 average annual export of these ditches.

[4] The 1953-56 average annual native surface water runoff of this subbasin was estimated from the flows recorded at USGS gaging station #06719500, "Clear Creek at Golden, Colorado" and from diversions from Ralston Creek above where it issues onto the plains. This gaging station is located near Clear Creeks' canyon mouth and this point on Ralston Creek is located at its canyon mouth. The drainage area above these locations defines this subbasin. The 1953-56 average annual surface water runoff recorded by USGS gaging station #06719500, "Clear Creek at Golden, Colorado" was 114,307 acre-feet, (Appendix C, Table C4-10). This was 68.5 percent of the long term average annual runoff recorded at this gaging station. The average annual surface water runoff of Ralston Creek has been estimated to be 5,599 acre-feet (Appendix A, Table A4-16, Footnote[5]). It was assumed that the 1953-56 average annual surface water runoff of this creek was also 68.5 percent of the long term average, or 3,835 acre-feet.

[5] Appendix A, Table A4-16. The long term average annual native surface water runoff of this subbasin minus the long term average annual consumptive use of surface water by agriculture, municipalities, and industries, and reservoir evaporation.

[6] Appendix A, Table A4-16. The long term average annual native surface water runoff of this subbasin.

TABLE A4-19: Computation of Native Surface Water Runoff

Subbasin: Boulder Creek
Supply Condition: Average Annual, Long Term
USGS Gaging Station(s) and Period: #06729500, 1959-75
#06727000, 1917-60
#06730300, 1960-75

Average Annual Upstream Man-Caused Effect	Influence (Acre-Feet)
A. Computation of the net influence of upstream man-caused effects on the gaging stations recorded flow with respect to its drainage areas native surface water runoff	
Export of surface water by the South Boulder Conduit	+ 6,280[1]
NET INFLUENCE	+ 6,280
B. Computation of the native surface water runoff	
Average annual runoff as measured by the USGS Gaging Station(s)	116,552[2]
Average annual net influence of upstream man-caused effects	+ 6,280
Average annual native surface water runoff	122,832

[1] Denver Board of Water Commissioners, 1968, 73, 75. Moffat Tunnel imports to this subbasin are either stored in Gross reservoir or exported by the South Boulder Conduit. Very little ever passes the gaging station or South Boulder Creek, so no corrections for these imports were necessary. The value entered as being exported by the South Boulder Conduit is the 1959-75 average annual export of South Boulder Creek native flows.

[2] The long term average annual native surface water runoff of the Boulder Creek subbasin was estimated from the flows recorded at USGS gaging stations #06729500, "South Boulder Creek near Eldora Springs, Colorado", #06727000, "Boulder Creek near Orodell, Colorado", and #06730300, "Coal Creek near Plainview, Colorado", (Appendix C, Tables C4-12, - 13, and - 14). These gaging stations are located in the foothills near the canyon mouths of the mainstem and South Boulder Creek and Coal Creek.

Surface water accruals below these gaging stations were assumed negligible. The periods of record of these gaging stations used in this analysis were selected to adjust for as little upstream perturbations as possible.

TABLE A4-19: (continued)

The average annual recorded runoff of gaging station #06729500 during water years 1959-75 was 46,427 acre-feet; of gaging station #06727000 during water years 1917-60 it was 66,842 acre-feet; and of gaging station #06730300 during water years 1960-75 it was 3,283 acre-feet.

TABLE A4-20: Computation of Native Surface Water Runoff

Subbasin: Boulder Creek
Supply Condition: 1970 Water Year
USGS Gaging Station(s) and Period: #06729500, 1970
#06727000, 1970
#06730300, 1970

1970 Upstream Man-Caused Effect	Influence (Acre-Feet)
A. Computation of the net influence of upstream man-caused effects on the gaging stations recoeded flow with respect to its drainage areas native surface water runoff	
Export of surface water by the South Boulder Conduit	+11,830[1]
Export of surface water by the Betasso Water Treatment Plant Conduit	+13,581[2]
Storage change in reservoirs	+ 3,383[3]
NET INFLUENCE	+28,794
B. Computation of the native surface water runoff	
1970 runoff as measured by the USGS gaging station(s)	134,120[4]
1970 net influence of upstream man-caused effects	+28,794
1970 native surface water runoff	162,914

[1] Denver Board of Water Commissioners, 1973. Moffat Tunnel imports to this subbasin are either stored in Gross Reservoir or exported by the South Boulder Conduit. Very little ever passed the gaging station on South Creek so no corrections were necessary. The value entered as being exported by the South Boulder Diversion Conduit is the 1970 export of South Boulder Creek native flows.

[2] Janonis, 1977. This value represents the amount of native surface water runoff the City of Boulder's Betasso water treatment plant diverted above, and therefore bypassed, the gaging station on the main stem of Boulder Creek.

[3] Division 1 Water Commissioners, 1970. This value represents the total net increase in storage in several small reservoirs above these gaging stations. (Does not include storage change in Gross reservoir, whos main function is to regulate and store Moffat tunnel imports).

[4] The 1970 surface water runoff of this subbasin was estimated from the flows recorded at the USGS gaging stations #06729500, "South Boulder

TABLE A4-20: (continued)

Creek near Eldorado Springs, Colorado", #06727000, "Boulder Creek near Orodell, Colorado", and #06730300, "Coal Creek near Plainview, Colorado", (Appendix C, Tables C4-12, -13, and -14). These gaging stations are located in the foothills near the canyon mouths of the mainstem and South Boulder Creek and Coal Creek. Surface water accruals below these gaging stations were assumed negligible. The 1970 recorded runoff at gaging station #06729500 was 55,040 acre-feet, at #06270000 it was 74,330 acre-feet, and at #06730300 it was 4,750 acre-feet.

TABLE A4-21: Computation of Native Surface Water Runoff

Subbasin: Boulder Creek
Supply Condition: Average Annual, 4 Year Drought Period
USGS Gaging Station(s) and Period: #06729500, 1953-56
#06727000, 1953-56
#06730300, 1953-56

1953-56 Average Annual Upstream Man-Caused Effect	Influence (Acre-Feet)
A. Computation of the net influence of upstream man-caused effects on the gaging stations recorded flow with respect to its drainage areas native surface water runoff (excluding the consumptive use of surface water by municipalities, agriculture, and industries, and reservoir evaporation)	
NET INFLUENCE	0
B. Computation of the native surface water "adjusted runoff"	
1953-56 average annual runoff as measured by the USGS gaging station(s)	83,824[1]
1953-56 average annual net influence of upstream man-caused effects	0
1953-56 average annual native surface water "adjusted runoff"	83,824
C. Computation of the native surface water runoff	

$$\frac{\text{1953-56 Drought Period Average Annual "Adjusted Runoff"}}{\text{Long Term Average Annual "Adjusted Runoff"}} = \frac{\text{83,824 Acre-Feet}}{\text{122,832 Acre-Feet}^{2}} = 0.6824$$

Therefore, 68.24 percent of the long term average annual native surface water runoff of this subbasin is assumed to be the average annual native surface water runoff during a four year drought period, or,

[0.6824][122,832 acre-feet[3]] = 83,824 Acre-Feet

[1] The 4 year drought period average annual surface water runoff of this subbasin was estimated from the flows recorded at USGS gaging station #06729500, "South Boulder Creek near Eldorado Springs, Colorado", #06727000, "Boulder Creek near Orodell, Colorado", and #06730300, "Coal Creek near Plainview, Colorado", (Appendix C, Tables C4-12, -13, and -14). These gaging stations are located in the foothills near the canyon mouths of the mainstem and South Boulder Creek and Coal Creek. Surface water accruals below these gaging stations were assumed negligible. The 1953-56 average annual recorded runoff at gaging

TABLE A4-21: (continued)

station #06729500 was 32,903 acre-feet and at #06727000 it was 48,538 acre-feet. Gaging station #06730300 was not operating during this period; a correlation was preformed to determine what it would have recorded if it was on lines then. The 1917-60 average annual recorded runoff of Boulder Creek by station #06727000 was 66,842 acre-feet; the 1953-56 average annual runoff recorded by this gaging station was 48,538 acre-feet or 72.6 percent of the long term average. Therefore, it was assumed, if gaging station #06730300 was operating, then it too would have recorded 72.6 percent of its long term average, or 2,383 acre-feet.

[2] Appendix A, Table A4-19. The average annual native surface water runoff of this subbasin minus the surface water consumptive use (upstream of the gaging stations) of municipalities, industries, and agriculture and evaporation from reservoirs.

[3] Appendix A, Table A4-19. The average annual native surface water runoff of this subbasin.

TABLE A4-22: Computation of Native Surface Water Runoff

Subbasin: Saint Vrain Creek
Supply Condition: Average Annual, Long Term
USGS Gaging Station(s) and Period: #06724000, 1930-49
#7245, 1930-49

1930-49 Average Annual Upstream Man-Caused Effect	Influence (Acre-Feet)
A. Computation of the net influence of upstream man-caused effects on the gaging stations recorded flow with respect to its drainage areas native surface water runoff	
Export of surface water by Agricultural ditches	+ 8,334[1]
NET INFLUENCE	+ 8,334
B. Computation of the native surface water runoff	
Average annual runoff as measured by the USGS gaging station(s)	109,266[2]
Average annual net influence of upstream man-caused effects	+ 8,334
Average annual native surface water runoff	117,600

[1] This figure was determined through an analysis of the 1930-49 flows recorded at USGS gaging station #06724000, "Saint Vrain Creek at Lyons, Colorado", and the 1930-49 corrected flows of Saint Vrain Creek at this point given by the USBR, 1959. The agricultural ditches referred to here divert surface water just above the gaging station and deliver it to agricultural lands down stream.

[2] The long term average annual surface water runoff of this subbasin was estimated from the flows recorded at the USGS gaging stations #06724000, "Saint Vrain Creek at Lyons, Colorado" and #7245 "Lefthand Creek near Boulder, Colorado", (Appendix C, Tables C4-16 and -17). These gaging stations are located in the foothills near the canyon mouths of the Saint Vrain Creek and Coal Creek. Surface water accruals below these gaging stations were assumed negligible. The 1930-49 average annual recorded runoff of the Saint Vrain Creek at station #06724000 was 87,266 acre-feet. USGS gaging station #7245 was only operated during water years 1930-31, 1948-53, 1956-57; for this 10 year period, the average annual recorded runoff was 26,761 acre-feet. The USBR has correlated the flow past this gaging station with nearby gaging stations for years of missing record between 1930 and 1949. They estimated the average annual discharge of Lefthand Creek at this point during this 20 year period to be 22,000 acre-feet. This figure was considered more representative of long term conditions and therefore was used in this analysis.

TABLE A4-23: Computation of Native Surface Water Runoff

Subbasin: Saint Vrain Creek
Supply Condition: 1970 Water Year
USGS Gaging Station(s) and Period: #0672400, 1970
#7245, 1970

1970 Upstream Man-Caused Effect	Influence (Acre-Feet)
A. Computation of the net influence of upstream man-caused effects on the gaging stations recorded flow with respect to its drainage areas native surface water runoff	
Export of surface water by agricultural ditches	+ 8,334[1]
Storage change in reservoirs	- 81[2]
NET INFLUENCE	+ 8,253
B. Computation of the native surface water runoff	
1970 runoff as measured by the USGS gaging station(s)	123,296[3]
1970 net influence of upstream man-caused effects	+ 8,253
1970 native surface water runoff	131,549

[1] Assumed to be the average annual export, see Footnote[1], Table A4-22.

[2] Division 1 Water Commissioners, 1970. This value represents the total net releases from storage by several small reservoirs above the gaging stations.

[3] The 1970 surface water runoff of this subbasin was estimated from the flows recorded at the USGS gaging stations #06724000, "Saint Vrain Creek at Lyons, Colorado" and #7245 "Lefthand Creek near Boulder, Colorado", (Appendix C, Tables C4-16 and -17). These gaging stations are located in the foothills near the canyon mouths of Saint Vrain and Coal Creek. Surface water accruals below these gaging stations were assumed negligible. The 1970 runoff of Saint Vrain Creek at station #06724000 was 98,480 acre-feet. Gaging station #7245 on Lefthand Creek was discontinued in 1957; a correlation was preformed to determine what it would have recorded if it was on line during that period. The 1930-49 average annual recorded runoff of Saint Vrain Creek by station #06724000 was 87,266 acre-feet; the 1970 runoff recorded by this station was 112.8 percent of the long term average. Therefore, it was assumed that if station #7245 was operating in 1970, it too would have recorded flows 112.8 percent of the long term average or 24,816 acre-feet.

TABLE A4-24: Computation of Native Surface Water Runoff

Subbasin: Saint Vrain Creek
Supply Condition: Average Annual, 4 Year Drought Period
USGS Gaging Station(s) and Period: #06724000, 1953-56
#7245, 1953-56

1953-56 Average Annual Upstream Man-Caused Effect	Influence (Acre-Feet)
A. Computation of the net influence of upstream man-caused effects on the gaging stations recorded flow with respect to its drainage areas native surface water runoff (excluding the consumptive use of surface water by municipalities, agriculture, and industries, and reservoir evaporation)	
Export of surface water by agricultural ditches	+ 8,334[1]
NET INFLUENCE	+ 8,334
B. Computation of the native surface water "adjusted runoff"	
1953-56 average annual runoff as measured by the USGS gaging station(s)	66,486[2]
1953-56 average annual net influence of upstream man-caused effects	+ 8,334
1953-56 average annual native surface water "adjusted runoff"	74,820
C. Computation of the native surface water runoff	

$$\frac{\text{1953-56 Drought Period Average Annual "Adjusted Runoff"}}{\text{Long Term Average Annual "Adjusted Runoff"}} = \frac{74{,}820 \text{ Acre-Feet}}{117{,}600 \text{ Acre-Feet}^{3}} = 0.6362$$

Therefore, 63.62 percent of the long term average annual native surface water runoff of this subbasin is assumed to be the average annual native surface water runoff during a four year drought period, or,

[0.6362][117,600 acre-feet[4]] = 74,820 Acre-Feet

[1] Assumed to be the average annual export, see Footnote[1], Table A4-22.

[2] The 1953-56 average annual surface water runoff of this subbasin was estimated from the flows recorded at the USGS gaging stations #06724000, "Saint Vrain Creek at Lyons, Colorado" and #7245, "Lefthand Creek near Boulder, Colorado", (Appendix C, Tables C4-16 and -17).

TABLE A4-24: (continued)

These gaging stations are located in the foothills near the canyon mouths of Saint Vrain Creek and Coal Creek. Surface water accruals below these gaging stations were assumed negligible.

The 1953-56 average annual runoff of Saint Vrain Creek at station #06724000 was 53,110 acre-feet. Gaging station #7245 was not operated continuously during this period; a correlation study was preformed to determine what it would have recorded if it was on line then. The 1930-49 average annual recorded runoff of Saint Vrain Creek by station #06724000 was 87,266 acre-feet; the 1953-56 average annual runoff recorded by this station was 53,110 acre-feet or 60.8 percent of the long term average. Therefore, it was assumed that if station #7245 was operating then it too would have recorded flows 60.8 percent of its long term average, or 13,376 acre-feet.

[3] Appendix A, Table A4-22. The average annual native surface water runoff of this subbasin minus the surface water consumptive use (upstream of the gaging stations) or municipalities, industries, and agriculture and evaporation from reservoirs.

[4] Appendix A, Table A4-22. The average annual native surface water runoff of this subbasin.

TABLE A4-25: Computation of Native Surface Water Runoff

Subbasin: Big Thompson River
Supply Condition: Average Annual, Long Term
USGS Gaging Station(s) and Period: #6-7420, 1930-49
#06738000, 1930-49
#7395, 1930-49

1930-49 Average Annual Upstream Man-Caused Effect	Influence (Acre-Feet)
A. Computation of the net influence of upstream man-caused effects on the gaging stations recorded flow with respect to its drainage areas native surface water runoff	
NET INFLUENCE	0
B. Computation of the native surface water runoff	
Average annual runoff as measured by the USGS Gaging Station(s)	147,600[1]
Average annual net influence of upstream man-caused effects	0
Average annual native surface water runoff	147,600

[1] The long term average annual surface water runoff of this subbasin was estimated from the flows recorded at the USGS gaging stations #6-7420, "Little Thompson River near Berthoud, Colorado" #06738000, "Big Thompson River at mouth of canyon near Drake, Colorado", and #7395 "Buckhorn Creek near Masonville, Colorado", (Appendix C, Tables C4-19, -20, and -21). These gaging stations are located in the foothills near the canyon mouths of the Big and Little Thompson Rivers and Buckhorn Creek. Surface water accruals below these gaging stations were assumed negligible.

In 1959 the USBR adjusted the flows of these gaging stations for upstream perturbations and correlated their flows with nearby gaging stations for any missing periods of record between 1930 and 1949. They reported the following:

Gaging Station Number	1930-49 Average Annual Runoff (Acre-Feet)
#06738000	126,100
6-7420	9,300
7395	12,200

TABLE A4-26: Computation of Native Surface Water Runoff

Subbasin: Big THompson River
Supply Condition: 1970 Water Year
USGS Gaging Station(s) and Period: #6-7420, 1970
#06738000, 1970
#7395, 1970

1970 Upstream Man-Caused Effect	Influence (Acre-Feet)
A. Computation of the net influence of upstream man-caused effects on the gaging stations recorded flow with respect to its drainage areas native surface water runoff	
Consumptive use of surface water by municipalities	+ 497[1]
Import of surface water by the Eureka Ditch	- 32[2]
Export of surface water by the Olympus and Dille Tunnels	+88,083[3]
NET INFLUENCE	+88,548
B. Computation of the native surface water runoff	
1970 runoff as measured by the USGS gaging station(s)	88,458[4]
1970 net influence of upstream man-caused effects	+88,548
1970 native surface water runoff	177,006

[1] Janonis, 1977.

[2] Appendix B, Table B3-2.

[3] USGS, 1970b. Since 1953, all Alva B, Adams Tunnel imports to this subbasin have bypassed the gaging station on the Big Thompson River; being diverted by the Olympus tunnel. However, this tunnel along with the Dillie tunnel, another CBT project facility, also divert native Big Thompson River flows around the gaging station at the mouth of its canyon. The value shown is the combined amount diverted during the 1970 water year.

[4] The 1970 water year surface water runoff of this subbasin was estimated from the flows recorded at the USGS gaging stations #6-7420, "Little Thompson River near Berthoud, Colorado", #06738000, "Big Thompson River at mouth of canyon near Drake, Colorado" and #7395 "Buckhorn Creek near Masonville, Colorado", (Appendix C, Tables C4-19,

TABLE A4-26: (continued)

-20, and -21). These gaging stations are located in the foothills near the canyon mouths of the Big and Little Thompson Rivers and Buckhorn Creek. Surface water accruals below these gaging stations were assumed negligible.

The 1970 runoff of the Big Thompson River at station #06738000 was 62,680 acre-feet. Corrected for upstream perturbations within its drainage area, the native surface water runoff of the Big Thompson River at this point was 151,228 acre-feet or 119.9 percent of the long term average. Gaging stations #6-7420 and #7395 were discontinued prior to 1970. It was assumed that if they were operating during the 1970 water year, they too would have recorded 119.9 percent of long term average, or 11,150 acre-feet and 14,628 acre-feet respectively.

TABLE A4-27: Computation of Native Surface Water Runoff

Subbasin: Big Thompson River
Supply Condition: Average Annual, 4 Year Drought Period
USGS Gaging Station(s) and Period: #6-7420, 1953-56
#06738000, 1953-56
#7395, 1953-56

The 1953-56 average annual surface water runoff of this subbasin was estimated from the flows recorded at the USGS gaging stations #6-7420, "Little Thompson River near Berthoud, Colorado", #06738000, "Big Thompson River at mouth of canyon near Drake, Colorado", and #7395, "Buckhorn Creek near Masonville, Colorado", (Appendix C, Tables C4-19, -20, and -21). These gaging stations are located in the foothills near the canyon mouths of the Big and Little Thompson Rivers and Buckhorn Creek. Surface water accruals below these gaging stations were assumed negligible.

Because of the lack of data regarding upstream perturbations on the Big and Little Thompson Rivers during 1953-56 (specifically those of the CBT project) it was assumed that the average annual native surface water runoff of this subbasin during this period was depressed from the long term average, the same as its neighbor, the Saint Vrain Creek Subbasin, was. Therefore, 63.62 percent (from Table A4-24) of the Big Thompson's estimated long term average annual native surface water runoff was assumed to have been available to the subbasin during 1953-56, or 93,903 acre-feet/year.

TABLE A4-28: Computation of Native Surface Water Runoff

Subbasin: Cache La Poudre
Supply Condition: Average Annual, Long Term
USGS Gaging Station(s) and Period: #06752000, 1950-70

1950-70 Average Annual Upstream Man-Caused Effect	Influence (Acre-Feet)
A. Computation of the net influence of upstream man-caused effects on the gaging stations recorded flow with respect to its drainage areas native surface water runoff.	
Consumptive use of surface water by irrigated agriculture	+ 1,933[1]
Import of surface water from the North Platte River Basin by transbasin diversion structures	-21,100[2]
Export of surface water by the Fort Collins Pipeline	+ 6,300[3]
Export of surface water by agricultural ditches	+54,200[4]
Import of surface water from the Colorado River Basin by the Grand River Ditch	-17,000[5]
NET INFLUENCE	+24,333
B. Computation of the native surface water runoff	
Average annual runoff as measured by the USGS gaging station(s)	210,500[6]
Average annual net influence of upstream man-caused effects	+24,333
Average annual native surface water runoff	234,833

[1] Janonis and Gerlek, 1977.

[2] During the 1950-70 period, the following transbasin diversion structures imported North Platte River Basin water to Cache La Poudre River subbasin above gaging station #06752000:

Laramie Poudre Tunnel (Appendix B, Table B1-4)
Skyline Ditch (Appendix B, Table B1-5)
Wilson Ditch (Appendix, B, Table B1-1)
Michigan Ditch (Appendix B, Table B1-8)
Cameron Pass Ditch (Appendix B, Table B1-7)
Bob Creek Ditch (Appendix B, Table B1-3)
Columbine Ditch (Appendix B, Table B1-2)

TABLE A4-28: (continued)

[3] Holland, 1971. The Fort Collins Pipeline diverts water above gaging station #06752000 and delivers it to Fort Collins, which is located outside of this gaging stations drainage area.

[4] Holland, 1971. During 1950-70 the following agricultural ditches diverted water upstream of gaging station #06752000 for irrigation below:

Diversion Structure	1950-70 Average Annual Diversion (acre-feet)
North Poudre Supply Canal	12,400
Poudre Valley and Canyon Canal	20,400
North Poudre Ditch	21,400
TOTAL	54,200

[5] Appendix B, Table B3-1.

[6] The long term average annual native surface water runoff of the Cache La Poudre River Subbasin was estimated from the flows recorded at USGS gaging station #06752000, "Cache La Poudre River at mouth of canyon, near Fort Collins, Colorado", (Appendix C, Table C4-23). Surface water accruals below this gaging station were assumed negligible.

TABLE A4-29: Computation of Native Surface Water Runoff

Subbasin: Cache La Poudre
Supply Condition: 1970 Water Year
USGS Gaging Station(s) and Period: #06752000, 1970

1970 Upstream Man-Caused Effect	Influence (Acre-Feet)
A. Computation of the net influence of upstream man-caused effects on the gaging stations recorded flow with respect to its drainage areas native surface water runoff	
Consumptive use of surface water by irrigated agriculture	+ 1,933[1]
Change in reservoir storage	- 963[2]
Import of surface water from the North Platte River Basin by transbasin diversion structures	-19,420[3]
Import of surface water from the Colorado River Basin by the Grand River Ditch	-12,830[4]
Export of surface water by the Fort Collins Pipeline	+ 8,000[5]
Export of surface water by agricultural ditches	+81,700[6]
NET INFLUENCE	+58,420
B. Computation of the native surface water runoff	
1970 runoff as measured by the USGS gaging station(s)	262,800[7]
1970 net influence of upstream man-caused effects	+58,420
1970 native surface water runoff	321,220

[1] Janonis and Gerlek, 1977.

[2] Holland, 1971.

[3] During 1970, the following transbasin diversion structures imported North Platte River Basin water to Cache La Poudre River Subbasin above gaging station #06752000:

Laramie Poudre Tunnel (Appendix B, Table B1-4)
Skyline Ditch (Appendix B, Table B1-5)
Wilson Ditch (Appendix B, Table B1-1)

TABLE A4-29: (continued)

Michigan Ditch (Appendix B, Table B1-8)
Cameron Pass Ditch (Appendix B, Table B1-7)

[4] Appendix B, Table B3-1.

[5] Holland, 1971. The Fort Collins Pipeline diverts water above gaging station #06752000 and delivers it to Fort Collins, which is located outside of this gaging stations drainage area.

[6] Holland, 1971. During 1970, the following agricultural ditches diverted water upstream of gaging station #06752000 for irrigation below:

Diversion Structure	1970 Average Annual Diversion (Acre-Feet)
North Poudre Supply Canal	31,100
Poudre Valley and Canyon Canal	23,600
North Poudre Ditch	27,000
TOTAL	81,700

[7] The 1970 water year native surface water runoff of the Cache La Poudre River Subbasin was estimated from the flows recorded at USGS gaging station #06752000, "Cache La Poudre River at mouth of canyon, near Fort Collins, Colorado", (Appendix C, Table C4-23). Surface water accruals below this gaging station were assumed negligible.

TABLE A4-30: Computation of Native Surface Water Runoff

Subbasin: Cache La Poudre
Supply Condition: Average Annual, 4 Year Drought Period
USGS Gaging Station(s) and Period: #06752000, 1953-56

1953-56 Average Annual Upstream Man-Caused Effect	Influence (Acre-Feet)
A. Computation of the net influence of upstream man-caused effects on the gaging stations recorded flow with respect to its drainage areas native surface water runoff (excluding the consumptive use of surface water by municipalities, agriculture, and industries, and reservoir evaporation)	
Import of surface water from the North Platte River Basin by transbasin diversion structures	-22,000[1]
Import of surface water from the Colorado River Basin by the Grand River Ditch	-17,300[2]
Export of surface water by the Fort Collins Pipeline	+ 6,225[3]
Export of surface water by agricultural ditches	+34,475[4]
Change in reservoir storage	- 475[5]
NET INFLUENCE	+ 925
B. Computation of the native surface water "adjusted runoff"	
1953-56 average annual runoff as measured by the USGS gaging station(s)	155,850[6]
1953-56 average annual net influence of upstream man-caused effects	+ 925
1953-56 average annual native surface water "adjusted runoff"	156,775

C. Computation of the native surface water runoff

$$\frac{\text{1953-56 Drought Period Average Annual "Adjusted Runoff"}}{\text{Long Term Average Annual "Adjusted Runoff"}} = \frac{\text{156,775 Acre-Feet}}{\text{232,900 Acre-Feet}^{7}} = 0.6731$$

Therefore, 67.31 percent of the long term average annual native surface water runoff of this subbasin is assumed to be the average annual native surface water runoff during a four year drought period, or,

TABLE A4-30: (continued)

[0.6731] [234,833 acre-feet[8]] = 158,066 Acre-Feet

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[1] During the 1953-56 period, the following transbasin diversion structures imported North Platte River Basin water to Cache La Poudre River Subbasin above gaging station #06752000:

Laramie Poudre Tunnel (Appendix B, Table B1-4)
Skyline Ditch (Appendix B, Table B1-5)
Wilson Ditch (Appendix B, Table B1-1)
Michigan Ditch (Appendix B, Table B1-8)
Cameron Pass Ditch (Appendix B, Table B1-7)
Bob Creek Ditch (Appendix B, Table B1-3)
Columbine Ditch (Appendix B, Table B1-2)

[2] Appendix B, Table B3-1.

[3] Holland, 1971. The Fort Collins Pipeline diverts water above gaging station #06752000 and delivers it to Fort Collins, which is located outside of this gaging stations drainage area.

[4] Holland, 1971. During 1953-56, the following agricultural ditches diverted water upstream of gaging station #06752000 for irrigation below:

Diversion Structure	1953-56 Average Annual Diversion (acre-feet)
North Poudre Supply Canal	4,150
Poudre Valley and Canyon Canal	10,900
North Poudre Ditch	19,425
	34,475

[5] Holland, 1971.

[6] The long term average annual native surface water runoff of the Cache La Poudre River Subbasin was estimated from the flows recorded at USGS gaging station #06752000, "Cache La Poudre River at mouth of canyon, near Fort Collins, Colorado", (Appendix C, Table C4-23). Surface water accruals below this gaging station were assumed negligible.

[7] Appendix A, Table A4-28. The average annual native surface water runoff of this subbasin minus the surface water consumptive use (upstream of the gaging station) of municipalities, industries, and agriculture and evaporation from reservoirs.

[8] Appendix A, Table A4-28. The average annual native surface water runoff of this subbasin.

TABLE A4-31: Computation of Native Surface Water Runoff

Subbasin: South Platte River-Transition
Supply Condition: Average Annual, Long Term

The South Platte River-Transition Subbasin is an aggregation of the drainage areas of selected tributaries of the South Platte between its mountains and plains reach. Included is the plains drainage of Clear and Bear Creeks and the lower drainage of Cherry Creek below Cherry Creek Lake. In addition, the entire drainage area of several minor intermittant plains tributaries are also included; the more important are Sand, Deer, First, Second, and Third Creeks and two streams, each named Big Dry and Little Dry Creeks.

The long term average annual surface water runoff of this subbasin was estimated im part from gaging station records and in part from the yield of absolutely decreed storage rights to the small drainage areas located completely within its boundaries.

Tributary	Long Term Average Annual Native Surface Water Runoff
Lower Cherry Creek	7,301[1]
Lower Clear Creek	0[2]
Lower Bear Creek	0[2]
Deer Creek	4,000[3]
Big Dry Creek (west bank)	639[4]
Little Dry Creek (west bank)	179[5]
Others	222[6]
TOTAL	12,341

[1] Appendix A, Table A4-7.

[2] Assumed negligible.

[3] USBR, 1959. Value is the 1930-49 average.

[4] The major absolutely decreed storage rights to Big Dry Creek are as follows (Wilkinson, 1974):

Reservoir	Absolutely Decreed Capacity (Acre-Feet)
German #2	92.50
German #3	19.51
German #4	36.14
German #6	22.95
German #8	54.41
German #9	18.36
German #12	91.82
Church Lower	135.96

TABLE A4-31: (continued)

North Star	128.57
Pamona #2	109.97
TOTAL	710.19

It was assumed that because of the early priority of these rights, their entire amount would be yielded each year. However, because of sedimentation, the actual reservoir capacity in the basin is approximately 90 percent of the decreed capacity (Clark, 1976). Therefore,

$$(.90)(710.19) = 639$$

[5] The major absolutely decreed storage rights to Little Dry Creek are as follows, (Wilkinson, 1974):

Reservoir	Absolutely Decreed Capacity (Acre-Feet)
Coal Ridge (Sandhill)	199.04
Kelley	N/A
TOTAL	199.04

It was assumed that because of the early priority of these rights, their entire amount would be yielded each year. However, because of sedimentation, the actual reservoir capacity in the basin is approximately 90 percent of the decreed capacity (Clark, 1976). Therefore,

$$(.90)(199.04) = 179$$

[6] The major absolutely decreed storage rights to the various other minor tributaries in the South Platte River-Transition Subbasin are as follows, (Wilkinson, 1974):

Reservoir	Source	Absolutely Decreed Storage Capacity (acre-feet)
Marshall	Bratner Gulch	35.17
Brantner #2	Bratner Gulch	10.79
J. B. Smith	Todd Creek	150.00
Maul	First Creek	32.87
Parson-Holmes	Second Creek	18.00
TOTAL		246.83

It was assumed that because of the early priority of these rights, their entire amount would be yielded each year. However, because of sedimentation, the actual reservoir capacity in the basin is approximately 90 percent of the decreed capacity (Clark, 1976). Therefore,

$$(.90)(246.83) = 222$$

TABLE A4-32: Computation of Native Surface Water Runoff

Subbasin: South Platte River-Transition
Supply Condition: 1970 Water Year

The South Platte River-Transition Subbasin in an aggregation of the drainage areas of selected tributaries of the South Platte between its mountains and plains reach. Included is the plains drainage of Clear and Bear Creeks and the lower drainage of Cherry Creek below Cherry Creek Lake. In addition, the entire drainage area of several minor intermittant plains tributaries are also included; the more important are Sand, Deer, First, Second, and Third Creeks and two streams each named Big Dry and Little Dry Creeks.

The 1970 water year average annual native surface water runoff of this subbasin was estimated in part from gaging station records and in part from the yield of absolutely decreed storage rights to the small drainage areas located completely within its boundaries.

Tributary	1970 Native Surface Water Runoff
Lower Cherry Creek	4,034[1]
Lower Clear Creek	0[2]
Lower Bear Creek	0[2]
Deer Creek	4,000[3]
Big Dry Creek (west bank)	639[3]
Little Dry Creek (west bank)	179[3]
Others	222[3]
TOTAL	9,074

[1] Appendix A, Table A4-8.

[2] Assumed to be negligible.

[3] Assumed to be the average annual values, (Table A4-31).

TABLE A4-33: Computation of Native Surface Water Runoff

Subbasin: South Platte River-Transition
Supply Condition: Average Annual, 4 Year Drought Period (1953-56)

The South Platte River-Transition Subbasin is an aggregation of the drainage areas of selected tributaries of the South Platte between its mountains and plains reach. Included is the plains drainage of Clear and Bear Creeks and the lower drainage of Cherry Creek below Cherry Creek Lake. In addition, the entire drainage area of several minor intermittant plains tributaries are also included; the more important are Sand, Deer, First, Second, and Third Creeks and two streams each named Big Dry and Little Dry Creeks.

As seen in Table A4-31, the average annual native surface water runoff of this subbasin was estimated to be 12,341 acre-feet per year.

During the 1953-56 period, the native surface water runoff of the lower portion of the Cherry Creek drainage included in this subbasin was 41.59 percent of the long term average, (Appendix A, Table A4-9).

It was assumed that this entire subbasin was likewise effected. Therefore,

$$(.4159)(12{,}341\text{A-F/Y}) = 5{,}133 \text{ A-F/Y}$$

APPENDIX B

RECORDS OF TRANSBASIN DIVERSIONS CONCERNING THE SOUTH PLATTE AND ADJACENT RIVER BASINS

INTRODUCTION

Contained within this appendix are yearly diversions records of the transbasin diversion structures that interact between the North Platte, Colorado, Arkansas, and South Platte River Basins.

SECTION B1

TRANSBASIN DIVERSIONS FROM THE NORTH PLATTE RIVER BASIN

TO THE SOUTH PLATTE RIVER BASIN

TABLE B1-1: Yearly Transbasin Diversions Through the Wilson Supply Ditch From the Laramie River Subbasin, North Platte River Basin to the Catch La Poudre River Subbasin, South Platte River Basin.

Water Year	Diversions Through the Wilson Supply Ditch (Acre-Feet)		
	Deadman Creek[1] Diversions	Sand Creek[2] Diversions	Total Diversions[3]
1902	N.A.	N.A.	1,920
1903	N.A.	N.A.	1,710
1904	N.A.	N.A.	6,810
1905	N.A.	N.A.	0
1906	N.A.	N.A.	5,000
1907	N.A.	N.A.	5,400
1908	N.A.	N.A.	2,090
1909	N.A.	N.A.	0
1910	N.A.	N.A.	783
1911	N.A.	N.A.	4,420
1912	N.A.	N.A.	2,150
1913	N.A.	N.A.	0
1914	N.A.	N.A.	935
1915	N.A.	N.A.	1,990
1916	N.A.	N.A.	2,870
1917	N.A.	N.A.	0
1918	N.A.	N.A.	3,240
1919	N.A.	N.A.	2,510
1920	N.A.	N.A.	0
1921	N.A.	N.A.	0
1922	N.A.	N.A.	3,210
1923	N.A.	N.A.	4,940
1924	N.A.	N.A.	1,770
1925	N.A.	N.A.	4,220
1926	N.A.	N.A.	2,576
1927	N.A.	N.A.	3,400
1928	N.A.	N.A.	1,300
1929	N.A.	N.A.	5,515
1930	N.A.	N.A.	2,830
1931	N.A.	N.A.	2,190
1932	N.A.	N.A.	4,495
1933	N.A.	N.A.	6,263
1934	N.A.	N.A.	1,363
1935	2,810	2,652	5,462
1936	1,030	2,362	3,392
1937	1,150	2,542	3,692
1938	1,990	5,091	6,281
1939	874	1,781	2,655
1940	609	611	1,220
1941	877	1,756	2,633
1942	0	0	0

(continued)

TABLE BI-1: (continued)

Water Year	Deadman Creek[1] Diversions	Sand Creek[2] Diversions	Total[3] Diversions
1943	0	1,142	1,142
1944	0	1,699	1,699
1945	772	3,191	3,963
1946	940	2,708	3,648
1947	1,010	4,330	5,340
1948	903	2,706	3,609
1949	1,280	2,403	3,683
1950	1,130	2,310	3,440
1951	1,220	4,036	5,256
1952	592	2,160	2,752
1953	871	1,155	2,026
1954	762	276	1,038
1955	1,170	428	1,598
1956	1,720	1,665	3,385
1957*	361	921	1,282
1958	461	1,396	1,857
1959	871	1,236	2,107
1960	1,390	1,801	3,191
1961	211	940	1,151
1962	1,131	3,796	4,927
1963	655	409	1,064
1964	1,074	1,389	2,463
1965	900	2,194	3,094
1966	638	293	931
1967	920	1,476	2,396
1968	1,150	3,179	4,329
1969	1,273	343	1,616
1970	165	2,715	2,880
1971	N.A.	N.A.	853
1972	N.A.	N.A.	2,370
1973	N.A.	N.A.	1,380
1974	N.A.	N.A.	4,340
1975	N.A.	N.A.	N.A.
Annual Average Diversions:			
Prior to the Laramie River Agreement	987	2,137	2,797
Since the Laramie River Agreement	834	1,628	2,383

[1] Jack Neutze, 1976.
[2] By Subtraction; Column 3 minus Column 1.
[3] United States Geological Survey 1958, 64a, 69a, 71, 72, 73a, 73b, 74 and 75.
* Enactment date of the Laramie River Agreement, February 1957 (5th Month of the 1957 water year).
N.A.-Not Available.

TABLE B1-2: Yearly Transbasin Diversions through the Columbine Ditch From the Laramie River Subbasin, North Platte River Basin to the Catch La Poudre River Subbasin, South Platte River Basin.

Water Year	Acre-Feet[1]
1921	504
1922	180
1923	329
1924	9
1925	257
1926	0
1927	371
1928	369
1929	585
1930	158
1931	210
1932	174
1933	0
1934	0
1935	0
1936	0
1937	0
1938	0
1939	0
1940	78
1941	75
1942	0
1943	0
1944	0
1945	0
1946	163
1947	188
1948	0
1949	27
1950	86
1951	135
1952	0
1953	0
1954	72
1955	165
1956	225
1957*	-
Average Annual Diversion:	121

[1]United States Geological Survey, 1958 and 64a.

*Enactment date of the Laramie River Agreement, February 1957 (5th Month of the 1957 water year). By court order arising from Wyoming vs Colorado, 289 U.S. 573, diversions through the Columbine Ditch were suspended.

TABLE B1-3: Transbasin Diversions through the Bob Creek Ditch from the Laramie River Subbasin, North Platte River Basin to the Catch La Poudre River Subbasin, South Platte River Basin.

Water Year	Acre-Feet[1]
1920	916
1921	1,330
1922	508
1923	1,100
1924	0
1925	738
1926	0
1927	1,030
1928	526
1929	1,140
1930	631
1931	633
1932	822
1933	0
1934	0
1935	0
1936	0
1937	0
1938	0
1939	0
1940	167
1941	274
1942	220
1943	0
1944	0
1945	0
1946	350
1947	524
1948	0
1949	176
1950	301
1951	384
1952	0
1953	0
1954	224
1955	559
1956	705
1957*	-
Average Annual Diversion:	358

[1] United States Geological Survey, 1958 and 64a.

* Enactment date of the Laramie River Agreement, February 1957 (5th Month of the 1957 water year). By court order arising from Wyoming vs Colorado, 289 U.S. 573, diversions through the BOB Creek Ditch were suspended.

TABLE B1-4: Yearly Transbasin Diversions through the Laramie-Poudre Runnel from the Laramie River Subbasin, North Platte River Basin to the Catch La Poudre River Subbasin, South Platte River Basin.

Water Year	Acre-Feet[1]	Water Year	Acre-Feet[1]
1914	813	1946	9,470
1915	4,960	1947	14,370
1916	4,510	1948	11,360
1917	392	1949	10,770
1918	10,700	1950	15,490
1919	4,090	1951	14,580
1920	12,120	1952	15,060
1921	8,970	1953	14,450
1922	7,350	1954	14,010
1923	10,680	1955	14,820
1924	4,230	1956	15,000
1925	8,660	1957*	15,060
1926	8,930	1948	13,720
1927	7,190	1949	17,920
1928	10,680	1960	15,980
1929	7,770	1961	10,400
1930	4,330	1962	13,950
1931	2,900	1963	16,670
1932	13,430	1964	15,520
1933	13,450	1965	18,300
1934	6,060	1966	19,130
1935	14,120	1967	10,740
1936	12,970	1968	17,030
1937	12,290	1969	15,000
1938	9,480	1970	14,990
1939	13,070	1971	14,110
1940	7,410	1972	16,190
1941	7,490	1973	16,690
1942	10,240	1974	17,870
1943	8,960	1975	17,130
1944	9,080		
1945	8,600		
Average Annual Diversion:			
Prior to the Laramie River Agreement	9,657		
Since the Laramie River Agreement	15,630		

[1] United States Geological Survey, 1958, 64a, 69a, 71, 72, 73a, 73b, 74, and 75.

* Enactment date of the Laramie River Agreement, February 1957 (5th Month of the 1957 water year).

TABLE BI-5: Yearly Transbasin Diversions through the Skyline Ditch from the Laramie River Subbasin, North Platte River Basin to the Catch La Poudre River Subbasin, South Platte River Basin.

Water Year	Acre-Feet[1]	Water Year	Acre-Feet[1]	Water Year	Acre-Feet[1]
1895	14,230	1922	15,480	1949	7,800
1896	16,620	1923	17,240	1950	2,960
1897	16,700	1924	13,720	1951	3,640
1898	13,430	1925	15,040	1952	1,770
1899	17,360	1926	18,940	1953	4,790
1900	17,990	1927	21,380	1954	4,920
1901	24,330	1928	19,900	1955	3,680
1902	21,740	1929	24,480	1956	2,270
1903	24,580	1930	18,240	1957*	3,500
1904	25,100	1931	13,350	1958	587
1905	13,610	1932	18,300	1959	1,420
1906	16,640	1933	17,300	1960	2,560
1907	15,750	1934	10,550	1961	1,300
1908	17,660	1935	18,930	1962	0
1909	12,650	1936	21,510	1963	2,590
1910	17,000	1937	15,700	1964	3,420
1011	17,190	1938	21,710	1965	772
1912	20,190	1939	14,870	1966	0
1913	15,630	1940	7,230	1967	1,500
1914	10,210	1941	6,640	1968	2,140
1915	15,000	1942	8,330	1969	3,710
1916	20,320	1943	9,730	1970	1,550
1917	10,570	1944	10,590	1971	1,810
1918	15,360	1945	10,570	1972	2,350
1919	14,920	1946	9,090	1973	2,680
1920	14,760	1947	3,830	1974	651
1921	14,120	1948	7,780	1975	1,680

Average Annual Diversion:	
Prior to the Laramie River Agreement	14,128
Since the Laramie River Agreement	1,707

[1] United States Geological Survey, 1958, 64a, 69a, 71, 72, 73a, 73b, 74, and 75.

* Enactment date of the Laramie River Agreement, February 1957 (5th Month of the 1957 water year).

TABLE B1-6: Yearly Transbasin Diversions through the Lost Lake Outlet from the Laramie River Subbasin, North Platte River Basin to the Catch La Poudre River Subbasin, South Platte River Basin.

Water Year	Acre-Feet[1]	Water Year	Acre-Feet[1]
1899	332	1926	863
1900	104	1927	454
1901	497	1928	411
1902	260	1929	470
1903	374	1930	231
1904	532	1931	106
1905	154	1932	0
1906	158	1933	0
1907	170	1934	0
1908	269	1935	0
1909	427	1936	0
1910	217	1937	0
1911	280	1938	0
1912	372	1939	0
1913	34	1940	132
1914	0	1941	185
1915	63	1942	409
1916	277	1943	504
1917	414	1944	217
1918	637	1945	0
1919	53	1946	0
1920	280	1947	0
1921	451	1948	0
1922	210	1949	0
1923	634	1950*	0
1924	0		
1925	0		
Average Annual Diversion:	215		

[1] United States Geological Survey, 1958.

* By order of the Colorado State Engineer, diversions through this ditch were discontinued in 1950 (Evans, 1971).

TABLE B1-7: Yearly Transbasin Diversions through the Cameron Pass Ditch from the North Platte River-Mountains Subbasin, North Platte River Basin to the Catch La Poudre River Subbasin, South Platte River Subbasin.

Water Year	Acre-Feet[1]	Water Year	Acre-Feet[1]
1913	88	1944	186
1914	197	1945*	297
1951	307	1946	262
1916	527	1947	0
1917	101	1948	0
1918	232	1949	149
1919	283	1950	131
1920	259	1951	311
1921	42	1952	116
1922	257	1953	125
1923	218	1954	133
1924	89	1955	186
1925	384	1956	264
1926	377	1957	63
1927	373	1958	0
1928	333	1959	126
1929	389	1960	156
1930	253	1961	0
1931	307	1962	0
1932	385	1963	0
1933	423	1964	0
1934	168	1965	0
1935	279	1966	0
1936	352	1967	0
1937	237	1968	103
1938	448	1969	1
1939	255	1970	0
1940	234	1971	0
1941	287	1972	111
1942	0	1973	407
1943	0	1974	296
		1974	276

Average Annual Diversion:	
Prior to the North Platte River Decree	260
Since the North Platte River Decree	107

[1] United States Geological Survey, 1958, 64a, 69a, 71, 72, 73a, 73b, 74, and 75.

* Enactment date of the North Platte River Decree, October 1, 1945 (1st day of the 1946 water year).

TABLE B1-8: Yearly Transbasin Diversions through the Michigan Ditch From the North Platte River-Mountains Subbasin, North Platte River Basin to the Catch La Poudre River Subbasin, South Platte River Basin.

Water Year	Acre-Feet[1]	Water Year	Acre-Feet[1]
1905	861	1941	3,400
1906	1,920	1942	786
1907	3,980	1943	1,540
1908	4,120	1944	1,810
1909	3,750	1945*	3,090
1910	2,310	1946	1,940
1911	2,840	1947	3,260
1912	4,750	1948	1,910
1913	2,600	1949	2,360
1914	2,360	1950	2,070
1915	2,120	1951	4,310
1916	5,820	1952	2,080
1917	1,380	1953	1,450
1918	2,380	1954	0
1919	2,400	1955	0
1920	3,780	1956	1,860
1921	3,120	1957	1,170
1922	3,360	1958	0
1923	5,470	1959	1,540
1924	2,410	1960	1,470
1925	7,690	1961	127
1926	6,000	1962	0
1927	4,810	1963	0
1928	4,440	1964	484
1929	5,500	1965	1,080
1930	3,600	1966	0
1931	4,420	1967	0
1932	4,540	1968	1,440
1933	4,880	1969	0
1934	1,010	1970	0
1935	3,880	1971	0
1936	4,480	1972	1,770
1937	2,420	1973	1,890
1938	4,930	1974	1,790
1940	1,780	1975	1,710

Average Annual Diversion:	
Prior to the North Platte River Decree	3,389
Since the North Platte River Decree	1,190

[1] United States Geological Survey, 1958, 64a, 69a, 71, 72, 73a, 73b, 74, and 75.

* Enactment date of the North Platte River Decree, October 1, 1945 (1st day of the 1946 water year).

SECTION B2

TRANSBASIN DIVERSIONS FROM THE COLORADO RIVER BASIN

TO THE NORTH PLATTE RIVER BASIN

TABLE B2-1: Yearly Transbasin Diversions through the Cheyenne Tunnel from the Little Snake River Subbasin, Colorado River Basin to the North Platte River-Mountains Subbasin, North Platte River Basin.

Water Year	Acre-Feet[1]
1965	9,241
1966	3,269
1967	9,152
1968	7,848
1969	8,207
1970	8,229
1971**	4,308
1972	7,200
1973*	8,216
1974	6,751
1975	5,062
1976	7,300
Annual Average Diversion for Water Years System was Operated at Capacity:	7,316

[1] 1965-69 values from Banner, 1976; 1970-76 values from Sherard, 1977.

* East Slope storage facilities, Hoy Park and Rob Ray Reservoirs, full, lost spring runoff over spillways.

** System operated below capacity for repairs.

NOTE: This Colorado River Basin water is exchanged for the native surface flows of the North Platte River-Mountains Subbasin which are exported via the Cheyenne Pipeline to the Crow Creek Subbasin of the South Platte River Basin.

SECTION B3

TRANSBASIN DIVERSIONS FROM THE COLORADO RIVER BASIN TO THE SOUTH PLATTE RIVER BASIN

TABLE B3-1: Yearly Transbasin Diversions through the Grand River Ditch from the Colorado River-Mountains Subbasin, Colorado River Basin to the Catch La Poudre River Subbasin, South Platte River Basin.

Water Year	Acre-Feet[1]	Water Year	Acre-Feet[1]	Water Year	Acre-Feet[1]
1896	293	1923	12,550	1950	16,160
1897	532	1924	7,510	1951	24,970
1898	112	1925	16,720	1952	21,380
1899	300	1926	14,500	1953	19,750
1900	1,300	1927	16,490	1954	12,740
1901	1,570	1928	13,530	1955	16,150
1902	1,520	1929++	19,900	1956	20,470
1903	1,880	1930	13,700	1957	16,060
1904	1,980	1931	10,590	1958	13,770
1905	6,170	1932	13,850	1959	18,570
1906	12,000	1933	12,190	1960	23,010
1907	12,600	1934*	7,690	1961	9,880
1908+	16,800	1935	11,280	1962	24,010
1909	15,600	1936	19,030	1963	15,600
1910	10,240	1937	13,640	1964	16,730
1911	9,710	1938	25,210	1965	16,370
1912	15,840	1939	18,630	1966	14,240
1913	10,090	1940	17,220	1967	8,950
1914	7,610	1941	19,190	1968	16,260
1915	12,210	1942	20,150	1969	18,350
1916	14,520	1943	17,530	1970	12,830
1917	7,590	1944	16,650	1971	14,950
1918	14,370	1945	23,300	1972	18,520
1919	10,130	1946	18,820	1973	14,760
1920	15,170	1947	24,820	1974	15,640
1921	9,210	1948	17,730	1975**	21,830
1922	12,450	1949	17,190		
1935-74 Average Annual Diversion			17,513		

[1] United States Geological Survey, 1958, 64a, 69a, 71, 72, 73a, 73b, 74, and 75.

+ 11 of the total 15 miles of the Grand River Ditch were completed.

++ Long Draw Reservoir completed.

* The main intercepting canal of this ditch was enlarged.

** Completion of the expansion of Long Draw Reservoir and the lining of parts of the Grand River Ditch.

TABLE B3-2: Yearly Transbasin Diversions through the Eureka Ditch from the Colorado River-Mountains Subbasin, Colorado River Basin to the Big Thompson River Subbasin, South Platte River Basin.

Water Year	Acre-Feet[1]
1940	36
1941	76
1942	0
1943	133
1944	85
1945	186
1946	152
1947	175
1948	102
1949	91
1950	77
1951	124
1952	103
1953	26
1954	27
1955	125
1956	52
1957	124
1958	64
1959	0
1960	69
1961	39
1962	68
1963	87
1964	76
1965	190
1966	114
1967	188
1968	63
1969	116
1970	32
1971	12
1972	53
1973	0
1974	15
1975	0
Average Annual Diversion	80

[1] United States Geological Survey, 1958, 64a, 69a, 71, 72, 73a, 73b, 74, and 75.

TABLE B3-3: Yearly Transbasin Diversions through the Alva B. Adams Tunnel from the Colorado River-Mountains Subbasin, Colorado River Basin to the Big Thompson River Subbasin, South Platte River Basin.

Water Year	Acre-Feet[1]
1947	4,610
1948	9,240
1949	17,480
1950	26,270
1951	56,310
1952	56,020
1953	180,000
1954	302,100
1955	256,600
1956*	210,700
1957	195,200
1958	208,400
1959	273,000
1960	243,600
1961	208,700
1962	204,700
1963	285,400
1964	318,400
1965	211,000
1966	235,400
1967	267,500
1968	198,600
1969	170,500
1970	204,600
1971	190,800
1972	235,000
1973	203,700
1974	231,100
1975	239,300
1957-75 Average Annual Diversion	227,626

[1] United States Geological Survey, 1958, 64a, 69a, 71, 72, 73a, 73b, 74, and 75.

* Completion of the east slope distribution system, the last phase in the construction of the Colorado Big Thompson Project.

TABLE B3-4: Yearly Transbasin Diversions through the Moffat Water Tunnel to the Boulder Creek Subbasin, South Platte River Basin from the Fraser River and Williams Forks River Subbasins, Colorado River Basin.

Water Year	Diversions through the Moffat Water Tunnel (AC-FT)		
	Fraser River Subbasin Diversions[1]	Williams Fork River Subbasin Diversions[1]	Total Diversions[1]
1936+	12,140	--	12,140
1937	21,630	--	21,630
1938	43,180	--	43,180
1939	30,860	--	30,860
1940	29,390	--	29,390
1941	36,290	--	36,290
1942	11,320	--	11,320
1943	32,490	--	32,490
1944	16,390	--	16,390
1945	36,600	--	36,600
1946	32,620	--	32,620
1947	23,600	--	23,600
1948	24,260	--	24,260
1949	24,660	--	24,660
1950++	29,560	--	29,560
1951	33,800	--	33,800
1952	31,230	--	31,230
1953	35,070	--	35,070
1954	19,540	--	19,540
1955	37,020	--	37,020
1956	53,430	--	53,430
1957	48.180	--	48,180
1958	13,650	--	13,650
1959*	61,398	1,468	62,866
1960	51,564	2,928	54,492
1961	49,194	4,314	53,508
1962	62,776	1,988	64,764
1963	39,832	5,840	45,672
1964	54,216	9,828	64,044
1965	70,366	5,162	75,528
1966	42,796	8,050	50,846
1967	48.742	4,452	53,194
1968	63,152	6,020	69,172
1969	34,732	3,502	38,234
1970	41,874	2,112	43,986
1971	36,030	2,544	38,574
1972	54,766	6,574	61,340
1973	32,454	390	32,844
1974	64,244	4,394	68,638
1975**	55,580	5,840	61,420

(continued)

TABLE B3-4 (continued)

Water Year	Diversions through the Moffat Water Tunnel (AC FT)		
	Fraser River Subbasin Diversions[1]	Williams Fort River Subbasin Diversions[1]	Total Diversions[1]
1951-58 Average Annual Diversion	33,990	--	33,990
1960-74 Average Annual Diversion	49,782	4,540	54,322

[1] 1959-75 values from the Denver Board of Water Commissioners 1968, 72, 75. 1936-58 values from United States Geological Survey, 1958 and 64a.

+ In June of 1936, the 1st diversions through the Moffat water tunnel were made. The collection system then included three collection ditches taking water in the Fraser River subbasin from Vasques and Ranch Creeks and the Fraser River. However, only a few hundred feet of the Ranch Creek collection ditch was complete at this time.

++ The Ranch Creek collection ditch was completed in 1950.

* In July of 1959 the Moffatt Projects collection system was expanded to include diversions from the Williams Fork River subbasin and additional Fraser River subbasin diversions through the lengthening of the Fraser River and Ranch Creek collection ditches.

** On May 12, 1975 the Ranch Creek Collection Ditch was expanded further. Additional Fraser River subbasin diversions by this enlargement of the Moffat Projects collection system amounted to 6,052 acre-feet in the 1975 water year (Denver Board of Water Commissioners, 1975). Incremental diversions by this enlargement are expected to average about 5000 acre feet annually.

Table B3-5: Yearly Transbasin Diversions Through the Berthoud Pass Ditch From Fraser River Subbasin, Colorado River Basin to the Clear Creek Subbasin, South Platte River Basin.

Water Year	Acre-Feet[1]	Water Year	Acre-Feet[1]
1910	420	1944	430
1911	434	1945	1,040
1912	210	1946	397
1913	1,160	1947	166
1914	476	1948	561
1915	650	1949	327
1916	832	1950	490
1917	504	1951	716
1918	868	1952	730
1919	476	1953	594
1920	0	1954	217
1921	100	1955	458
1922	576	1956	396
1923	1,370	1957	568
1924	1,160	1958	429
1925	1,050	1959	996
1926	452	1960	973
1927	424	1961	311
1928	422	1962	922
1929	1,210	1963	558
1930	1,030	1964	663
1931	312	1965	1,190
1932	768	1966	591
1933	555	1967	793
1934	649	1968	708
1935	545	1969	586
1936	720	1970	291
1937	0	1971	806
1938	777	1972	466
1940	892	1973	754
1941	572	1974	809
1942	609	1975	402
1943	-261		
Average Annual Diversion	612		

[1] United States Geological Survey, 1958, 64a, 69a, 71, 72, 73a, 73b, 74, and 75.

TABLE B3-6: Yearly Transbasin Diversions Through the Jones Pass Tunnel from the Williams Fork River Subbasin, Colorado River Basin to the Clear Creek Subbasin, South Platte River Basin.

Water Year	Acre-Feet[1]	Water Year	Acre-Feet[1]
1940	9,560	1958	0
1941	8,190	1959*	1,040
1942	1,600	1960	2,880
1943	4,060	1961	4,250
1944	3,860	1962	1,650
1945	11,050	1963	5,200
1946	11,000	1964	9,360
1947	2,070	1965	5,600
1948	2,050	1966	8,050
1949	1,890	1967	4,452
1950	9,090	1968	6,020
1951	11,140	1969	3,502
1952	6,810	1970	2,112
1953	7,420	1971	2,544
1954	5,480	1972	6,574
1955	10,300	1973	390
1956	8,880	1974	4,394
1957	4,250	1975	5,840
Average Annual Diversion	5,557		

[1]1959-75 values from the Denver Board of Water Commissioners, 1968, 72, 75.
1940-58 values from the United States Geological Survey, 1958 and 64a.

*Since July of 1959, water diverted through the Jones Pass Tunnel has been rediverted back to the Colorado River Basin. The diversion structure responsible for this transfer is the Vasquez Tunnel whose entrance portal lies immediately adjacent to the Jones Pass Tunnels Exit Portal. Through the Vasquez tunnel this water is brought back under the continental divide to the Fraser River subbasin. There it is transported via collection ditch to the entrance portal of the Moffat water tunnel where it is diverted back to the South Platte River Basin, this time to the Boulder Creek subbasin. The Jones Pass Tunnel is now considered a component of the Moffat water tunnel's collection system.

TABLE B3-7: Yearly Transbasin Diversions through the Vidler Tunnel from the Blue River Subbasin, Colorado River Basin to the Clear Creek Subbasin, South Platte River Basin

Water Year	Acre-Feet[1]
1971	64
1972	47
1973	57
1974	58
1975	12
Average Annual Diversions	48

[1] United States Geological Survey, 1971, 72, 73b, 74, and 75.

TABLE B3-8: Yearly Transbasin Diversions through the Harold D. Roberts Tunnel from the Blue River Subbasin, Colorado River Basin to the North Fork of the South Platte River Subbasin, South Platte River Basin.

Water Year	Diversions from the Blue River Subbasin (AC-FT)[1]	Infiltration From the Aquifer (AC-FT)[2]	Total (AC-FT)[3]
1964	NA	NA	26,800
1965	NA	NA	30,290
1966	NA	NA	26,580
1967	NA	NA	52,950
1968	42,330	3,330	45,660
1969	45,752	2,858	48,610
1970	10,212	408	10,620
1971	18,450	540	18,990
1972	33,232	1,048	34,280
1973	1,983	262	2,245
1974	32,938	1,792	34,730
1975	44,334	2,926	47,260
Average Annual Diversions	28,654	1,645	31,585

[1] By subtracting Column 3 minus Colume 2.

[2] Denver Board of Water Commissioners, 1968, 72, 75.

[3] United States Geological Survey, 1969a, 71, 72, 73a, 73b, 74, and 75.

NA=Not Available.

TABLE B3-9: Yearly Transbasin Diversions through the Boreas Pass Ditch from the Blue River Subbasin, Colorado River Basin to the South Platte River-Mountains Subbasin, South Platte River Basin.

Water Year	Acre-Feet[1]	Water Year	Acre-Feet[1]
1933	289	1955	268
1934	73	1956	260
1935	215	1957	475
1936	430	1958	250
1937	149	1959	197
1938	275	1960	181
1939	31	1961	127
1940	171	1962	133
1941	0	1963	0
1942	0	1964	0
1943	0	1965	52
1944	0	1966	0
1945	0	1967	0
1946	0	1968	42
1947	0	1969	0
1948	0	1970	0
1949	0	1971	111
1950	69	1972	0
1951	176	1973	0
1952	13	1974	6
1953	273	1975	39
1954	136		
Average Annual Diversion	103		

[1] United States Geological Survey, 1958, 64a, 69a, 71, 72, 73a, 73b, 74, and 75.

TABLE B3-10: Yearly Transbasin Diversions through the East and West Hoosier Pass Ditches from the Blue River Subbasin, Colorado River Basin to the South Platte River-Mountains Subbasin, South Platte River Basin.

Water Year	East Hoosier Pass Ditch (AC.FT)[1]	West Hoosier Pass Ditch (AC.FT)[1]
1935	242	67
1936	473	182
1947	149	146
1938	497	155
1939*	322	159
1940**	101	--
Average Annual Diversions	297	142

[1] United States Geological Survey, 1958.

* By court order, diversions through the West Hoosier Pass Ditch were discontinued in 1939, (USGS, 1954).

** By court order, diversions through the East Hoosier Pass Ditch were discontinued in 1940, (USGS, 1954).

TABLE B3-11: Yearly Transbasin Diversions Through the Hoosier Pass Tunnel from the Blue River Subbasin, Colorado River Basin to the South Platte River-Mountains Subbasin, South Platte River Basin

Water Year	Acre-Feet[1]
1952*	2,380
1953	4,840
1954	3,550
1955	6,450
1956	9,290
1957	7,110
1958	6,420
1959	8,500
1960	8,220
1961	6,200
1962	11,450
1963	9,850
1964	9,650
1965	8,040
1966	7,860
1967	9,930
1968	10,080
1969	7,750
1970	6,100
1971	12,940
1972	10,420
1973	5,834
1974	10,780
1975	8,460
1953-75 Average Annual Diversion	8,249

[1] United States Geological Survey, 1964a, 66, 67, 68, 69c, 70a, 70b, 71, 72, 73b, 74, and 75.

* Diversions began on June 30, 1952 (9th month of the 1952 water year).

NOTE: All of the diversions through the Hoosier Pass Tunnel to the South Platte River Basin are again diverted by the Montgomery Pipeline and transported to the Arkansas River Basin.

SECTION B4

TRANSBASIN DIVERSIONS FROM THE COLORADO RIVER BASIN TO THE ARKANSAS RIVER BASIN

TABLE B4-1: Yearly Transbasin Diversions Through the Fremont Pass Ditch from the Blue River Subbasin, Colorado River Basin to the Arkansas River-Mountains Subbasin, Arkansas River Basin.

Water Year	Acre-Feet[1]
1929	1,110
1930	1,220
1931	1,030
1932	2,490
1933	1,820
1934	1,800
1935	1,630
1936	1,900
1937	1,110
1938	1,650
1939	1,100
1940	635
1941	589
1942	0
1943*	362
Average Annual Diversion	1,230

[1] United States Geological Survey, 1954.

* Since August of 1943, there has been no diversion through this ditch as the water is now used within the Blue River Subbasin for mining operations.

TABLE B4-2: Yearly Transbasin Diversions through the Columbine Ditch from the Eagle River Subbasin, Colorado River Basin to the Arkansas River-Mountains Subbasin, Arkansas River Basin.

Water Year	Acre-Feet[1]	Water Year	Acre-Feet[1]
1931	246	1952	1,020
1932	1,290	1953	1,040
1933	1,230	1954	844
1934	1,260	1955	1,160
1935	1,340	1956	1,390
1936	1,780	1957	1,110
1937	1,280	1958	0
1938	1,780	1959	1,330
1939	1,270	1960	1,880
1940	1,110	1961	1,090
1941	1,320	1962	1,580
1942	0	1963	958
1943	1,160	1964	1,490
1944	134	1965	2,030
1945	1,090	1966	984
1946	1,250	1967	1,570
1947	0	1968	1,750
1948	0	1969	1,910
1949	0	1970	2,160
1950	1,270	1971	886
1951	1,740	1972	1,970
		1973	1,900
		1974	1,690
		1975	2,000
Average for 45 Years of Record	1,202		

[1] United States Geological Survey, 1954, 64b, 66, 67, 68, 69b, 69c, 70b, 71, 72, 73b, 74, and 75.

TABLE B4-3: Yearly Transbasin Diversions through the Ewing Ditch from the Eagle River Subbasin, Colorado River Basin to the Arkansas River-Mountains Subbasin, Arkansas River Basin.

Water Year	Acre-Feet[1]	Water Year	Acre-Feet[1]
1908	2,340	1942	0
1909	1,510	1943	0
1910	1,960	1944	0
1911	2,380	1945	609
- 1912	1,580	1946	1,030
1913	2,360	1947	1,340
1914	1,590	1948	146
1915	2,410	1949	1,340
1916	2,460	1950	783
1917	2,210	1951	1,420
1918	1,820	1952	1,820
1919	1,740	1953	1,140
1920	1,790	1954	498
1921	1,660	1955	415
1922	1,890	1956	1,100
1923	2,330	1957	1,360
1924	2,320	1958	1,340
1925	1,610	1959	1,060
1926	1,700	1960	1,300
1927	1,810	1961	665
1928	1,100	1962	1,540
1929	612	1963	290
1930	443	1964	815
1931	809	1965	1,380
1932	550	1966	529
1933	303	1967	757
1934	185	1968	1,020
1935	540	1969	1,250
1936	375	1970	1,340
1937	1,400	1971	1,350
1938	936	1972	716
1939	173	1973	1,110
1940	376	1974	934
1941	0	1975	1,140
1942			
Average for 67 Years of Record	1,176		

- Flows were not recorded for the entire water year.

[1] United States Geological Survey, 1954, 64b, 66, 67, 68, 69b, 69c, 70b, 71, 72, 73, 74, and 75.

TABLE B4-4: Yearly Transbasin Diversions through the Wurtz Ditch from the Eagle River Subbasin, Colorado River Basin to the Arkansas River-Mountains Subbasin, Arkansas River Basin.

Water Year	Acre-Feet[1]	Water Year	Acre-Feet[1]
1932	716	1955	1,350
1933	1,680	1956	2,590
1934	1,370	1957	2,640
1935	2,900	1958	2,040
1936	3,740	1959	1,930
1937	1,750	1960	2,200
1938	2,580	1961	1,420
1939	1,470	1962	2,740
1940	992	1963	1,300
1941	2,010	1964	1,760
1942	2,090	1965	3,410
1943	2,560	1966	1,370
1944	1,800	1967	1,560
1945	2,020	1968	2,270
1946	2,210	1969	2,390
1947	2,880	1970	3,870
1948	2,330	1971	3,610
1949	2,690	1972	3,270
1950	1,990	1973	3,250
1951	2,940	1974	2,910
1952	2,950	1975	3,430
1953	2,010		
1954	905		
Average for 44 Years of Record	2,270		

[1] United States Geological Survey, 1954, 64b, 66, 67, 68, 69b, 70b, 71, 72, 73b, 74, and 75.

TABLE B4-5: Yearly Diversions by the Homestake Project Facilities.

Water Year	Homestake Tunnel Diversions From the Eagle River Subbasin, Colorado River Basin to the Arkansas River-Mountains Subbasin, Arkansas River Basin (AC.FT)[1]	Homestake Pipeline Diversions From the Arkansas River-Mountains Subbasin, Arkansas River Basin (AC.FT)		
		To the South Platte River-Mountains Subbasin, South Platte River Basin (turn outs through the Aurora-Homestake Pipeline)[1]	To Below the Arkansas River-Mountains Subbasin in the Arkansas River Drainage[2]	Total[3]
1966*	--	--	545	545
1967**	4,420	2,140	6,543	8,683
1968	20,370	8,420	7,628	16,048
1969	30,770	8,020	1,045	9,065
1970	23,010	3,370	19,452	22,822
1971	45,230	2,240	21,812	24,052
1972	17,280	6,360	24,997	31,357
1973	23,400	6,570	10,910	17,480
1974	25,030	10,790	13,553	24,343
1975	59,870	8,880	23,355	32,235
1968-75 Average Annual Diversions	30,620	6,831	15,344	22,175

[1] United States Geological Survey, 1967, 68, 69c, 70b, 71, 72, 73b, 74, and 75.

[2] By subtracting Column 4 minus Column 2.

[3] Miskel, 1976.

* Homestake Pipeline diversions began in 1966.

** Homestake Tunnel diversions began in June 1967. Turnouts from the Homestake Pipeline through the Aurora-Homestake Pipeline began on August 24, 1967.

TABLE B4-6: Yearly Transbasin Diversions through the Busk-Ivanhoe Tunnel from the Roaring Fork Drainage of the Colorado River to the Arkansas River-Mountains Subbasin, Arkansas River Basin.

Water Year	Acre-Feet[1]	Water Year	Acre-Feet[1]
1925	1,610	1951	5,130
1926	4,190	1952	6,340
1927	5,760	1953	5,080
1928	4,650	1954	3,200
1929	6,640	1955	5,270
1930	5,280	1956	4,400
1931	2,960	1957	5,510
1932	6,370	1958	2,650
1933	5,200	1959	5,180
1934	3,470	1960	5,310
1935	5,010	1961	4,950
1936	7,070	1962	7,240
1937	5,350	1963	3,700
1938	5,540	1964	5,470
1939	5,320	1965	5,870
1940	4,020	1966	3,880
1941	3,810	1967	4,830
1942	823	1968	7,130
1943	4,850	1969	6,750
1944	2,100	1970	7,910
1945	4,900	1971	7,460
1946	4,640	1972	6,720
1947	1,440	1973	6,320
1948	1,000	1974	5,680
1949	4,300	1975	7,100
1950	3,410		
Average for 51 Years of Record	4,878		

[1] United States Geological Survey, 1954, 64b, 66, 67, 68, 69b, 69c, 70b, 71, 72, 73b, 74, and 75.

TABLE B4-7: Yearly Transbasin Diversions through the Charles H. Boustead Tunnel from the Roaring Fork Drainage of the Colorado River to the Arkansas River-Mountains Subbasin, Arkansas River Basin.

Water Year	Acre-Feet
1972	32,070
1973	36,580
1974	33,830
1975	36,870
Average for 4 Years of Record	34,837

[1] United States Geological Survey, 72, 73b, 74, and 75.

TABLE B4-8: Yearly Transbasin Diversions through the Twin Lakes Tunnel from the Roaring Fork Drainage of the Colorado River to the Arkansas River-Mountains Subbasin, Arkansas River Basin.

Water Year	Acre-Feet[1]	Water Year	Acre-Feet[1]
1935	18,020	1956	36,440
1936	24,240	1957	32,740
1937	31,920	1958	24,030
1938	45,460	1959	40,420
1939	37,060	1960	41,920
1940	27,040	1961	36,050
1941	36,090	1962	57,970
1942	13,400	1963	31,940
1943	48,020	1964	41,660
1944	37,730	1965	45,720
1945	44,780	1966	38,490
1946	39,320	1967	47,550
1947	37,310	1968	49,860
1948	25,030	1969	50,570
1949	38,190	1970	62,020
1950	34,880	1971	51,660
1951	44,920	1972	43,710
1952	51,360	1973	55,900
1953	40,300	1974	43,490
1954	27,470	1975	49,540
1955	35,060		
Average of 41 Years of Record	39,495		

[1] United States Geological Survey 1954, 64b, 66, 67, 68, 69b, 69c, 70b, 71, 72, 73b, 74, and 75.

APPENDIX C

STREAM FLOW GAGING RECORDS OF THE UNITED STATES GEOLOGICAL SURVEY FOR THE SOUTH PLATTE AND ADJACENT RIVER BASINS

SECTION C1 - Gaging stations in the North Platte River Basin

Table C1-1: USGS #06620000, "North Platte River near Northgate, Colorado."
Table C1-2: USGS #06658500, "Laramie River near Jelm, Wyoming."

SECTION C2 - Gaging stations in the Colorado River Basin

Table C2-1: USGS #09034500, "Colorado River at Hot Sulphur Springs, Colorado."
Table C2-2: USGS #340, "Fraser River at Granby, Colorado."
Table C2-3: USGS #09037500, "Williams Fork near Parshall, Colorado."
Table C2-4: USGS #09053500, "Blue River above Green Mountain Reservoir, Colorado."
Table C2-5: USGS #09059500, "Piney River near State Bridge, Colorado."
Table C2-6: USGS #090700000, "Eagle River below Gypsum, Colorado."
Table C2-7: USGS #09253000, "Little Snake River near Slater, Colorado."

SECTION C3 - Gaging stations in the Arkansas River Basin

Table C3-1: USGS #07087200, "Arkansas River at Buena Vista, Colorado."

SECTION C4 - Gaging stations in the South Platte River Basin

Table C4-1: USGS #06707000, "North Fork South Platte River at South Platte, Colorado."
Table C4-2: USGS #06707500, "South Platte at South Platte, Colorado."
Table C4-3: USGS #06708000, "South Platte at Waterton, Colorado."
Table C4-4: USGS #06710500, "Bear Creek at Morrison, Colorado."
Table C4-5: USGS #7110, "Turkey Creek near Morrison, Colorado."
Table C4-6: USGS #06711500, "Bear Creek at mouth, near Sheridan, Colorado."
Table C4-7: USGS #06709500, "Plum Creek near Louviers, Colorado."
Table C4-8: USGS #06713000, "Cherry Creek below Cherry Creek Lake, Colorado."
Table C4-9: USGS #6-7135, "Cherry Creek at Denver, Colorado."
Table C4-10: USGS #06719505, "Clear Creek at Golden, Colorado."
Table C4-11: USGS #06720000, "Clear Chreek at mouth, near Denlay, Colorado."
Table C4-12: USGS #06729500, "South Boulder Creek near Eldorado Springs, Colorado."

INTRODUCTION

Contained within this appendix is information about, and the yearly runnoff records of, selected gaging stations within the North Platte, Colorado, Arkansas, and South Platte River Basins.

The discharge measurements of these gaging stations were used in determining the drought condition, the 1970, and the long term average annual native surface water runoff of the subbasins within these river basins.

For each gaging station the following is given; location, drainage area, period of record, type of gage, extremes of record, accuracy, remarks on upstream water resource development, and the yearly recorded runoff.

The accuracy of the gaging stations discharge measurements is given as, "Excellent," "Good," "Fair," or "Poor." Table C-1 explains these ratings.

TABLE C-1: Accuracy ratins of the gaging stations discharge measurements.

Ratings	Explanation: 95% of the daily discharge measurements are within this percent of actual
Excellent	5
Good	10
Fair	15
Poor	greater than 15

SECTION C1

GAGING STATIONS IN THE NORTH PLATTE RIVER BASIN

TABLE C1-1: USGS Gaging Station #06620000, "North Platte River near Northgate, Colorado."[1]

Location: Lat 40° 57'10" long 106°20'21" in SW¼SW¼ sec. 11, T.11 N., R.80 W., Jackson County, on right bank 350 ft downstream from bridge on State Highway 125, 0.8 mi upstream from Camp Creek, 4.2 mi northwest of Northgate, and 4.4 mi south of Colorado-Wyoming State Line.

Drainage Area: 1,431 Square miles

Period of Record: May to November 1904 (published as "Near Pinkhampton"), May 1915 to current year. Monthly discharge only for some periods.

Gage: Water stage recorder. Datum of gage is 7810.39 ft above mean sea level. May 11 to Nov. 9, 1904, staff gage near present site at different datum. Apr. 30, 1915, to May 12, 1916 staff gage, May 13, 1916, to Sept. 17, 1917, chain gage, Sept. 18, 1917, to Apr. 7, 1918, staff gage, and Apr. 8, 1918 to Aug. 21, 1961, water stage recorder, at site 0.8 miles downstream at datum 3.36 ft lower.

Extremes: Maximum discharge, 6,720 cfs, June 11, 1923. Minimum daily discharge, 19 cfs, July 11-19, 1934.

Accuracy: Records are generally good, except those for winter periods which are poor.

Remarks: Natural flow of stream affected by transbasin diversions exporting surface flows, several small storage reservoirs, and diversions above the station for the irrigation of about 130,000 acres of hay meadows.

Yearly Runoff:

Water Year	Acre-Feet
1904	-
1905	-
1915	-
1916	367,000
1917	636,000
1918	416,000
1919	197,000
1920	469,000
1921	496,000
1922	263,000
1923	508,000
1924	383,000
1925	298,000
1926	505,000
1927	394,000

(continued)

TABLE C1-1: (continued)

Water Year	Acre-Feet
1928	474,000
1929	506,000
1930	318,000
1931	173,000
1932	429,000
1933	256,000
1934	89,100
1935	200,800
1936	332,100
1937	215,300
1938	400,300
1939	204,700
1940	155,300
1941	188,000
1942	240,700
1943	287,100
1944	184,000
1945	322,400
1946	231,300
1947	313,500
1948	275,000
1949	403,800
1950	242,400
1951	327,000
1952	493,600
1953	197,400
1954	105,000
1955	161,200
1956	271,500
1957	563,200
1958	273,800
1959	219,400
1960	273,600
1961	233,600
1962	522,400
1963	182,800
1964	174,000
1965	411,100
1966	162,400
1967	274,300
1968	288,900
1969	287,100
1970	386,000
1971	400,500
1972	237,300
1973	405,800

(continued)

TABLE Cl-1: (continued)

Water Year	Acre-Feet
1974	417,000
1975	304,600
Average for 60 years of record	315,755

- Flows were not recorded for the entire water year.

[1]United States Geological Survey, 1958, 64a, 69a, 71, 72, 73a, 73b, 74, and 75.

TABLE C1-2: USGS Gaging Station #06658500, "Laramie River near Jelm, Colorado."[1]

Location: Lat 41°00'08", long 106°00'51", in SE¼SE¼ sec. 15, T.12 N., R.77 W., Albany County, on right bank 35 ft downstream from bridge on county road, 0.2 mile north of Colorado-Wyoming State line, 0.5 mile upstream from Johnson Creek, and 4 miles south of Jelm.

Drainage Area: 294 Square miles

Period of Record: June 1904 to October 1905, October 1910 to Sept. 1971 (discontinued). Monthly discharge only for some periods.

Gage: Water-stage recorder. Datum of gage is 7,683.36 ft above mean sea level. June 22, 1904, to Oct. 31, 1905, nonrecording gage at site 0.8 mile upstream at different datum. May 7 to July 13, 1911, nonrecording gage and July 14, 1911, to Sept. 3, 1921, water-stage recorder, on downstream side of bridge 35 ft upstream at present datum.

Extremes: Maximum discharge, 1930 cfs, June 9, 1923. Minimum recorded discharge, 5.6 cfs, December 2, 1933.

Accuracy: Records are generally good, except those for winter periods which are poor.

Remarks: Natural flow of stream affected by transbasin diversions exporting surface flows, several small storage reservoirs, and diversions above the gaging station for the irrigation of about 4,520 acres of land above the station and for about 120 acres below.

Yearly-runoff

Water Year	Acre-Feet
1904	-
1905	133,000
1906	-
1911	125,000
1912	190,000
1913	101,000
1914	187,000
1915	84,000
1916	125,000
1917	246,000
1918	149,000
1919	76,200
1920	165,000
1921	171,100

(continued)

TABLE C1-2: (continued)

Water Year	Acre-Feet
1922	182,900
1923	165,000
1924	140,000
1925	a89,200
1926	166,000
1927	115,000
1928	155,000
1929	157,000
1930	94,100
1931	76,100
1932	115,000
1933	115,000
1934	40,770
1935	102,400
1936	99,930
1937	84,450
1938	139,800
1939	74,860
1940	84,860
1941	92,370
1942	117,300
1943	117,100
1944	77,140
1945	112,100
1946	107,700
1947	135,600
1948	102,000
1949	125,200
1950	88,630
1951	138,700
1952	138,600
1953	60,830
1954	44,180
1955	61,390
1956	109,200
1957	179,700
1958	99,020
1959	96,260
1960	96,440
1961	107,600
1962	168,600
1963	63,000
1964	87,260
1965	133,600
1966	66,090
1967	110,700
1968	115,600

(continued)

TABLE C1-2: (continued)

Water Year	Acre-Feet
1969	101,200
1970	145,600
1971	156,800
Average for 62 years of record	116,227

- Flows were not recorded for the entire water year.

[1]United States Geological Survey, 1958, 64a, 69a, 71, and 73a.

SECTION C2

GAGING STATIONS IN THE COLORADO RIVER BASIN

TABLE C2-1: USGS Gaging Station #09034500, "Colorado River at Hot Sulphur Springs, Colorado."[1]

Location: Lat 40°05'00", Long 106°05'15", in NE¼NE¼ Sec. 2, T.1N., R.78W, Grand County on left bank about 1,000 ft north of U.S. Highway 40, 1 mile north east of Hot Sulphur Springs, 4.5 miles upstream from Beaver Creek, and approximately 5.5 miles downstream from the Fraser River Confluence.

Drainage Area: 825 Square miles

Period of Record: July 1904 to current year. Monthly discharge only for some periods. Prior to 1907 and 1914-18 published as Grand River at Hot Sulphur Springs and as Grand River at Sulphur Springs 1907-13.

Gage: Water-stage recorder. Altitude of gage is 7,670 ft (from railroad elevations). July 28, 1904, to Apr. 16, 1906, staff gage on bridge 1.7 miles downstream at different datum. Apr. 17, 1906, to Sept. 18, 1930, chain gage at bridge 1.4 miles downstream at datum 7,651.26 ft above mean sea level, unadjusted. Supplemental staff gage at different datum at site 1.7 miles downstream, used for winter records.

Extremes: Maximum discharge observed, 10,300 cfs, June 15, 1921; minimum daily 33 cfs, Sept. 27, 1956.

Accuracy: Generally, records are good, except those for winter periods which are fair.

Remarks: Natural flow of stream affected by transbasin diversions exporting surface flows, storage reserviors, and diversions above station for irrigation of about 13,000 acres.

Yearly Runoff:

Water Year	Acre-Feet
1904	-
1905	561,800
1906	565,900
1907	720,400
1908	343,100
1909	691,600
1910	341,800
1911	497,300
1912	672,300
1913	407,200
1914	719,700
1915	423,900
1916	468,800

(continued)

TABLE C2-1: (continued)

Water Year	Acre-Feet
1917	675,200
1918	639,400
1919	360,600
1920	692,000
1921	697,800
1922	375,400
1923	538,400
1924	506,600
1925	400,200
1926	656,200
1927	521,200
1928	596,600
1929	561,000
1930	460,600
1931	334,300
1932	462,400
1933	465,800
1934	254,500
1935	397,300
1936	549,500
1937	320,700
1938	562,900
1939	353,000
1940	293,100
1941	358,300
1942	434,100
1943	376,500
1944	334,000
1945	388,500
1946	306,300
1947	498,200
1948	372,800
1949	478,000
1950	155,900
1951	219,600
1952	345,600
1953	164,200
1954	80,370
1955	103,100
1956	142,300
1957	282,700
1958	220,800
1959	124,200
1960	160,600
1961	102,000
1962	356,000
1963	87,700
1964	95,620

(continued)

TABLE C2-1: (continued)

Water Year	Acre-Feet
1965	182,800
1966	93,320
1967	131,000
1968	110,100
1969	169,700
1970	224,300
1971	310,200
1972	131,000
1973	237,800
1974	260,600
1975*	NA

Average annual runoff for the period of record is relatively meaningless due to the changes in water resources development within this gaging station's drainage area.

- Flows were not recorded for the entire water year.
*-Records not published as of the date of this study.
[1]United States Geological Survey, 1954, 64b, 66, 67, 68, 69c, 70a, 70b, 71, 72, 73b, and 74.

TABLE C2-2: USGS Gaging Station #340, "Fraser River at Granby, Colorado."[1]

Location: Lat 40°05'00", Long 105°56'50", in Sec. 1, T.1N., R.76½W., on left bank just downstream from Tenmile Creek, half a mile southwest of Granby and 2 ½ miles upstream from the Fraser River Confluence with the mainstem of the Colorado River.

Drainage Area: 285 Square miles

Period of Record: July 1904 to September 1909, Sept. 1937 to Dec. 1955, (discontinued). Published as "near Conlter" in 1904.

Gage: Water-stage recorder. Altitude of gage is 7,900 ft (from topographic map). July 28, 1904, to Sept. 30, 1909, staff gage at former bridge near present site at different datum.

Extremes: Maximum discharge, 2,500 cfs, June 8, 1952; minimum daily discharge 5.8 cfs, Aug. 31, Sept. 1, 1954.

Accuracy: Not available.

Remarks: Natural flow of stream affected by transbasin diversions exporting surface flows and diversions above the gaging station for the irrigation of about 6,500 acres above the station and for about 1,500 acres below.

Yearly Runoff:

Water Year	Acre-Feet
1904	-
1905	136,900
1906	163,400
1907	193,600
1908	95,910
1909	198,400
1938	151,800
1939	89,060
1940	66,890
1941	92,260
1942	149,200
1943	113,000
1944	100,000
1945	102,100
1946	90,710
1947	157,300
1948	111,600
1949	138,600
1950	88,120
1951	170,800

(continued)

TABLE C2-2: (continued)

Water Year	Acre-Feet
1952	202,100
1953	121,900
1954	53,430
1955	91,110
1956	-
Average for 23 years of record	125,147

- Flows were not recorded for the entire water year.

[1]United States Geological Survey, 1954, and 64b.

TABLE C2-3: USGS Gaging Station #09037500, "Williams Fork near Parshall, Colorado."[1]

Location: Lat 40°00'01", long 106°10'45", in SW¼SW¼ Sec. 31, T.1N., R.78W., Grand County on right bank 150 ft downstream from bridge on State Highway 286, 3.7 miles downstream from Skylark Creek, 3.9 miles south of Parshall, 4.2 miles upstream from Williams Fork Reservoir Dam, and 6.3 miles upstream from William Fork Rivers Confluence within the main stem of the Colorado River.

Drainage Area: 184 Square miles

Period of Record: July 1904 to Sept. 1924, June 1933 to current year. Published as "near (Hot) Sulphur Springs" 1904-12 and as Williams River near Parshall June 1933 to Sept. 1958.

Gage: Water storage recorder. Datum of gage is 7,808.95 ft above mean sea level (datum of Denver Board of Water Commissioners). Prior to Oct. 18, 1919 state gage and Oct. 18, 1919 to Sept. 20, 1924 waterstage recorder, at site ½ miles downstream at different datum. June 19, 1933 to Aug. 8, 1938, water stage recorder at bridge 150 ft upstream at datum 1.00 ft higher.

Extremes: Maximum discharge observed, 2,620 cfs, June 14, 1918; minimum daily, 4.8 cfs, May 6, 8-10, 1972.

Accuracy: Generally, records are good, except those for winter periods which are poor.

Remarks: Natural flow of stream affected by a transbasin diversion structure exporting surface flows and by diversions above the station for the irrigation of about 1,300 acres of land. About 150 acres of land above the station are irrigated by diversions into the drainage area.

Yearly Runoff:

Water Year	Acre-Feet
1904	-
1905	99,170
1906	122,100
1907	141,300
1908	88,270
1909	144,600
1910	96,260
1911	100,700
1912	163,000
1913	108,500
1914	166,600

(continued)

TABLE C2-3: (continued)

Water Year	Acre-Feet
1915	122,100
1916	116,900
1917	156,500
1918	164,200
1919	96,030
1920	148,100
1921	159,400
1922	99,050
1923	121,700
1924	116,500
1933	-
1934	61,310
1935	97,020
1936	124,400
1937	77,110
1938	134,000
1939	90,450
1940	60,270
1941	75,880
1942	97,530
1943	89,070
1944	77,810
1945	86,500
1946	83,910
1947	128,000
1948	89,360
1949	110,200
1950	73,420
1951	108,400
1952	150,300
1953	82,450
1954	30,320
1955	46,730
1956	68,510
1957	125,800
1958	93,240
1959	68,050
1960	84,300
1961	58,550
1962	134,700
1963	28,120
1964	42,060
1965	90,680
1966	36,720
1967	63,260
1968	66,730
1969	69,060
1970	103,700

(continued)

TABLE C2-3: (continued)

Water Year	Acre-Feet
1971	111,300
1972	60,830
1973	94,700
1974	103,800
1975*	NA
Average for 61 years of record	98,203

- Flows were not recorded for the entire water year.
*-Records not published as of the date of this study.
[1]United States Geological Survey, 1954, 64b, 66, 67, 68, 69c, 70a, 71, 72, 73b, and 74.

TABLE C2-4: USGS Gaging Station #09053500, "Blue River above Green Mountain Reservoir, Colorado."[1]

Location: Lat 39°45'55", Long 106°13'20", in S¼ Sec. 34, T.2S., R.79W., Summit County, on left bank 300 ft north of old State Highway 9, just upstream of high-water line of Green Mountain Reservoir, 1.3 miles downstream from Bengh Creek, 18 miles southeast of Kremmling, and approximately 18 miles upstream from the Blue River Confluence with the mainstem of the Colorado River.

Drainage Area: 511 Square miles

Period of Record: October 1943 to Sept. 1971 (discontinued)

Gage: Water stage records. Datum of gage is 7,946.56 ft above mean sea level.

Extremes: Maximum discharge 5,020 cfs, June 11, 1952. Minimum daily prior to flow regulation by Dillon Reservoir (approximately 20 miles upstream) which began Sept. 3, 1963, 64 cfs, March 15, 1957. Minimum daily since Sept. 3, 1963, 33 cfs Oct. 20, 1963.

Accuracy: Generally, records are Good, except those for winter periods which are fair.

Remarks: Natural flow of stream affected by transbasin diversion structures exporting surface flows, Dillon Reservoir, and many small diversions for the irrigation of about 4,000 acres of hay meadows above the station. One small diversion structure imports water above the station from the Eagle River drainage for mining development.

Yearly Runoff:

Water Year	Acre-Feet
1944	252,900
1945	312,900
1946	299,800
1947	424,500
1948	345,100
1949	360,300
1950	298,800
1951	438,400
1952	415,400
1953	320,300
1954	170,700
1955	229,800
1956	323,800
1957	436,100

(continued)

TABLE C2-4: (continued)

Water Year	Acre-Feet
1958	310,900
1959	270,100
1960	290,400
1961	237,700
1962	364,000
1963	177,000
1964	127,000
1965	200,400
1966	185,400
1967	186,200
1968	218,900
1969	247,300
1970	368,100
1971	343,300

Average annual runoff for the period of record is relatively meaningless due to changes in water resources development within the gaging stations drainage.

[1]United States Geological Survey, 1954, 64b, 66, 67, 68, 69c, 70a, 70b, and 71.

TABLE C2-5: USGS Gaging Station #09059500, "Piney River near State Bridge, Colorado."[1]

Location: Lat 39°48'00", Long 106°35'00", in Sect. 16, T.35., R.85W; Eagle County, on left bank at downstream side of private bridge at Perry Olsen Ranch just downstream from Rock Creek, 6.0 miles southeast of State Bridge, and approximately 5 miles upstream from the Pinez Rivers Confluence with the mainstem of the Colorado River.

Drainage Area: 86.2 Square miles

Period of Record: May 1944 to current year.

Gage: Water-stage recorder. Datum of gage is 7,272.35 ft above mean sea level, unadjusted. Prior to Jyly 29, 1944, staff gage and July 29, 1944, to Oct. 24, 1947, water-stage recorder, at datum 2.38 ft higher.

Extremes: Maximum discharge 1,110 cfs, June 8, 1952; minimum daily 1.9 cfs, Sept. 1, 18, 19, 1954.

Accuracy: Generally, records are good, except for those of no gage height which are poor.

Remarks: Natural flow of stream affected by diversions above station for the irrigation of about 400 acres of land.

Yearly Runoff:

Water Year	Acre-Feet
1944	-
1945	54,700
1946	49,390
1947	69,101
1948	62,550
1949	58,420
1950	45,280
1951	56,370
1952	73,760
1953	45,620
1954	21,990
1955	38,920
1956	47,230
1957	81,080
1958	63,360
1959	47,800
1960	53,360
1961	35,120
1962	83,980
1963	26,640
1964	39,070

(continued)

TABLE C2-5: (continued)

Water Year	Acre-Feet
1965	74,620
1966	40,360
1967	47,070
1968	51,780
1969	51,490
1970	64,840
1971	67,720
1972	52,510
1973	73,120
1974	61,330
1975*	NA
Average for 30 years of record	54,616

- Flows were not recorded for the entire water year.
*-Records not published as of the date of this study.
[1]United States Geological Survey, 1954, 64b, 66, 67, 68, 69c, 70a, 70b, 71, 72, 73b, and 74.

TABLE C2-6: USGS Gaging Station #09070000, "Eagle River below Gypsum, Colorado."[1]

Location: Lat 39°38'58", Long 106°57'11", in SW NW Sec. 5, T.5S., R.85W., Eagle County, on right bank 30 ft downstream from bridge on U.S. Highways 6 and 24 at Gypsum, 150 ft downstream from Gypsum Creek and approximately 7 miles upstream from the Eagle River Confluence with the mainstem of the Colorado River.

Drainage Area: 944 Square miles

Period of Record: October 1946 to current year.

Gage: Water-stage recorder. Altitude of gage is 6,275 ft from topographic map.

Extremes: Maximum discharge, 6,580 cfs, June 11, 1952; minimum daily discharge, 110 cfs, Feb. 21, 1955, Feb. 3, 1956, Dec. 26, 27, 1962.

Accuracy: Generally, records are good.

Remarks: Natural flow of stream affected by transbasin diversions exporting surface flows and many small diversions for the irrigation of approximately 17,000 acres (estimated from landuse maps published by the U.S. Soil Conservation Service).

Yearly Runoff:

Water Year	Acre-Feet
1947	547,800
1948	475,700
1949	460,200
1950	396,300
1951	464,200
1952	560,700
1953	402,900
1954	221,100
1955	292,300
1956	391,600
1957	622,900
1958	430,200
1959	366,100
1960	406,900
1961	295,700
1962	563,800
1963	258,100
1964	310,100
1965	522,900

(continued)

TABLE C2-6: (continued)

Water Year	Acre-Feet
1966	285,100
1967	315,900
1968	368,900
1969	361,500
1970	477,000
1971	456,100
1972	364,200
1973	454,400
1974	441,100
1975*	NA
Average for 28 years of record	411,918

*-Records not published as of the date of this study.
[1]United States Geological Survey, 1954, 64b, 66, 67, 68, 69c, 70g, 70b, 71, 72, 73b, and 74.

TABLE C2-7: USGS Gaging Station #09253000, "Little Snake River near Slater, Colorado."[1]

Location: Lat 40°59'58", Long 107°08'34", in SW¼NW¼ Sec. 15, T.12N., R.87W., Routt County, on left bank just downstream from highway bridge at Focus Ranch, 0.2 miles downstream from Spring Creek and 12 mi east of Slater.

Drainage Area: 285 Square miles

Period of Record: October 1942 to September 1947, October 1950 to current year.

Gage: Water-stage recorder. Datum of gage is 6,831.00 ft above mean sea level.

Extremes: Maximum discharge, 4,180 cfs, April 25, 1974; minimum daily, 8.6 cfs, Sept. 10, 1944.

Accuracy: Generally, records are good, except for those during winter periods and periods of no gage heights which are poor.

Remarks: Natural flow of stream affected by a transbasin diversion structure exporting surface flows and by diversions for the irrigation of about 2,000 acres of land.

Yearly Runoff:

Water Year	Acre-Feet
1943	155,000
1944	145,800
1945	200,200
1946	152,000
1947	178,400
1951	153,100
1952	226,600
1953	113,000
1954	75,600
1955	114,600
1956	173,400
1957	229,600
1958	188,200
1959	100,500
1960	139,800
1961	103,300
1962	218,800
1963	97,140
1964	151,700
1965	189,600
1966	103,600
1967	144,800

(continued)

TABLE C2-7: (continued)

Water Year	Acre-Feet
1968	185,900
1969	149,800
1970	207,700
1971	248,300
1972	147,700
1973	171,900
1974	279,000
1975*	NA
Average for 29 years of record	163,636

*-Records not published as of the date of this study.
[1]United States Geological Survey, 1954, 64b, 66, 67, 68, 69c, 70b, 70c, 71, 72, 73b, and 74.

SECTION C3

GAGING STATIONS IN THE ARKANSAS RIVER BASIN

TABLE C3-1: USGS Gagning Station #07087200, "Arkansas River at Buena Vista, Colorado."[1]

Location: Lat 38°50'56", long 106°07'27", in NW¼NW¼ Sec. 9, T.14S, R.78W., Chaffee County, on right bank of northeast corner of Buena Vista City limits and 1.1 miles upstream from Cottonwood Creek.

Drainage Area: 611 square miles

Period of Record: October 1964 to current year.

Gage: Water-stage recorder. Altitude of gage is 7,920 ft from topographic map.

Extremes: Maximum discharge, 3,640 cfs, July 13, 1965. Minimum daily 60 cfs, January 10, 11, 1975.

Accuracy: Generally, records are good, except those for winter periods which are poor.

Remarks: Natural flow of stream affected by transbasin diversions exporting and importing water, storage reservoirs, and diversions for the irrigation of about 7,400 acres of irrigated land.

Yearly Runoff:

Water Year	Acre-Feet
1965	446,300
1966	331,300
1967	310,000
1968	351,900
1969	356,200
1970	453,300
1971	396,100
1972	375,700
1973	384,600
1974	365,900
1975	394,400
Average of 11 years of record	378,700

[1]United States Geological Survey, 1966, 67, 68, 69b, 69c, 70b, 71, 72, 73b, 74, and 75.

SECTION C4

GAGING STATIONS IN THE SOUTH PLATTE RIVER BASIN

TABLE C4-1: USGS Gaging Station #06707000, "North Fork South Platte River at South Platte, Colorado."[1]

Location: Lat 39°24'32", long 105°10'31", in SW¼ sec. 25, T.7S., R.70W., Jefferson County, on left bank 0.2 miles west of South Platte and 0.3 miles upstream from mouth.

Drainage Area: 479 Square miles

Period of Record: June 1909 to September 1910, April 1913 to current year. Monthly discharge only for some periods.

Gage: Water-stage recorder. Datum of gage is 6,090.55 ft above mean sea level, adjustment of 1912. Prior to May 13, 1925, non-recording gage at same site and datum.

Extremes: Maximum discharge, 2,050 cfs, June 13, 1949. Minimum observed, 4.0 cfs, Dec. 8, 1932.

Accuracy: Generally, records are good, except for those during winter periods and periods of indefinite stage-discharge relation which are poor.

Remarks: Small diversions above station for minor irrigation. Trans-basin diversion from the Blue River subbasin of the Colorado River Basin above station through Harold D. Roberts Tunnel since 1964.

Yearly Runoff:

Water Year	Acre-Feet
1908	-
1909	96,600
1913	-
1914	247,000
1915	133,000
1916	99,900
1917	137,000
1918	135,000
1919	131,000
1920	146,000
1921	223,000
1922	111,000
1923	166,000
1924	158,000
1925	58,600
1926	165,000
1927	94,300
1928	112,000

(continued)

TABLE C4-1: (continued)

Water Year	Acre-Feet
1929	86,800
1930	119,000
1931	95,200
1932	79,000
1933	131,000
1934	65,300
1935	88,370
1936	138,800
1937	85,630
1938	161,200
1939	103,000
1940	50,130
1941	122,800
1942	192,700
1943	83,370
1944	105,400
1945	106,800
1946	73,970
1947	139,600
1948	135,800
1949	166,900
1950	62,740
1961	94,100
1952	110,500
1953	74,380
1954	42,280
1955	63,790
1956	76,700
1957	162,900
1958	99,150
1959	70,900
1960	90,420
1961	95,480
1962	106,900
1963	40,650
1964*	81,490
1965	181,200
1966	86,210
1967	122,100
1968	129,600
1969	195,800
1970	209,300
1971	129,900
1972	124,900
1973	174,900

(continued)

TABLE C4-1: (continued)

Water Year	Acre-Feet
1974	124,600
1975	158,100
Average for 63 years of record	118,366

- Flows were not recorded for the entire water years.
*-Harold D. Roberts Tunnel began diversions from the Colorado River Basin, Blue River Subbasin on October 1, 1963.
[1]USGS, 1958, 64a, 69a, 71, 72, 73a, 75b, 74, and 75.

TABLE C4-2: USGS Gaging Station #06707500, "South Platte at South Platte, Colorado."[1]

Location: Lat 39°24'33", long 105°10'10", in SE¼ sec. 25, T.7S, R.70W., Jefferson County, on left bank at South Platte, 200 ft downstream from bridge on State Highway 75 and 400 ft downstream from North Fork.

Drainage Area: 2,579 Square miles

Period of Record: July 1887 to September 1891, May to October 1892, October 1895 to September 1897, October 1898 to June 1900, October 1900 to current year. Monthly discharge only for some periods. Published as "at" or "near Deansbury," "at Deansbury and Platte Canyon," "at" or "near Platte Canyon," prior to 1901, and as "below North Fork, at South Platte" 1914.

Gage: Water-stage recorder. Datum of gage is 6,078 .43 ft above mean sea level, adjustment of 1912. Prior to Mar. 28, 1902, staff gages or water-stage recorder at several sites less than 9 miles downstream at various datums. Mar. 28, 1902, to May 6, 1905, staff gage at bridge 200 ft upstream at different datum. May 7, 1905, to Mar. 13, 1910, staff gage at present site and datum.

Extremes: Maximum discharge, 6,320 cfs, June 8, 1921. Minimum daily determined, 10 cfs, Dec. 5, 1899.

Accuracy: Generally, records are good, except for those during winter periods which are poor.

Remarks: Diversions for irrigation of about 72,520 acres located above the station. Natural flow of stream affected by several large reservoirs, and several transbasin diversions, structures importing water from the Arkansas and Colorado River Basins.

Yearly Runoff:

Water Year	Acre-Feet
1887	-
1888	188,000
1889	147,000
1890	174,000
1891	290,000
1892	-
1893	-
1896	170,000
1897	266,000
1899	324,000
1900	-

(continued)

TABLE C4-2: (continued)

Water Year	Acre-Feet
1901	216,000
1902	85,900
1903	142,000
1904	192,000
1905	276,000
1906	245,000
1907	362,000
1908	138,000
1909	358,000
1910	263,000
1911	193,000
1912	295,000
1913	273,000
1914	650,000
1915	344,000
1916	250,000
1917	319,000
1918	298,000
1919	363,000
1920	312,000
1920	561,000
1922	289,000
1923	321,000
1924	388,000
1925	193,000
1926	341,000
1927	220,000
1928	245,000
1929	244,000
1930	301,000
1931	254,000
1932	191,000
1933	275,000
1934	157,800
1935	166,700
1936	292,600
1937	179,800
1938	286,500
1939	232,700
1940	125,000
1941	250,500
1942	608,100
1943	194,200
1944	229,100
1945	247,800
1946	194,300
1947	333,100
1948	396,400

(continued)

TABLE C4-2: (continued)

Water Year	Acre-Feet
1949	432,600
1950	173,200
1951	193,700
1952	214,100
1953	496,700
1954	464,500
1955	462,200
1956	152,000
1957	277,500
1958	255,800
1959	153,400
1960	190,100
1961	193,500
1962	276,500
1963	155,400
1964	201,200
1965	281,200
1966	190,400
1967	195,000
1968	231,100
1969	342,800
1970	558,800
1971	273,600
1972	238,300
1973	468,400
1974	263,700
1975	288,100
Average for 82 years of record	263,066

- Flows were not recorded for the entire water year.
[1]USGS, 1958, 64a, 69a, 71, 72, 73a, 73b, 74, 75.

TABLE C4-3: USGS Gaging Station #06708000, "South Platte at Waterton, Colorado."[1]

Location: Lat 39°29'18", long 105°05'32", in NE sec. 34, T.6S., R.69W., Jefferson County, on left bank 168 ft downstream from bridge on State Highway 221, 0.4 miles south of Waterton, 4.7 miles west of Louviers, and 6 miles upstream from Plum Creek.

Drainage Area: 2,621 Square miles

Period of Record: May 1926 to current year. Monthly discharge only prior to 1934.

Gage: Water-stage recorder. Datum of gage is 5,484.43 ft above mean sea level, adjustment of 1912.

Extremes: Maximum discharge, 5,700 ft^3/s, Apr. 31, 1942. Minimum daily, 0.1 ft^3/s, Mar. 6, 7, 1933, Feb. 28 to Mar. 20, 1938.

Accuracy: Generally, records are good except for those during winter periods which are fair.

Remarks: Diversions for irrigation of about 72,520 acres located above the station. Natural flow of stream affected by several large reservoirs, several transbasins diversion structures importing water from the Colorado and Arkansas River Basins and several diversion structures exporting water from the gaging stations drainage area.

Yearly Runoff:

Water Year	Acre-Feet
1926	-
1927	80,000
1928	94,800
1929	112,000
1930	143,000
1931	96,100
1932	83,700
1933	150,000
1934	64,860
1935	92,570
1936	174,500
1937	87,610
1938	147,300
1939	102,700
1940	41,530
1941	132,400
1942	513,900
1943	88,730
1944	112,400

(continued)

TABLE C4-3: (continued)

Water Year	Acre-Feet
1945	136,700
1946	77,690
1947	226,000
1948	276,000
1949	307,500
1950	56,970
1951	68,010
1952	87,920
1953	69,210
1954	44,330
1955	73,580
1956	65,940
1957	210,000
1958	160,300
1959	64,880
1960	101,400
1961	84,810
1962	153,000
1963	47,030
1964	74,240
1965	107,600
1966	68,010
1967	59,000
1968	86,960
1969	183,700
1970	383,900
1971	102,100
1972	70,860
1973	285,400
1974	61,240
1975	106,400

Average annual runoff for the period of record is relatively meaningless due to the changes in water resources development within the gaging stations drainage area.

- Flows were not recorded for the entire water year.
[1]USGS, 1958, 64a, 69a, 71, 72, 73a, 73b, 74, and 75.

TABLE C4-4: USGS Gaging Station #06710500, "Bear Creek at Morrison, Colorado."[1]

Location: Lat 39°39'11", long 105°11'43", in SE¼SW¼ sec. 35, T.4S., R.70W., Jefferson County, on left bank at Morrison, 180 ft upstream from bridge on U.S. Highway 285 and 0.2 miles upstream from Mount Vernon Creek.

Drainage Area: 164 Square miles

Period of Record: September 1887 to September 1891, May 1895 to December 1901, February 1902 (gage heights only), October 1919 to current year. No winter records for water years 1888-90, 1896, 1898, 1900. Monthly discharge only for some periods. Published as "near Morrison" 1900-1902, as "at Starbuck" 1919-28, and as "Idledale" 1929-34.

Gage: Water-stage recorder. Datum of gage ie 5,780.43 ft above mean sea level, datum of 1929. Prior to Apr. 1, 1899, staff gage at site a quarter of a mile downstream at different datum. Apr. 1, 1899, to Feb. 28, 1902, staff gage at site a quarter of a mile upstream at different datum. Oct. 1, 1919, to Feb. 28, 1921, staff gage, and Mar. 1, 1921, to Sept. 30, 1934, water stage recorder at site 4 miles upstream at different datum. Oct. 1, 1934 to Oct. 10, 1961, water stage recorder at site 80 ft downstream at same datum.

Extremes: Maximum discharge 8,600 cfs, estimated, July 24, 1896. Minimum daily, 0.8 cfs, Nov. 26, 1939, result of freezeup.

Accuracy: Records good except for those for winter periods which are fair.

Remarks: Small diversions for minor irrigation above station.

Yearly Runoff:

Water Year	Acre-Feet
1887	-
1888	-
1889	-
1890	-
1891	47,700
1895	-
1896	-
1897	52,700
1898	-
1899	35,800
1900	-

(continued)

TABLE C4-4: (continued)

Water Year	Acre-Feet
1901	30,100
1902	-
1920	46,100
1921	77,700
1922	33,500
1923	76,300
1924	65,500
1925	19,400
1926	84,800
1927	31,900
1928	39,900
1929	30,800
1930	32,900
1931	36,500
1932	18,900
1933	42,100
1934	20,540
1935	28,630
1936	45,560
1937	29,160
1938	69,320
1939	30,840
1940	13,640
1941	49,110
1942	90,490
1943	31,280
1944	46,410
1945	26,810
1946	21,460
1947	50,990
1948	44,040
1949	72,870
1950	16,060
1951	25,520
1952	38,220
1953	32,750
1954	10,550
1955	18,430
1956	16,670
1957	75,200
1958	36,910
1959	25,570
1960	32,180
1961	42,700
1962	28,670
1963	10,890
1964	19,010
1965	51,890

(continued)

TABLE C4-4: (continued)

Water Year	Acre-Feet
1966	17,320
1967	22,240
1968	25,740
1969	72,000
1970	66,420
1971	34,410
1972	20,380
1973	72,990
1974	29,030
1975	32,440
Average for 60 years of record	38,932

- Flows were not recorded for the entire water year.

[1]USGS, 1958, 64a, 69a, 71, 72, 73a, 73b, 74, 75.

TABLE C4-5: USGS Gaging Station #7110, "Turkey Creek near Morrison, Colorado."[1]

Location: Lat 39°38'10", long 105°10'05", in NE¼ sec. 12, T.5S., R.70W., on left bank at downstream side of county bridge, 2 miles upstream from mouth and 2 miles southeast of Morrison.

Drainage Area: 50.1 Square miles

Period of Record: June 1942 to September 1946, March 1947 to September 1953. (Discontinued)

Gage: Water-stage recorder. Datum of gage is 5,717.54 ft above mean sea level, datum of 1929 (levels by Corps of Engineers). Prior to Mar. 8, 1947, staff gage at same site and datum.

Extremes: Maximum discharge, 1,200 cfs Aut. 24, 1946. No flow at times.

Accuracy: Not available.

Remarks: Small diversions above station for irrigation. Spickerman ditch, which diverts from Bear Creek and Turkey Creek, wastes some water above station.

Yearly Runoff:

Water Year	Acre-Feet
1942	-
1943	1,260
1944	7,900
1945	503
1946	936
1947	-
1948	7,320
1949	6,460
1950	678
1951	726
1952	3,820
1953	1,190
Average for 10 years of record	3,079

- Flows were not recorded for the entire water year.
[1]USGS, 1958, 64a.

TABLE C4-6: USGS Gaging Station #06711500, "Bear Creek at mouth, near Sheridan, Colorado."[1]

Location: Lat 39°39'08", long 105°01'57", in NW¼NW¼ sec. 5, T.5S., R. 68W., Arapahoe County, on left bank just downstream from bridge on road to Fort Logan Mental Health Center, at Highway Department maintenance building at northwest city limits of Sheridan, 1.3 miles upstream from mouth, and 2.1 miles west of city hall in Englewood.

Drainage Area: 260 Square miles

Period of Record: April to November 1914, March 1927 to current year. Monthly discharge only prior to October 1933. Published as "at Sheridan Junction" 1934-41.

Gage: Water-stage recorder. Altitude of gage is 5,295 ft (from topographical map). Apr. 1 to Nov. 30, 1914, staff gage and Feb. 23, 1927, to June 18, 1932, water-stage recorder, at site 1 mile downstream at different datums. June 19, 1931, to Oct. 8, 1953, water-stage recorder at site 0.8 mile downstream at datum 5,282.72 ft above mean sea level, datum of 1929, prior to June 6, 1949, and at datum 6,280.72 ft. thereafter. Oct. 9, 1953 to Aug. 1969 water-stage recorder at present site at datum 1.0 ft higher.

Extremes: Maximum discharge, 8,150 cfs, May 7, 1969; no flow July 13, 1954.

Accuracy: Records good except those for winter period which are fair.

Remarks: Storage and diversions above station for Agricultural, Municipal, and Industrial uses.

Yearly Runoff:

Water Year	Acre-Feet
1914	-
1915	-
1927	-
1928	27,300
1929	10,100
1930	10,000
1931	15,300
1932	17,080
1933	32,900
1934	7,110
1935	11,570
1936	14,740
1937	13,930
1938	55,230

(continued)

TABLE C4-6: (continued)

Water Year	Acre-Feet
1939	21,480
1940	5,440
1941	30,560
1942	98,490
1943	15,800
1944	39,200
1945	14,740
1946	11,820
1947	49,950
1948	39,710
1949	60,530
1950	8,410
1951	9,880
1952	31,980
1953	8,500
1954	4,730
1955	6,480
1956	8,880
1957	64,520
1958	30,520
1959	14,800
1960	29,980
1961	37,870
1962	27,910
1963	5,220
1964	7,750
1965	46,220
1966	12,540
1967	14,090
1968	20,240
1969	80,930
1970	72,610
1971	38,230
1972	51,650
1973	96,640
1974	31,100
1975	32,250
Average for 48 years of record	28,103

- Flows were not recorded for the entire water year.
[1]USGS, 1958, 62a, 69a, 71, 72, 73a, 73b, 74 and 75.

TABLE C4-7: USGS Gaging Station #06709500, "Plum Creek near Louviers, Colorado."[1]

Location: Lat 39°29'04", long 105°00'07", in SE¼ sec. 33, T.6S, R.68W., Douglas County, on right bank at downstream side of bridge on county road from U.S. Highway 85 to Louviers, three-quarters of a mile northeast of Louviers, 1¼ miles downstream from Indian Creek, and 7½ miles upstream from mouth.

Drainage Area: 302 Square miles

Period of Record: October 1947 to current year.

Gage: Water-stage recorder. Altitude of gage is 5,585 ft (from topographical map). Prior to Feb. 12, 1957, at site 2½ miles downstream, prior to Oct. 1, 1954, at datum 5,518.71 ft above mean sea level, datum of 1929, and Oct. 1, 1954, to Feb. 11, 1957, at datum 5,517.19 ft above mean sea level, datum of 1929.

Extremes: Maximum discharge, 154,000 cfs, June 16, 1965, no flow at times in 1951-52, 1956-60, 1963-64.

Accuracy: Generally, records are poor.

Remarks: Diversions upstream for irrigation of about 1,700 acres (estimated from U.S. Soil Conservation Land Use Maps).

Yearly Runoff:

Water Year	Acre-Feet
1948	28,980
1949	19,610
1950	4,410
1951	4,340
1952	11,060
1953	9,100
1954	4,570
1955	8,490
1956	3,650
1957	34,660
1958	13,730
1959	18,070
1960	41,010
1961	27,600
1962	17,670
1963	3,040
1964	7,400
1965	47,500
1966	11,230
1967	11,620
1968	12,210

(continued)

TABLE C4-7: (continued)

Water Year	Acre-Feet
1969	31,420
1970	29,240
1971	22,790
1972	6,260
1973	86,590
1974	39,200
1975	21,000
Annual average for 28 years of record	20,589

[1]USGS, 1958, 64a, 69a, 70b, 71, 72, 73a, 73b, 74, 75.

TABLE C4-8: USGS Gaging Station #06713000, "Cherry Creek below Cherry Creek Lake, Colorado."[1]

Location: Lat 39°39'12", long 104°51'41", in SW¼SW¼ sec. 35, T.4S, R. 67W., Arapahoe County, on right bank 2,000 ft downstream from Cherry Creek Dam, 2.2 miles southeast of Sullivan, 9 miles southeast of Civic Center in Denver, and 11 miles upstream from mouth.

Drainage Area: 385 Square miles

Period of Record: June 1950 to current year.

Gage: Water-stage recorder and concrete control. Datum of gage is 5,490.51 ft above mean sea level, datum of 1929 (Corps of Engineers).

Extremes: Maximum discharge 1,440 cfs, July 31, 1956, no flow most of time since May, 1957. Maximum flood known, 34,000 cfs, Aug. 3, 1933, by slope-area measurement near present site, (Castlewood Dam failure).

Accuracy: Generally, records are good.

Remarks: Several diversions upstream for irrigation of about 3,038 acres (estimated from U.S. Soil Conservation Service Land Use Maps), Cherry Creek Lake 2,000 ft upstream, began flood flow regulation June 1950, (capacity 96,000 acre-feet) and began permanent storage on May 15, 1957.

Yearly Runoff:

Water Year	Acre-Feet
1950*	-
1951	2,510
1952	2,440
1953	1,990
1954	1,550
1955	2,640
1956	2,870
1957**	1,230
1958	615
1959	197
1960	7,990
1961	933
1962	2,800
1963	2,020
1964	1,690
1965	16,610
1966	1,160
1967	0

(continued)

TABLE C4-8: (continued)

Water Year	Acre-Feet
1968	0
1969	0
1970	940
1971	0
1972	0
1973	18,800
1974	11,950
1975	1,910
Average annual runnof since 1957 (18 years of record)	3,756

- Flows were not recorded for the entire water year.
* Cherry Creek Lake began flood flow regulation in June of 1950.
**Cherry Creek Lake began permanent storage on May 15, 1957.
[1]USGS, 1958, 64a, 69a, 70b, 71, 72, 73a, 73b, 74, 75.

TABLE C4-9: USGS Gaging Station #6-7135, "Cherry Creek at Denver, Colorado."[1]

Location: Lat 39°44'58", long 105°00'08", in NE¼ sec. 33, T.3S, R.68W., Denver County, on right bank on downstream side of Wazee Stree Bridge in Denver, 0.5 miles upstream from mouth.

Drainage Area: 409 Square miles

Period of Record: August 1942 to September 1969 (discontinued).

Gage: Water-stage recorder. Datum of gage is 5,175.48 feet above mean sea level. Prior to Jan. 23, 1945, wire-weight gage at Broadway Bridge 1.8 miles upstream at datum 57.29 ft higher. Jan. 23 to Feb. 26, 1945, wire-weigh gage at Downing Street Bridge 2.8 miles upstream from present site at different datum. Feb. 27, 1945, to Sept. 30, 1947, wire-weight gages at Washington Street Bridge 2.4 miles upstream from present site at datum 72.31 ft higher and Oct. 1, 1947, to Sept. 30, 1949, at datum 71.31 ft higher than present datum. Oct. 1, 1949, to July 15, 1951, wire-weight gage at Market Street Bridge 0.1 mile upstream from present site at datum 8.49 ft higher. July 16, 1951 to Sept. 30, 1964, water-stage recorder at present site at datum 0.86 ft higher.

Extremes: Maximum discharge observed (prior to flood flow regulation by Cherry Creek Lake which began in June, 1950), 3,120 cfs, Aug. 5, 1945. Minimum daily discharge, 0.4 cfs June 16-18, 1948. Flood of July 26, 1885, reached a discharge of 20,000 cfs, by float measurement. Flood of May 19, 20, 1964, reached a somewhat higher stage. Flood of Aug. 3, 1933, reached a discharge of about 15,000 cfs, as determined by rise of South Platte River at Denver (Castlewood Dam failure).

Accuracy: Generally, records are good.

Remarks: Several diversions above station for irrigation of about 3,038 acres (estimated from U.S. Soil Conservation Service Land Use Maps). Cherry Creek Lake, about 11 miles upstream, began flood flow regulation in June 1950 (capacity 96,000 acre-feet) and began permanent storage on May 15, 1957.

Yearly Runoff:

Water Year	Acre-Feet
1942	-
1943	14,440
1944	26,220
1945	21,650
1946	10,270
1947	26,480

(continued)

TABLE C4-9: (continued)

Water Year	Acre-Feet
1948	26,000
1949	9,920
1950†	8,010
1951	6,550
1952	11,330
1953	5,900
1954	4,360
1955	5,980
1956	6,560
1957*	6,360
1958	7,270
1959	5,900
1960	12,680
1961	8,890
1962	10,080
1963	8,980
1964	7,290
1965	24,330
1966	8,360
1967	9,090
1968	7,360
1969**	11,400
Average annual runoff prior to 1957	13,276
Average annual runoff since 1957	10,136

- Flows were not recorded for the entire water year.
* Cherry Creek Lake began permanent storage on May 15, 1957.
**Gaging station discontinued September 1969.
† Cherry Creek Lake began flood flow regulation in June of 1950. This does not appreciably affect runoff as flood water is released as soon as possible after it accures.
[1]USGS, 1958, 64a, 69a, 73a.

TABLE C4-10: USGS Gaging Station #06719505, "Clear Creek at Golden, Colorado."[1]

Location: Lat 39°45'11", long 105°14'05", in NE¼NW¼ sec. 33, T.3S., R.70W., Jefferson County, on left bank 100 ft downstream from U.S. Highway 6 bridge at west edge of Golden, 0.7 miles downstream from headgate of Church ditch, and 13.3 miles downstream from North Clear Creek.

Drainage Area: 400 Square miles

Period of Record: Oct. 1908 to Dec. 1909, June 1911 to current year. Prior to Oct. 1974, published as "near Golden."

Gage: Water-stage recorder. Datum of gage is 5,695 ft (from topographic map). Prior to May 15, 1919, at site half a mile upstream at different datum. May 15, 1919, to Mary. 16, 1934, at present site at datum 3.13 ft higher. Mar. 17, 1934, to Aug. 29, 1941, at present site at datum 4.00 ft higher. Aug. 30, 1941, to Apr. 16, 1942, at present site at datum 3.00 ft higher. Apr. 17, 1942, to Jan. 20, 1943, at site 600 ft downstream at datum 7.50 ft lower. Jan 21, 1947 to Oct. 1974, water-stage recorder, 0.9 miles upstream, at an elevation of 5,735.27 feet.

Extreme: Maximum discharge, 4,890, Sept. 9, 1933. Minimum daily recorded, 10.0 cfs, March 4, 1966. Maximum discharge since at least 1867, 8,700 cfs, Aug. 1, 1888, from reports of State Engineer of Colorado for Station 5.5 miles upstream.

Accuracy: Generally, records good except those for winter periods which are fair.

Remarks: Natural flow of stream affected by diversion for agriculture, several small reservoirs above station, and transbasin diversions from Colorado River Basin through the Berthoud Pass Ditch and Jones Pass Tunnel.

Yearly Runoff:

Water Year	Acre-Feet
1909	247,000
1910	-
1911	-
1912	225,000
1913	150,000
1914	306,000
1915	183,000
1916	145,000
1917	178,000
1918	197,000

(continued)

TABLE C4-10: (continued)

Water Year	Acre-Feet
1919	147,000
1920	184,000
1921	279,000
1922	125,000
1923	195,000
1924	208,000
1925	107,000
1926	241,000
1927	161,000
1928	178,000
1929	142,000
1930	156,000
1931	110,000
1932	119,000
1933	190,000
1934	134,400
1935	167,900
1936	215,500
1937	148,100
1938	242,300
1939	138,000
1940	111,000
1941	175,300
1942	170,600
1943	161,600
1944	158,700
1945	155,600
1946	127,500
1947	221,900
1948	164,900
1949	220,000
1950	120,600
1951	170,400
1952	195,800
1953	140,600
1954	66,630
1955	110,200
1956	139,900
1957	275,600
1958	153,400
1959	135,000
1960	171,200
1961	151,900
1962	167,100
1963	80,340
1964	105,700
1965	213,400
1966	93,600

(continued)

TABLE C4-10: (continued)

Water Year	Acre-Feet
1967	109,500
1968	130,000
1969	201,600
1970	211,400
1971	192,400
1972	122,500
1973	193,200
1974	155,500
1975	142,000
Average for 65 years of record	166,819

- Flows were not recorded for the entire water year.
[1]USDA, 1958, 64a, 71, 72, 73a, 73b, 74, 75.

TABLE C4-11: USGS Gaging Station #06720000, "Clear Creek at mouth, near Derby, Colorado."[1]

Location: Lat 39°49'42", long 104°57'30", in SW¼SW¼ sec. 36, T.2S., R 68W., Adams County, on right bank 210 ft downstream from York Street bridge, 0.6 miles upstream from mouth, and 2.5 miles west of Derby.

Drainage Area: 575 Square miles

Period of Record: April to November 1914, March 1927 to current year. Prior to October 1933 monthly discharge only.

Gage: Water-stage recorder. Altitude of gage is 5,110 ft (from topographical map). Apr. 1 to Nov. 30, 1914, chain gage at bridge 160 ft upstream at different datum. Feb. 25, 1927, to June 7, 1942, water-stage recorder at several sites within 1,000 ft of present site at various datums. June 8, 1942, to May 30, 1948, water-stage recorder at site 160 ft upstream at datum 4.00 ft higher, May 31, 1948, to Aug. 27, 1956, at datum 2.00 ft higher, and Aug. 28, 1956, to Nov. 14, 1957, at datum 1.00 ft higher. Nov. 15, 1957, to July 15, 1958, water-stage recorder at present site at datum 1.00 ft higher. July 16, 1958 to Sept. 1965, water-stage recorder at site 50 ft upstream of datum 1.56 ft higher.

Extremes: Maximum discharge 4,070 cfs, July 24, 1965. Minimum daily, 0.4 cfs, March 11, 1943.

Accuracy: Generally, records are good.

Remarks: Natural flow of stream affected by transbasin diversions from the Colorado River Basin, reserviors, diversions to Agriculture, Municipal and Industires, and return flows.

Yearly Runoff:

Water Year	Acre-Feet
1914	-
1915	-
1927	-
1928	76,500
1929	39,900
1930	28,000
1931	20,800
1932	27,700
1933	61,500
1934	37,200
1935	35,520
1936	74,330
1937	52,660
1938	116,000

(continued)

TABLE C4-11: (continued)

Water Year	Acre-Feet
1939	50,740
1940	29,880
1941	51,840
1942	118,400
1943	55,080
1944	63,830
1945	71,200
1946	30,300
1947	121,200
1948	61,930
1949	115,300
1950	40,590
1951	78,380
1952	110,700
1953	59,800
1954	12,100
1955	26,970
1956	57,300
1957	170,900
1958	99,500
1959	59,110
1960	71,610
1961	78,060
1962	93,550
1963	17,930
1964	32,180
1965	179,800
1966	32,870
1967	40,540
1968	47,920
1969	120,500
1970	116,300
1971	79,440
1972	43,790
1973	114,500
1974	65,190
1975	64,240
Average for 48 years of record	67,741

- Flows were not recorded for the entire water years.
[1]USGS, 1958, 64a, 69a, 71, 72, 73a, 73b, 74, 75.

TABLE C4-12: USGS Gaging Station #06729500, "South Boulder Creek near Eldorado Springs, Colorado."[1]

Location: Lat 39°55'52", long 105°17'43", in SE¼ sec. 26, T.1S., R.71W., Boulder County, on left bank 0.2 miles downstream from South Draw, 1.0 miles west of Eldorado Springs, 1.8 miles downstream from South Boulder diversion canal, 5.0 miles south of Boulder, and 6.7 miles downstream from Gross Reservior.

Drainage Area: 190 Square miles

Period of Record: April 1888 to October 1892, May 1895 to September 1901, August 1904 to current year. No winter records for water years 1889-92, 1900. Monthly discharge only for some periods. Prior to January 1911, published as "at" or "near Marshall;" January 1911 to December 1913 as "at Eldorado Springs."

Gage: Water-stage recorder. Altitude of gage is 6,080 ft (from topographical map). Prior to Sept. 25, 1929, staff gage or water-stage recorder at sites 1 mile downstream at different datums. Sept. 25, 1929, to May 2, 1934, water-stage recorder at site a quarter of a mile downstream at different datum. May 3, 1934, to Sept. 3, 1938, water-stage recorder at site 250 ft upstream at datum 4.00 ft higher than present datum. Sept. 4, 1938, to May 9, 1940, staff gages at site about 300 ft upstream or water-stage recorder at site half a mile downstream at different datums.

Extremes: Maximum discharge, 7,390 cfs, Sept. 2, 1938; no flow Oct. 15, 1932.

Accuracy: Generally, records are good except those for winter period which are fair.

Remarks: Records for periods June 1900 to Sept. 1901, Aug. 1904 to Sept. 1908, and Oct. 1909 to Sept. 1911 are not adjusted for diversions by Community ditch and South Boulder and Coal Creek ditch; all other records contain the flows in these ditches. Many small diversions above station for irrigation. Water is imported above Gross Reservoir from Colorado River Basin through Moffat Water Tunnel. Most of this imported water and some South Boulder Creek water flows is exported from drainage area 1.5 miles upstream from station. Flow regulated since May 1, 1955 by Gross Reservoir (cap. 43,060 ac-ft) 6.7 miles above station.

Yearly Runoff:

Water Year	Acre-Feet
1888	-
1889	-
1890	-
1891	-
1892	-
1893	-
1895	-
1896	43,600
1897	81,700
1898	54,600
1899	96,500
1900	-
1901	37,900
1904	-
1905	64,600
1906	60,400
1907	77,500
1908	32,300
1909	99,100
1910	27,300
1911	38,000
1912	57,100
1913	37,800
1914	95,600
1915	74,700
1916	44,900
1917	58,500
1918	64,900
1919	44,700
1920	63,000
1921	86,000
1922	33,200
1923	70,900
1924	75,900
1925	27,600
1926	78,200
1927	46,700
1928	55,700
1929	42,900
1930	50,600
1931	38,800
1932	36,800
1933	57,700
1934	30,150
1935	49,160
1936	57,120
1937	47,610
1938	82,110
1939	38,800

(continued)

TABLE C4-12: (continued)

Water Year	Acre-Feet
1940	33,010
1941	52,040
1942	77,460
1943	52,800
1944	52,250
1945	51,000
1946	37,440
1947	84,830
1948	43,540
1949	62,920
1950	39,120
1951	68,630
1952	67,950
1953	41,850
1954	16,850
1955	34,010
1956	36,900
1957	97,400
1958	54,830
1959	54,000
1960	61,420
1961	45,360
1962	55,750
1963	26,480
1964	34,010
1965	67,760
1966	16,370
1967	38,130
1968	42,460
1969	65,500
1970	55,040
1971	53,330
1972	35,760
1973	42,270
1974	51,370
1975	44,250
Average for 76 years of record	53,374

- Flows were not recorded for the entire water year.
[1]USGS, 1958, 64a, 69a, 71, 72, 73a, 73b, 74, 75.

TABLE C4-13: USGS Gaging Station, #0672700, "Boulder Creek near Orodell, Colorado."[1]

Location: Lat 40°00'23", long 105°19'49", in NE¼SW¼ sec. 34, T.1N., R.71W., Boulder County, on left bank along State Highway 119, 0.7 miles southwest of old Orodell, 1.1 miles upstream from Fourmile Creek, and 2.9 miles southwest of courthouse in Boulder.

Drainage Area: 102 Square miles

Period of Record: August to October 1887, April to October 1888, October 1906 to November 1914, March 1916 to current year. Monthly discharge only for some periods. Figures of daily discharge for Feb. 3-10, 17-25, 1912, published in WSP 326, have been found to be unreliable and should not be used. Published as North Boulder Creek, Colorado 1887-88 and as "at Orodell" March 1907 to December 1916.

Gage: Water-stage recorder. Altitude of gage is 5,826 ft from topographic map. Prior to Sept. 1, 1907, nonrecording gage and Sept. 1, 1907, to May 11, 1917, water-stage recorder, at sites 1.1 miles downstream, just upstream from Fourmile Creek, at different datums.

Extremes: Maximum discharge, 2,500 ft^3/s, June 6, 1921. Minimum daily 1 ft^3/s, Jan. 29, Feb. 1-3, 16-24, 1933.

Accuracy: Generally, records are good.

Remarks: Flow regulated by Barker Reservoir (capacity, 11,500 acre-feet). Low flow during non-irrigation season regulated by Orodell powerplant 1,500 ft upstream from station.

Yearly Runoff:

Water Year	Acre-Feet
1887	-
1888	-
1889	-
1907	94,800
1908	49,100
1909	89,300
1910	37,500
1911	47,900
1912	76,300
1913	51,000
1914	105,000
1915	-
1916	-

(continued)

TABLE C4-13: (continued)

Water Year	Acre-Feet
1917	63,900
1918	84,300
1919	61,600
1920	70,900
1921	101,000
1922	70,400
1923	81,200
1924	90,000
1925	51,800
1926	100,000
1927	67,400
1928	82,500
1929	71,300
1930	63,100
1931	62,900
1932	64,300
1933	50,500
1934	43,080
1935	62,170
1936	79,270
1937	54,200
1938	78,630
1939	54,720
1940	46,320
1941	55,720
1942	77,600
1943	64,230
1944	61,650
1945	60,570
1946	52,820
1947	81,340
1948	57,430
1949	69,020
1950	50,820
1951	76,320
1952	89,020
1953	63,500
1954	34,580
1955	41,800
1956	54,270
1957	105,700
1958	70,010
1959	63,870
1960	75,010
1961	61,220
1962	65,290
1963	48,980
1964	41,050
1965	85,190

(continued)

TABLE C4-13: (continued)

Water Year	Acre-Feet
1966	33,240
1967	43,400
1968	54,330
1969	79,460
1970	74,330
1971	71,720
1972	44,690
1973	64,990
1974	54,600
1975	55,260
Average for 67 years of record	65,190

- Flows were not recorded during the entire water year.

[1]USGS, 1958, 64a, 69a, 71, 72, 73a, 73b, 74, 75.

TABLE C4-14: USGS Gaging Station #06730300, "Coal Creek near Plainview, Colorado."[1]

Location: Lat 39°52'40", long 105°16'36", in SE¼NE¼ sec. 13, T.2S., R.71W., Jefferson County, on left bank 100 ft upstream from culvert on State Highway 72, 1.2 miles south of Plainview, 4.9 miles downstream from Beaver Creek and 9 miles north of Golden.

Drainage Area: 15.1 Square miles

Period of Record: August 1959 to current year.

Gage: Water-stage recorder and concrete control. Altitude of gage is 6,540 ft from topographic map. Prior to June 17, 1964, water-stage recorder at site 60 ft downstream at datum 4.49 ft lower.

Extremes: Maximum discharge, 2,060 cfs, May 7, 1969, no flow for many days in most years.

Accuracy: Generally, records are good except those for period of no gage-height record, which are poor.

Remarks: No diversions above station.

Yearly Runoff:

Water Year	Acre-Feet
1959	-
1960	4,610
1961	4,100
1962	2,540
1963	824
1964	1,220
1965	3,610
1966	398
1967	2,340
1968	2,130
1969	7,770
1970	4,750
1971	4,790
1972	988
1973	7,820
1974	2,300
1975	2,340
Average for 16 years of record	3,283

- Flows were not recorded for the entire water year.

[1]USGS, 1964a, 69a, 71, 72, 73a, 73b, 74, 75.

TABLE C4-15: USGS Gaging Station #7305, "Boulder Creek at mouth, near Longmont, Colorado."[1]

Location: Lat 40°08'05", long 105°01'00", in SW¼ sec 16, T.2N., R.68W., on right bank 200 ft downstream from Burlington Railway bridge, 1,800 ft upstream from State Highway 254, 2¼ miles upstream from mouth, and 5 miles southeast of city hall in Longmont.

Drainage Area: 439 Square miles

Period of Record: March 1927 to September 1949, May 1961 to September 1955. Prior to October 1933 monthly discharge only. Published as "near mouth, near Longmont" 1934.

Gage: Water-stage recorder. Altitude of gage is 4,880 ft (from topographic map). Prior to June 10, 1939, at site half a mile downstream at different datum. June 10, 1939, to Sept. 30, 1949, at site 2,000 ft downstream at different datum. Datum raised 2.0 ft June 10, 1939.

Extremes: Maximum discharge, 4,410 cfs, Sept. 3, 1938, no flow at times in 1934-36, 1942, 1946, 1954.

Accuracy: Not available.

Remarks: Natural flow to stream affected by transbasin diversions from the Colorado River Basin, diversions to agriculture, municipalities, and industries, many storage reservoirs and return flow.

Yearly Runoff:

Water Year	Acre-Feet
1927	-
1928	63,900
1929	33,000
1930	33,400
1931	26,700
1932	5,970
1933	25,500
1934	15,160
1935	21,240
1936	27,980
1937	34,330
1938	85,430
1939	44,850
1940	3,230
1941	29,210
1942	149,400
1943	36,240

(continued)

TABLE C4-15: (continued)

Water Year	Acre-Feet
1944	52,740
1945	29,110
1946	20,750
1947	97,880
1948	45,790
1949	60,720
1951	-
1952	90,480
1953	13,280
1954	2,850
1955	4,550
Average for 26 years of record	40,527

\- Flows were not recorded for the entire water year.
[1]USGS, 1958, 64a.

TABLE C4-16: USGS Gaging Station #06724000, "Saint Vrain Creek at Lyons, Colorado."[1]

Location: Lat 40°13'05", long 105°15'34", in NW¼NW¼ sec. 20, T.3N., R.70W., Boulder County, on left bank 75 ft southwest of State Highways 7 and 66 at southeast edge of Lyons, 400 ft upstream from St. Vrain Supply Canal, and 0.4 miles downstream from confluence of North and South St. Vrain Creeks.

Drainage Area: 212 Square miles

Period of Record: August 1887 to September 1891, June 1895 to current year. Monthly discharge only for some periods. Published as "near Lyons" 1901, 1903.

Gage: Water-stage recorder. Altitude of gage is 5,292 ft from topographical map. Prior to Apr. 6, 1923, nonrecording gages near site at different datums. Apr. 6, 1923 to Sept. 30, 1956, water-stage recorder at same site at datum 1.00 ft higher.

Extremes: Maximum discharge, 10,500 cfs June 22, 1941; no flow Jan. 19, 1922, Jan. 12, 13, 1950. Outstanding floods occurred in June 1864 and May 1876. Flood in May or June 1894 reached a stage of 9.13 ft from information by local resident (discharge, about 9,800 cfs.

Accuracy: Generally, records are good.

Remarks: Diversion just above station by irrigation ditch exporting flows to lands below. Flow partly regulated by many small reservoirs.

Yearly Runoff:

Water Year	Acre-Feet
1887	-
1888	65,200
1889	61,100
1890	88,300
1891	166,000
1895	-
1896	84,400
1897	146,000
1898	82,900
1899	141,000
1900	124,000
1901	96,400
1902	48,400
1903	121,000

(continued)

TABLE C4-16: (continued)

Water Year	Acre-Feet
1904	91,400
1905	125,000
1906	110,000
1906	161,000
1908	62,600
1909	133,000
1910	52,300
1911	71,300
1912	118,000
1913	75,200
1914	151,000
1915	112,000
1916	94,100
1917	129,000
1918	100,000
1919	66,600
1920	105,000
1921	145,000
1922	58,200
1923	157,000
1924	141,000
1925	51,500
1926	139,000
1927	86,100
1928	102,000
1929	84,800
1930	77,400
1931	62,100
1932	67,600
1933	98,300
1934	57,860
1935	89,790
1936	106,800
1937	74,740
1938	115,400
1939	64,310
1940	55,480
1941	86,170
1942	127,500
1943	104,200
1944	82,340
1945	90,510
1946	56,440
1947	136,000
1948	72,780
1949	125,000
1950	63,520
1951	113,600
1952	137,400

(continued)

TABLE C4-16: (continued)

Water Year	Acre-Feet
1953	66,360
1954	33,480
1955	48,930
1956	63,870
1957	169,000
1958	88,800
1959	75,040
1960	74,740
1961	96,920
1962	77,260
1963	57,820
1964	49,510
1965	113,000
1966	38,550
1967	78,090
1968	67,290
1969	131,200
1970	98,480
1971	103,400
1972	65,240
1973	103,900
1974	69,180
1975	90,840
Average for 84 years of record	93,423

- Flows were not recorded for the entire water year.
[1]USGS, 1958, 64a, 69d, 71, 72, 73a, 73b, 74, 75.

TABLE C4-17: USGS Gaging Station #7245, "Left Hand Creek near Boulder, Colorado."[1]

Location: Lat 40°07'30", long 105°18'15", in NE¼ sec 23, T.2N., R.71W., on right bank 0.1 mile upstream from diversion dam of Lefthand ditch, 0.1 mile downstream from Spruce Gulch, and 7.5 miles north of Boulder.

Drainage Area: 52.0 Square miles

Period of Record: May 1929 to Sept. 1931, April 1947 to Dec. 1953, Oct. 1955 to Sept. 1957.

Gage: Water-stage recorder and Parshall flume, altitude of gage is 5,710 ft (from topographic map). Prior to Oct. 7, 1949, at site .35 miles upstream at different datum. Oct. 8, 1949 to May 12, 1957 at site 0.9 miles upstream at different datum.

Extremes: Maximum discharge 785 cfs, Aug. 3, 1951; minimum daily, 1.0 cfs, Jan. 4, 1950. Flood of June 4, 1949, reached a discharge of 1,140 cfs at site half a mile upstream.

Accuracy: Not available.

Remarks: Records for May 1929 to Sept. 1931 and April 1947 to Sept. 1949 do not include flow of small power ditch, capacity 7.5 cfs, which diverted above station. A large part of flow is water diverted from South Saint Vrain Creek for irrigation of lands along Lefthand Creek below station.

Yearly Runoff:

Water Year	Acre-Feet
1929	-
1930	21,000
1931	19,300
1947	-
1948	20,850
1949	29,380
1950	20,710
1951	31,120
1952	35,110
1953	23,890
1954	-
1956	22,970
1957	43,290
Average for 10 years of record	26,761

- Flows were not recorded for the entire water year.

[1]USGS, 1958, 64a.

TABLE C4-18: USGS Gaging Station #06731000, "Saint Vrain Creek at mouth, near Platteville, Colorado."[1]

Location: Lat 40°15'29", long 104°52'45", in SE¼NW¼ sec. 3, T.3N., R.67W., Weld County, on right bank 140 ft downstream from bridge on county road, 1.3 miles upstream from mouth, and 4.2 miles northwest of Platteville.

Drainage Area: 976 Square miles

Period of Record: July 1904 to December 1906, April to December 1915, March 1927 to current year. Prior to October 1933 monthly discharge only.

Gage: Water-stage recorder. Altitude of gage is 4,740 ft (from topographic map). July 1, 1904, to Dec. 31, 1906, and Apr. 1 to Dec. 31, 1915, staff gage at bridge 140 ft upstream at different datums. Feb. 24, 1927, to June 10, 1939, water-stage recorder at bridge 140 ft upstream and June 11, 1939, to Apr. 24, 1960, water-stage recorder at site 180 ft upstream, at different datum.

Extremes: Maximum discharge, 11,300 cfs, Sept. 3, 1938; minimum daily, 12 cfs, April 23, 1935.

Accuracy: Generally, records are good except those for winter period which are fair.

Remarks: Natural flow of stream affected by imports from the Colorado River Basin diversions to agriculture, municipalities, and industries, many storage reservoirs and return flows. Boulder Creek Confluence with Saint Vrain Creek occurs approximately 10 miles upstream.

Yearly Runoff:

Water Year	Acre-Feet
1904	-
1905	253,000
1906	131,000
1907	-
1915	-
1916	-
1927	-
1928	191,000
1929	106,000
1930	94,700
1931	76,900
1932	40,000
1933	104,000

(continued)

TABLE C4-18: (continued)

Water Year	Acre-Feet
1934	55,820
1935	99,490
1936	99,090
1937	110,200
1938	207,700
1939	120,600
1940	46,510
1941	88,790
1942	343,800
1943	154,300
1944	195,600
1945	100,700
1946	75,540
1947	296,200
1948	119,500
1949	233,600
1950	61,160
1951	132,800
1952	253,600
1953	76,100
1954	40,100
1955	40,770
1956	52,990
1957	332,900
1958	218,800
1959	143,100
1960	144,600
1961	204,100
1962	181,600
1963	87,790
1964	71,240
1965	213,400
1966	98,850
1967	168,200
1968	108,600
1969	245,200
1970	253,400
1971	229,700
1972	213,500
1973	230,300
1974	140,100
1975	162,900
Average for 50 years of record	147,597

- Flows were not recorded for the entire water year.
[1]USGS, 1958, 64a, 69a, 71, 72, 73a, 73b, 74, 75.

TABLE C4-19: USGS Gaging Station #6-7420, "Little Thompson River near Berthoud, Colorado."[1]

Location: Lat 40°15'30", long 105°12'15", in NW¼ sec. 2, T.3N., R.70W., on left bank at mouth of canyon, 7½ miles southwest of Berthoud.

Drainage Area: 101 Square miles

Period of Record: May 1929 to September 1930, April 1947 to September 1961 (discontinued).

Gage: Water-stage recorder. Altitude of gage is 5,220 ft (from topographic map). Prior to Apr. 22, 1947, at site a quarter of a mile upstream at different datum.

Extremes: Maximum discharge, 4,000 cfs, May 9, 1967; no flow at times in 1948-49, 1951, 1953-55.

Accuracy: Generally, records are fair except those for periods of no gage hight records, which are poor.

Remarks: One small diversion above station. Inflow from Colorado-Big Thompson project above station May 16, 1953, to Apr. 25, 1957.

Yearly Runoff:

Water Year	Acre-Feet
1929	-
1930	8,990
1947	-
1948	7,130
1949	25,400
1950	3,020
1951	9,930
1952	15,540
1953	21,970
1954	10,200
1955	9,790
1956	11,510
1957	33,220
1958	19,750
1959	9,910
1960	6,990
1961	19,260
Average for 15 years of record	14,177

- Flows were not recorded for the entire water year.

[1]USGS, 1958, 64a, 69a.

TABLE C4-20: USGS Gaging Station #06738000, "Big Thompson River at mouth of Canyon, near Drake, Colorado."[1]

Location: Lat 40°25'18", long 105°13'34", in SW¼SW¼ sec. 3,T.5N., R.70W., Larimer County, on right bank at mouth of canyon, 400 ft upstream from Handy Ditch diversion dam and 6.0 miles east of Drake.

Drainage Area: 304 Square Miles

Period of Record: August 1887 to September 1892, May 1895 to September 1903, October 1926 to September 1933 (no winter records prior to October 1932, except water years 1927-28), April 1938 to September 1949, March 1951 to current year. Monthly discharge only for some periods. Published as Big Thompson Creek at Arkins 1887-92, Big Thompson Creek near Arkins 1901-3, and as Thompson River at mouth of canyon, near Drake 1927-30, 1938-47.

Gage: Water-stage recorder. Datum of gage is 5,297.47 ft above mean sea level (Bureau of Reclamation bench mark). Aug. 25, 1887, to Sept. 30, 1892, and Apr. 1, 1899 to Sept. 21, 1903, staff gages at sites within half a mile downstream below Handy Ditch diversion dam at different datums. May 9, 1895, to Mar. 31, 1899, staff gage at site 1½ miles downstream and 600 ft downstream from Home Supply Ditch diversion dam at different datum. Oct. 1 to Dec. 31, 1926, staff gage at site 6½ miles upstream at different datum. Jan. 1, 1927 to Sept. 30, 1933, water-stage recorder at site 1 mile upstream at different datum. Apr. 19, 1938, to Sept. 30, 1949, water-stage recorder at site 50 ft downstream at datum 1.45 ft lower.

Extremes: Maximum discharge, 31,200, Aug. 1, 1976 (USGS, 1976); minimum daily, 0.20 cfs, Dec. 10-12, 1969.

Accuracy: Generally, records are good except those for winter periods, which are fair.

Remarks: Diverions above station for irrigation. Diversion from Colorado River to Big Thompson River basin above station through Alva B. Adams tunnel (see elsewhere in this report) began Aug. 10, 1947; since Apr. 15, 1953, this imported water has been diverted from Lake Estes through Olympus tunnel bypassing this station. Part of the natural flow of Big Thompson River has also been diverted through Olympus tunnel since May 17, 1965, and Dille tunnel since Apr. 20, 1959, and returned to river just below this station.

TABLE C4-20: (continued)

Yearly Runoff:

Water Year	Acre-Feet
1887	-
1888	-
1889	-
1890	-
1891	-
1892	-
1895	-
1896	-
1897	-
1898	-
1899	-
1900	-
1901	-
1902	-
1903	-
1927	128,000
1928	163,000
1929	-
1930	-
1931	-
1932	-
1933	121,000
1938	-
1939	91,200
1940	83,350
1941	122,400
1942	150,200
1943	145,600
1944	124,000
1945	144,200
1946	86,610
1947	180,900
1948	114,900
1949	169,800
1951	-
1952	161,700
1953	162,200
1954	61,530
1955	52,100
1956	61,530
1957	107,400
1958	85,760
1959	51,970
1960	51,410
1961	59,440
1962	70,740

(continued)

TABLE C4-20: (continued)

Water Year	Acre-Feet
1963	47,850
1964	46,690
1965	79,070
1966	52,060
1967	47,430
1968	60,680
1969	61,380
1970	62,680
1971	71,790
1972	49,670
1973	77,890
1974	59,570
1975	60,440
Average for 38 years of record	93,293

- Flows were not recorded for the entire water year.
[1]USGS, 1958, 64a, 69a, 71, 72, 73a, 73b, 74, 75.

TABLE C4-21: USGS Gaging Station #7395, "Buckhorn Creek near Masonville, Colorado."[1]

Location: Lat 40°27'15", long 105°11'50", in SE¼ sec 26, T.6N., R.70W., on right bank 1½ miles upstream from Buckhorn Reservoir Dam and 2½ miles south of Masonville.

Drainage Area: 131 Square miles

Period of Record: April 1947 to September 1955.

Gage: Water-stage recorder. Altitude of gage is 5,200 ft (from topographic map).

Extremes: Maximum discharge, 14,000 cfs Aug. 3, 1951; minimum daily, 0.1 cfs Sept. 22, 1948. Flood of June 15, 1923, discharge 10,500 cfs, by slope-area measurement, 1½ miles above station. Flood of Sept. 1, 1938, discharge, 10,200 cfs, by slope-area measurements, half a mile below station.

Accuracy: Not available.

Remarks: Diversions above station for irrigation of about 500 acres.

Yearly Runoff:

Water Year	Acre-Feet
1947	-
1948	7,940
1949	32,380
1950	2,910
1951	15,300
1952	20,440
1953	3,110
1954	1,000
1955	2,180
Average for 8 years of record	10,659

- Flows were not recorded for the entire water year.

[1]USGS, 1958, 64a.

TABLE C4-22: USGS Gaging Station #06744000, "Big Thompson River at mouth, near LaSalle, Colorado."[1]

Location: Lat 40°21'00", long 104°47'04", in SW¼SE¼ sec. 33, T.5.N., R.66W., Weld County, on left bank just southeast of gage on Evans Town ditch, 0.7 miles upstream from highway bridge, 1.6 miles upstream from mouth, and 4.2 miles west of LaSalle.

Drainage Area: 828 Square miles

Period of Record: April 1914 to October 1915, March 1927 to current year. Prior to October 1933 monthly discharge only. Published as Thompson River at mouth, near LaSalle, 1934-47.

Gage: Water-stage recorder. Altitude of gage is 4,680 ft from topographical map. Apr. 1, 1914, to Oct. 31, 1915, nonrecording gage and Mar. 1, 1927 to Sept. 30, 1951, water-stage recorder, at bridge 0.7 miles downstream at different datums. Datum lowered 0.50 ft May 21, 1962.

Extremes: Maximum discharge, 6,100 cfs, Aug. 5, 1951; no flow at times in 1934-35, 1948.

Accuracy: Generally, records are good.

Remarks: Natural flow of stream affected by transmountain diversions, storage reservoirs, power developments, diversions for irrigation above station, and return flow from irrigated areas.

Yearly Runoff:

Water Year	Acre-Feet
1914	-
1915	51,800
1916	-
1927	-
1928	41,700
1929	54,100
1930	57,500
1931	26,500
1932	19,400
1933	18,900
1934	15,520
1935	15,250
1936	20,420
1937	21,570
1938	44,610
1939	27,130

(continued)

TABLE C4-22: (continued)

Water Year	Acre-Feet
1940	12,560
1941	20,780
1942	48,440
1943	54,340
1944	35,570
1945	24,370
1946	21,040
1947	65,880
1948	38,460
1949	113,700
1950	22,660
1951	44,080
1952	91,080
1953	41,000
1954	54,540
1955	30,970
1956	27,700
1957	85,750
1958	145,600
1959	67,200
1960	45,650
1961	93,190
1962	105,300
1963	50,450
1964	38,890
1965	50,300
1966	45,640
1967	44,360
1968	41,670
1969	62,530
1970	96,500
1971	119,000
1972	51,480
1973	108,600
1974	76,150
1975	77,900
Average for 49 years of record	51,191

- Flows were not recorded for the entire water year.
[1]USGS, 1958, 64a, 69a, 71, 72, 73a, 73b, 74, 75.

TABLE C4-23: USGS Gaging Station #06752000, "Cache La Poudre River at mouth of canyon, near Fort Collins, Colorado."[1]

Location: Lat 40°39'52", long 105°13'26", in NW¼ sec. 15, T.8N., R.70W., Larimer County, on left bank at mouth of canyon, 0.5 miles downstream from headgate of Poudre Valley Canal, 1.2 miles upstream from Lewstone Creek, and 9.3 miles northwest of courthouse in Fort Collins.

Drainage Area: 1,055 Square miles

Period of Record: June to August 1881, May to July 1883, October 1883 to current year. Monthly discharge only for some periods. Records for Mar. 23 to Apr. 30 and July 4, to Aug. 20, 1883, published in WSP 9, have been found to be unreliable and should not be used. Prior to 1902, published as Cache la Poudre Creek or River at or near Fort Collins.

Gage: Water-stage recorder. Altitude of gage is 5,220 ft from topographic map.

Extremes: Maximum discharge not determined, occurred May 20, 1904; maximum discharge determined, 21,000 cfs June 9, 1891 (from reports of State engineer of Colorado), caused by failure of Chambers Lake Dam; minimum daily discharge, 1.6 cfs Nov. 20, 28, 1948, caused by diversion of Poudre Valley Canal 0.5 miles upstream.

Accuracy: Generally, records are good except those for winter periods, which are poor.

Remarks: Natural flow of stream affected by reservoirs, transmountain diversions, diversions above station for irritation, (most of which is below station) and diversions for municipal use.

Yearly Runoff:

Water Year	Acre-Feet
1881	-
1883	-
1884	675,000
1885	494,000
1886	318,000
1887	512,000
1888	192,000
1889	204,000
1890	244,000
1891	278,000
1892	216,000
1893	232,000

(continued)

TABLE C4-23: (continued)

Water Year	Acre-Feet
1894	321,000
1895	372,000
1896	236,000
1897	357,000
1898	201,000
1899	400,000
1900	496,000
1901	348,000
1902	166,000
1903	333,000
1904	375,000
1905	358,000
1906	296,000
1907	295,000
1908	261,000
1909	468,000
1910	166,000
1911	253,000
1912	321,000
1913	221,000
1914	406,000
1915	257,000
1916	281,000
1917	514,000
1918	317,000
1919	162,000
1920	364,000
1921	396,000
1922	206,000
1923	446,000
1924	447,000
1925	222,000
1926	381,000
1927	261,000
1929	302,000
1929	321,000
1930	222,000
1931	177,000
1932	261,000
1933	277,000
1934	135,200
1935	280,500
1936	294,400
1937	222,400
1938	259,400
1939	211,600
1940	167,700
1941	224,000

(continued)

TABLE C4-23: (continued)

Water Year	Acre-Feet
1942	313,700
1943	349,200
1944	226,600
1945	263,100
1946	214,300
1947	315,600
1948	225,300
1949	336,800
1950	212,700
1951	]97,100
1952	273,500
1953	162,800
1954	100,100
1955	144,500
1956	216,000
1957	322,500
1958	240,700
1959	215,600
1960	205,500
1961	270,300
1962	273,400
1963	110,900
1964	160,700
1965	281,100
1966	98,280
1967	166,200
1968	212,100
1909	191,400
1970	262,800
1971	311,100
1972	177,600
1973	321,500
1974	268,200
1975	221,400
Average for 92 years of record	277,159

- Flows were not recorded for the entire water year.
[1]USGS, 1958, 64a, 69a, 71, 73a, 73b, 74, 75.

TABLE C4-24: USGS Gaging Station #0675200, "Cache la Poudre River near Greeley, Colorado."[1]

Location: Lat 40°25'04", long 104°38'22", in NW¼ sec. 11, T.5N., R.65W., R.65W., Weld County, on right bank25 ft downstream from highway bridge, 2.9 miles east of courthouse in Greeley, and 3.0 miles upstream from mouth.

Drainage Area: 1,877 Square miles

Period of Record: March to October 1903, August to November 1904, January 1914 to December 1919, June 1924 to current year. Monthly discharge only for some periods.

Gage: Water-stage recorder. Altitude of gate is 4,610 ft (from topographic map). Prior to Apr. 4, 1916, staff gage and Apr. 4, 1916, to Dec. 17, 1919, water-stage recorder, at sites within 2 miles downstream at different datums. May 27, 1924, to Dec. 13, 1933, at present site at datum 0.51 ft higher.

Extremes: Maximum daily discharge, 4,200 cfs, June 24, 26, 1917; minimum daily, 0.8 cfs, Oct. 3, 1946.

Accuracy: Generally, records are good.

Remarks: Natural flow of stream affected by transmountain and transbasin diversions, storage reservoirs, power developments, diversions for muncipal supply, diversions above station for irrigation and return flow from irrigated areas.

Yearly Runoff:

Water Year	Acre-Feet
1903	-
1904	-
1905	-
1914	-
1915	74,000
1916	84,300
1917	286,000
1918	130,000
1919	70,600
1920	-
1924	-
1925	48,400
1926	100,000
1927	62,300
1928	103,000
1929	71,500

(continued)

TABLE C4-24: (continued)

Water Year	Acre-Feet
1930	65,700
1931	54,000
1932	34,200
1933	38,900
1934	32,600
1935	31,580
1936	29,150
1937	30,010
1938	30,820
1939	33,430
1940	20,270
1941	21,410
1942	82,250
1943	140,600
1944	40,450
1945	38,680
1946	36,140
1947	90,290
1948	43,020
1949	100,500
1950	30,650
1951	45,220
1952	65,970
1953	39,780
1954	28,410
1955	25,950
1956	37,870
1957	83,400
1958	160,800
1959	76,560
1960	57,060
1961	165,300
1962	161,800
1963	63,430
1964	46,180
1965	111,400
1966	52,890
1967	81,140
1968	52,420
1969	63,440
1970	129,000
1971	179,700
1972	96,700
1973	156,400
1974	122,800
1975	106,000
Average for 56 years of record	76,167

- Flows were not recorded for the entire water year.
[1]USGS, 1958, 64a, 69a, 71, 72, 73a, 73b, 74, 75.

TABLE C4-25: USGS Gaging Station #274, "Lonetree Creek near Granite Canyon, Wyoming."[1]

Location: Lat 41!05'10", long 105°11'10", in sec. 24, T.13N., R.70W., 1½ miles southwest of Granite Canyon.

Drainage Area: 23 Square miles

Period of Record: May 1933 to September 1938 (discontinued), records are not available for many months.

Gage: Water-stage recorder. Altitude of gage is 7,320 ft (from topographic map).

Extremes: Maximum discharge, 230 cfs (estimated) Sept. 8, 1933, no flow at times in most years.

Accuracy: Not available.

Remarks: Diversions above station for irrigation of about 700 acres.

Yearly Runoff:

Water Year	Acre-Feet
1933	-
1934	842
1935	3,000
1936	-
1937	-
1938*	-
Average for 2 years of record	1,912

- Flows not recorded for the entire water year.
* Gaging Station discontinued.
[1]USGS, 1958.

TABLE C4-26: USGS Gaging Station #7535, "Lonetree Creek near Nunn, Colorado."[1]

Location: Lat 40°46'00", long 104°47'25", in NE¼ sec. 8, T.9N., R.66W., on right bank 200 ft upstream from bridge on U.S. Highway 85 and 4½ miles north of Nunn.

Drainage Area: 199 Square miles.

Period of Record: July 1951 to September 1967 (discontinued).

Gage: Water-stage recorder. Altitude of gage is 5,320 ft (from topographic map).

Extremes: Maximum discharge, 775 cfs Aug. 7, 1955; no flow for many days in each year.

Accuracy: Not available.

Remarks: Flow is mainly return water from irrigation. There are many small diversions for irrigation and small reservoirs for stock water above station.

Yearly Runoff:

Water Year	Acre-Feet
1951	-
1952	249
1953	316
1954	25
1955	1,590
1956	647
1957*	676
Average for 6 years of record	550

- Flow not recorded for the entire water year.
* Gaging station discontinued.
[1]USGS, 1964a.

TABLE C4-27: USGS Gaging Station #06754000, "South Platte River near Kersey, Colorado."[1]

Location: Lat 40°24'44", long 104°33'46", in NW¼NW¼ sec. 9, T.5N., R.64W., Weld County, on downstream side of bridge on State Highway 37, 1.9 miles north of railroad in Kersey, and 2.5 miles downstream from CAche la Poudre River.

Drainage Area: 9,598 Square miles

Period of Record: May 1901 to December 1903, March 1905 to current year. Monthly discharge only for some periods. Published as "at Kersey" 1901-3.

Gage: Water-stage recorder. Datum of gage is 4,575.77 ft above mean sea level, datum of 1929. Prior to July 8, 1919, staff or chain gages at bridge 150 ft downstream at different datum. July 8, 1919, to Sept. 7, 1921, water-stage recoder at site 450 ft downstream from present site at different datum. Sept. 8, 1921, to Sept. 12, 1923, water-stage recorder at site 750 ft downstream from present site at different datum. Sept. 13, 1923, to July 2, 1935, at site 200 ft downstream at same datum.

Extremes: Maximum discharge, 31,500 cfs, May 8, 1973; minimum daily, 28 cfs, April 30, 1955.

Accuracy: Generally, records are good.

Remarks: Diversions above station for irrigation of about 888,000 acres. Natural flow of stream also affected by transbasin and transsubbasin diversions, storage reservoirs, power developments, ground-water withdrawals and return flow from irrigated areas.

Yearly Runoff:

Water Year	Acre-Feet
1901	-
1902	260,000
1903	337,000
1904	-
1905	-
1906	564,000
1907	810,000
1908	272,000
1909	893,000
1910	427,000
1911	182,000
1912	530,000
1913	425,000
1914	1,560,000

(continued)

TABLE C4-27: (continued)

Water Year	Acre-Feet
1915	828,000
1916	409,000
1917	1,020,000
1918	557,000
1919	400,000
1920	532,000
1921	1,230,000
1922	293,000
1923	773,000
1924	1,360,000
1925	245,000
1926	832,000
1927	390,000
1928	585,000
1929	369,000
1930	413,000
1931	293,000
1932	215,000
1933	392,000
1934	228,000
1935	258,000
1936	286,310
1937	296,300
1938	543,700
1939	468,900
1940	181,500
1941	327,900
1942	1,435,000
1943	472,200
1944	447,500
1945	372,000
1946	285,600
1947	890,900
1948	670,100
1949	667,100
1950	252,500
1951	352,400
1952	560,100
1953	264,000
1954	161,300
1955	159,000
1956	188,000
1957	836,200
1958	922,900
1959	402,500
1960	489,400
1961	767,800
1962	840,600
1963	294,000

(continued)

TABLE C4-27: (continued)

Water Year	Acre-Feet
1964	247,000
1965	811,900
1966	356,900
1967	510,100
1968	324,400
1969	896,200
1970	1,229,000
1971	944,000
1972	465,500
1973	1,599,000
1974	684,700
1975	611,400
Average for 72 years of record	561,342

- Flows were not recorded for the entire water year.

[1]USGS, 1958, 62a, 69a, 71, 72, 73a, 73b, 74, 75.

TABLE C4-28: USGS Gaging Station #278, "North Fork Crow Creek near Hecla, Wyoming."[1]

Location: Lat 41°13'40", long 105°11'50", in sec. 35, T.15N., R.70W., 600 ft upstream from high-water line of North Crow Creek Diversion Reservoir, 1¼ miles downstream from dam for Upper North Crow Creek Reservoir, 5½ miles northwest of Hecla, and 9 miles northwest of Granite Canyon.

Drainage Area: 27 Square miles, approximately.

Period of Record: June 1935 to Sept. 1944 (discontinued). Records are not available for many months.

Gage: Water-stage recorder. Altitude of gage is 6,920 ft (from topographic map).

Extremes: 1933-44; Maximum discharge not determined, occurred Sept. 8, 1933; no flow at times in 1939, 1940.

Accuracy: Not available.

Remarks: Diversions above station for irrigation of about 100 acres. Flow partly regulated by Upper North Crow Creek Reservoir.

Yearly Runoff:

Water Year	Acre-Feet
1933	-
1934	1,490
1935	1,890
1936	-
1937	-
1938	-
1939	-
1940	-
1941	-
1942	-
1943	-
1944*	-
Average for 2 years of record	1,690

- Flows were not recorded for the entire water year.
* Gaging station discontinued.
[1]USGS, 1958.

TABLE C4-29: USGS Gaging Station #05754500, "Middle Crow Creek near Hecla, Wyoming."[1]

Location: Lat 41°10'30", long 105°15'10", in sec. 20, T.14N., R.70W, Laramie County, on left bank a quarter of a mile upstream from high-water line of Granite Springs Reservoir, 4½ miles northwest of Hecla, and 7 miles northwest of Granite Canyon.

Drainage Area: 25.8 Square miles

Period of Record: April to July 1902, April to November 1903, April 1933 to September 1969 (discontinued). Monthly discharge only for some periods. Published as Middle Fork Crow Creek near Hecla 1933-45, 1948-55.

Gage: Water-stage recorder and Cippoletti weir. Altitude of gage is 7,270 ft (from topographic map). Apr. 1, 1902, to Nov. 21, 1903, staff gages at sites 1¼ miles downstream at different datums.

Extremes: Maximum discharge, 495 cfs, Sept. 8, 1933; no flow for many days in most years prior to December 1963.

Accuracy: Generally, records are good except for those during winter periods and periods of no gage-height record which are poor.

Remarks: Releases from Lake Owen into Middle Crow Creek above station for municipal use by city of Cheyenne began December 1963. No diversions above station.

Yearly Runoff:

Water Year	Acre-Feet
1902	-
1903	-
1904	-
1933	-
1934	912
1935	4,100
1936	1,670
1937	1,740
1938	4,320
1939	2,680
1940	818
1941	3,840
1942	7,580
1943	5,390
1944	4,160
1945	3,510
1946	1,520

(continued)

TABLE C4-29: (continued)

Water Year	Acre-Feet
1947	6,080
1948	2,070
1959	6,010
1950	2,340
1951	1,730
1952	3,550
1953	1,640
1954	648
1955	766
1956	942
1957	6,170
1958	3,840
1959	3,330
1960	1,220
1961	3,780
1962	3,820
1963	2,530
1964	5,720
1965	9,270
1966	3,060
1967	8,440
1968	7,880
1969*	6,400
Average for 36 years of record	3,708

- Flow were not recorded for the entire water years.
* Gaging station discontinued.
[1]USGS, 1958, 64a, 69a, and 73a.

TABLE C4-30: USGS Gaging Station #06755000, "South Crow Creek near Hecla, Wyoming."[1]

Location: Lat 40°07'35", long 105°11'38", in SE¼NE¼ sec. 2, T.13N., R.70W., Laramie County, on left bank just upstream from high water line of South Crow Creek Reservoir, 2.5 miles southwest of Hecla and 2.5 miles north west of Granite canyon.

Drainage Area: 13.9 Square miles

Period of Record: May 1955 to September 1969, (discontinued). Monthly discharge only for some periods, no winter records for water years 1936-50. Prior to October 1950, published as South Fork Crow Creek near Hecla.

Gage: Water-stage recorder, Altitude of gage is 7,130 feet (from topographic map).

Extremes: Maximum discharge 110 cfs, July 21, 1945; no flow for many days in most years.

Accuracy: Generally, records are poor.

Remarks: No diversions above station.

Yearly Runoff:

Water Year	Acre-Feet
1933	-
1934	406
1935	1,480
1936	-
1937	-
1938	-
1939	-
1940	-
1941	-
1942	-
1943	-
1944	-
1945	-
1946	-
1947	-
1948	-
1949	-
1950	-
1951	664
1952	1,190
1953	634

(continued)

TABLE C4-30: (continued)

Water Year	Acre-Feet
1954	328
1955	339
1956	454
1957	1,570
1958	1,340
1959	1,890
1960	709
1961	1,290
1962	1,150
1963	921
1964	543
1965	1,890
1966	820
1967	984
1968	1,260
1969*	730
Average for 21 years of record	981

- Flows were not recorded for the entire water year.
* Gaging station discontinued.
[1]USGS, 1958, 64a, 69a and 73a.

TABLE C4-31: USGS Gaging Station #7560, "Crow Creek near Cheyenne, Wyoming."[1]

Location: Lat 41°07'00", long 104°47'20", in SE¼ sec. 3, T.13W., R.66W., on left bank a quarter of a mile downstream from sewage-disposal plant and 3 3/4 miles southeast of State Capitol in Cheyenne.

Drainage Area: 297 Square miles

Period of Record: October 1922 to November 1924, July 1951 to Sept. 1957 (discontinued). Monthly discharge only for some periods.

Gage: Water-stage recorder for Parshall flume. Altitude of gage is 5,940 ft (from topographic map). Oct. 20, 1922, to Nov. 1, 1924, staff gage on bridge 1¼ miles downstream at different datum.

Extremes: Maximum discharge 395 cfs, June 14, 1955; minimum daily, 2.0 cfs Apr. 16, 17, 23, 1923. Flood of May 20, 1904, was estimated as 8,500 cfs at Cheyenne. Flood of June 2, 1929, reached a discharge of 8,200 cfs, by slope-area measurement about 5 miles upstream.

Accuracy: Not available

Remarks: In 1924 there were adjudicated rights for diversions above station for irrigation of 18,840 acres. At present practically all flow above station is diverted for municipal supply and irrigation. Flow at station is mainly drainage and waste water from Cheyenne. City of Cheyenne has prior right to divert 12,481 cfs for municipal supply above station. Ten small reservoirs above station (total capacity, about 400 acre-ft) for irrigation, stock water, and domestic use. Two reservoirs above station (total capacity, about 12,000 acre-ft) for municipal supply and power development for Cheyenne.

Yearly Runoff:

Water Year	Acre-Feet
1923	9,370
1924	17,700
1925	-
1951	-
1952	7,590
1953	6,960
1954	5,680
1955	7,400

TABLE C4-31: (continued)

Water Year	Acre-Feet
1956	6,200
1957*	8,720
Average for 8 years of record	8,702

- Flows were not recorded for the entire water year.
* Gaging Station discontinued.
[1]USGS, 1958 and 64a.

TABLE C4-32: USGS Gaging Station #7565, "Crow Creek near Barnesville, Colorado."[1]

Location: Lat 40°29'35", long 104°26'35", in NE¼NW¼ sec. 16, T.6N., R.63W., on left bank 1 mile upstream from wasteway of Greeley Canal No. 2, 2 miles northeast of Barnesville, and 15½ miles upstream from mouth.

Drainage Area: 1,324 Square miles

Period of Record: July 1951 to September 1957 (discontinued)

Gage: Staff gage. Altitude of gage is 4,670 ft (from topographic map).

Extremes: No flow was recorded over the entire period of record of this gaging station.

Accuracy: Not applicable

Remarks: All flow above station is normally diverted or stored in numerous small reservoirs for municipal supply, stock water, and irrigation.

[1]USGS, 1964a.

TABLE C4-33: USGS Gaging Station #7590, "Bijou Creek near Wiggins, Colorado."[1]

Location: Lat 40°14'53", long 104°02'08", in SW¼SW¼ sec. 6, T.3N., R.59W., on downstream side of fifth pier from right end of bridge on U.S. Highways 6 and 34, 2 miles northeast of Wiggins, and 5.7 miles downstream from Antelope Creek.

Drainage Area: 1,314 Square miles

Period of Record: April 1960 to September 1956 (discontinued)

Gage: Water-stage recorder. Altitude of gage is 4,490 ft (from topographic map).

Extremes: Maximum discharge, 50,100 cfs Aug. 3, 1951; no flow for most of each year.

Accuracy: Not available.

Remarks: Small diversions above station for irrgation.

Yearly Runoff:

Water Year	Acre-Feet
1950	-
1951	24,070
1952	3,750
1953	1,190
1954	2,370
1955	2,450
1956*	6,220
Average for 6 years of record	6,675

- Flows were not recorded for the entire water year.
* Gaging station discontinued.
[1]USGS, 1968, 64a.

TABLE C4-34: USGS Gaging Station #607581, "West Kiowa Creek at Elbert, Colorado."[1]

Location: Lat 39°12'38", long 104°32'16", to SE¼NE¼ sec. 3, T.10S., R.64W., on right bank 260 ft downstream from bridge on State Highway 217, a quarter of a mile south of Elbert, and half a mile upstream from mouth.

Drainage Area: 35.9 Square miles

Period of Record: August 1962 to September 1965 (discontinued)

Gage: Water-stage recorder. Altitude of gage is 6,740 ft (from topographic map).

Extremes: Maximum discharge, 20,000 cfs June 17, 1965; no flow for many days in each year. Maximum flood known, that of June 17, 1965. Flood of May 30-31, 1936, 43,500 cfs, by slope-area measurement of peak flow at site about 1 mile downstream (most of water is believed to have passed this station).

Accuracy: Generally, records are fair, except those for the 1965 water year, which are poor.

Remarks: Floodflows decreased by a series of about 12 retarding dams on West Kiowa Creek and tributaries above station.

Yearly Runoff:

Water Year	Acre-Feet
1962	-
1963	172
1964	88
1965*	2,220
Average for 3 years of record	827

- Flows were not recorded for the entire water year.
* Gaging station discontinued
[1]USGS, 1969a.

TABLE C4-35: USGS Gaging Station #6-7580, "Kiowa Creek at Elbert, Colorado."[1]

Location: Lat 39°12'35", long 104°32'00", in SE¼NE¼ sec. 3, T.10S., R.64W., on right bank a quarter of a mile southeast of Elbert and half a mile upstream from West Kiowa Creek.

Drainage Area: 28.6 Square miles

Period of Record: May 1955 to September 1965 (discontinued).

Gage: Water-stage recorder. Altitude of gage is 6,740 ft (from topographic map).

Extremes: Maximum discharge, 305 cfs Aug. 27, 1955; no flow for most of each year, no flow during water years 1963-64. Maximum flood known occurred May 30-31, 1935; discharge at site about 1 mile downstream, 43,500 cfs, by slope-area measurement of peak flow. Most of the water is believed to have passed this station.

Accuracy: Generally, records are poor.

Remarks: Floodflows decreased by a series of about 24 retarding dams on Kiowa Creek and tributaries.

Yearly Runoff:

Water Year	Acre-Feet
1955	-
1956	0
1957	129
1958	18
1959	0
1960	658
1961	7
1962	11
1963	0
1964	0
1965*	5,420
Average for 10 years of record	644

- Flows were not recorded for the entire water year.
* Gaging station discontinued.
[1]USGS, 1964a, 69a.

TABLE C4-36: USGS Gaging Station #6-7582, "Kiowa Creek at Kiowa, Colorado."[1]

Location: Lat 39°20', long 104°29', in SW¼ sec. 20, T.8S., R.63W., on left bank 0.7 miles upstream from bridge on State Highway 86 and 0.7 miles south of Kiowa.

Drainage Area: 111 Square miles

Period of Record: October 1955 to September 1965 (discontinued)

Gage: Water-stage recorder. Altitude of gage is 6,350 ft (estimated from nearby bench mark).

Extremes: Maximum discharge, 19,700 cfs June 17, 1965; no flow for many days in each year. Maximum flood known occurred May 30-31, 1935; discharge at Elbert about 9½ miles upstream, 43,500 cfs, and at site about 12 miles downstream, 110,000 cfs, by slope-area measurement of peak flow.

Accuracy: Generally, records are poor.

Remarks: Little or no diversion above station. Floodflow regulated to some extent by a series of about 64 retarding dams on Kiowa Creek and tributaries above station.

Yearly Runoff:

Water Year	Acre-Feet
1956	1,050
1957	5,140
1958	1,570
1959	884
1960	5,880
1961	1,930
1962	1,930
1963	1,060
1964	873
1965*	7,190
Average for 10 years of record	2,751

* Gaging station discontinued.
[1]USGS, 1964a, 69a.

TABLE C4-37: USGS Gaging Station #6-7583, "Kiowa Creek at Bennett, Colorado."[1]

Location: Lat 39°44'54", long 104°24'46", in NW¼ sec. 35, T.3S., R.63W., on left bank a quarter of a mile downstream from U.S. Highways 36, 40 and 287 (relocated), and 1 mile east of Bennett.

Drainage Area: 236 Square miles

Period of Record: March 1960 to September 1964 (discontinued)

Gage: Water-stage recorder. Altitude of gage is 5,430 ft (from topographic map). Prior to Oct. 1, 1960, at datum 0.15 ft higher.

Extremes: Maximum discharge, 3,420 cfs Sept. 22, 1963; no flow for many days in each year.

Accuracy: Generally, records are fair, except for those during water years 1963-64, winter periods, and no gage height record periods which are poor.

Remarks: Little or no diversion above station. Floodflow regulated to some extent by a series of retarding dams on Kiowa Creek and tributaries above station.

Yearly Runoff:

Water Year	Acre-Feet
1960	-
1961	2,700
1962	2,140
1963	2,200
1964*	1,460
Average for 4 years of record	2,125

- Flows were not recorded during the entire water year.
* Gaging station discontinued.
[1]USGS, 1964a, 1969a.

TABLE C4-38: USGS Gaging Station #286, "South Fork Lodgepole Creek near Federal, Wyoming."[1]

Location: Lat 41°16'20", long. 105"13'00", in sec. 15, T. 15N, R.70W., 5½ miles west of Federal and 9 miles upstream from mouth.

Drainage Area: 16 Square miles

Period of Record: June 1933 to September 1938, (discontinued). Records are not available for many months.

Gage: Water-stage recorder. Altitude of gage is 7,080 ft (from topographic map).

Extremes: Maximum discharge, 410 cfs Sept. 8, 1933; no flow at times during 1934, 1936-37.

Accuracy: Not available.

Remarks: Diversions above station for irrigation of about 100 acres.

Yearly Runoff:

Water Year	Acre-Feet
1933	-
1934	747
1935	1,670
1936	-
1937	-
1938*	-
Average for 2 years of record	1,209

- Flows were not recorded for the entire water year.

* Gaging station discontinued.

[1]USGS, 1958.

TABLE C4-39: USGS Gaging Station #285, "Lodgepole Creek near Federal, Wyoming."[1]

Location: Lat 41°18'40", long. 105°13'00", in sec. 34, T.16N., R.70W., 1¼ miles upstream from North Fork and 6 miles northwest of Federal.

Drainage Area: 25 Square miles approximately

Period of Record: June 1933 to September 1938, (discontinued). Records are not available for many months.

Gage: Water-stage recorder. Altitude of gage is 6,970 ft (from topographic map).

Extremes: Maximum discharge, 89 cfs May 31, 1935; no flow at times in most years.

Accuracy: Not available.

Remarks: Diversions above station for irrigation of about 200 acres.

Yearly Runoff:

Water Year	Acre-Feet
1933	-
1934	732
1935	2,770
1936	-
1937	-
1938*	-
Average for 2 years of record	1,751

- Flows were not recorded for the entire water year.
* Gaging station discontinued.
[1]USGS, 1958.

TABLE C4-40: USGS Gaging Station #06762500, "Lodgepole Creek at Bushnell, Nebraska."[1]

Location: Lat 41°13'43", long 103°48'03", in sec. 33, T.15W., R.57W., Kimball County, on right bank 1.5 miles east of Bushnell and 1.5 miles upstream from Oliver Reservoir. Approximately 11 miles downstream (east) from the Wyoming-Nebraska State line.

Drainage Area: 1,361 Square miles

Period of Record: October 1931 to current year. Records for March to September 1931 at site 1.5 miles (2.4 kn) upstream not equivalent owing to diversions. Monthly discharge only for some periods.

Gage: Water-stage recorder. Datus of gage is 4,812.3 ft above mean sea level. Prior to March 26, 1938, nonrecording gage at present site and datum.

Extremes: Maximum discharge, 16,500 cfs, Sept. 15, 1950; minimum daily 1.2 cfs Dec. 14, 1935.

Accuracy: Generally, records are fair.

Remarks: Natural flow of stream affected by ground-water withdrawals and diversions for irrigation and return flow from irrigation areas. Diversions for irrigation of about 12,600 acres above station.

Yearly Runoff:

Water Year	Acre-Feet
1931*	-
1932	12,630
1933	14,200
1934	9,700
1935	13,100
1936	9,400
1937	9,020
1938	11,080
1939	9,230
1940	7,790
1941	9,350
1942	9,260
1943	9,200
1944	9,480
1945	9,900
1946	9,660
1947	8,240
1948	9,150

(continued)

TABLE C4-40: (continued)

Water Year	Acre-Feet
1949	6,150
1950	8,830
1951	10,420
1952	7,400
1953	7,830
1954	6,310
1955	8,810
1956	6,890
1957	9,390
1958	10,150
1959	9,700
1960	8,720
1961	10,090
1962	9,640
1963	8,290
1964	5,270
1965	6,780
1966	7,650
1967	7,600
1968	7,700
1969	6,570
1970	5,940
1971	5,310
1972	4,840
1973	5,710
1974	4,600
1975	NA
Average annual runoff for 43 years of data	8,582

- Flows were not recorded for the entire water year.
* Gaging station at site 1.5 miles upstream. Flow records not equivalent owing to diversions.
NA Records not published as of the date of this study.
[1]USGS, 1958, 64a, 69a, 71, 72, 73a, 73b, 74, 75.

TABLE C4-41: USGS Gaging Station #06763500, "Lodgepole Creek at Ralton, Nebraska."[1]

Location: Lat 41°02'00", long 102°24'00", in NE1/4NE1/4 sec. 12, T.12N., R.45W., Deuel County, on right bank 20 ft downstream from county road bridge at Ralton, 2.1 miles north of Colorado-Nebraska State line, and 5.5 miles southeast of Chappell.

Drainage Area: 3,307 Square miles

Period of Record: March to September 1931, June 1951 to current year.

Gage: Water-stage recorder. Altitude of gage is 3,590 ft (from topographic map). March to September 1931, nonrecording gage at site 0.2 miles downstream at different datum.

Extremes: Maximum discharge, 4,560 cfs, Aug. 15, 1968; no flow at times in 1931, 1955, 1957, 1960, 1963-65, 1968, 1973-74.

Accuracy: Generally, records are fair, except for those during winter periods which are poor.

Remarks: Natural flow of stream affected by ground-water withdrawals and diversions for irrigation and return flow from irrigated areas. Diversion for irrigation of about 24,300 acres (98.3 km^2) above station.

Yearly Runoff:

Water Year	Acre-Feet
1931	-
1951	-
1952	14,350
1953	7,900
1954	7,670
1955	8,040
1956	4,140
1957	3,710
1958	14,410
1959	12,250
1960	6,080
1961	4,970
1962	8,210
1963	7,090
1964	1,450
1965	11,060
1966	10,320
1967	7,120
1968	13,460
1969	7,230

(continued)

TABLE C4-41: (continued)

Water Year	Acre-Feet
1970	6,210
1971	5,760
1972	3,150
1973	2,630
1974	1,070
1975	NA
Average annual runoff for 23 years of record	7,336

\- Flows were not recorded for the entire water year.
NA Records not published as of the date of this study.
[1]USGS, 1958, 64a, 69a, 71, 72, 73a, 73b, 74, 75.

TABLE C4-42: USGS Gaging Station #06764000, "South Platte River at Julesburg, Colorado."[1]

Location: Lat 40°58'46", long 102°15'15", in NW¼NE¼ (two channels) sec. 33, T.12N., R.44W., Sedgwick County, on left bank of channel no. 2, 800 ft downstream from bridge on U.S. Highway 385, 0.9 miles southeast of Julesburg, 3.0 miles upstream from Colorado-Nebraska State line, and 8 miles downstream from Lodgepole Creek.

Drainage Area: 23,138 Square miles

Period of Record: April 1902 to current year. Monthly discharge only for some periods. Published as "near Julesburg" 1903-08, 1915-16, and as "at Ovid" 1922-24.

Gage: Two water-stage recorders. Datum of gages is 3,446.76 feet above mean sea level. Apr. 1, 1902, to May 10, 1922, staff or chain gages, and Oct. 1, 1924, to Sept. 30, 1956, water-stage recorder on channel 1,600 ft to right to several sites within 1,800 ft of present site at various datums. May 11, 1922 to Sept. 30, 1924, water-stage recorder and supplemental chain gages at site about 8½ miles upstream at Ovid at different datum. Oct. 1, 1956, to Dec. 10, 1958, water-stage recorder at site 135 ft downstream at present datum (used as a supplemental gage Oct 1, 1941 to Sept. 30, 1956). Since Oct. 1, 1956 water-stage recorders on channels nos. 2 and 4. Channel no. 2: Oct. 1, 1956, to Sept. 22, 1965, at site 300 ft (41 m) downstream at present datum. Since May 11, 1973, supplementary water-stage recorder on channel no. 2 at bridge 800 ft (244 m) upstream at same datum.

Extremes: Maximum discharge: 37,600 cfs, June 20, 1965; no flow August 18-20, 1902, July 25 to August 7, 1903.

Accuracy: Generally, records are fair.

Remarks: Natural flow of stream affected by transbasin diversions, storage reservoirs, power developments, ground water withdrawals and diversions for irrigation of 1,200,000 acres above station, and reutrn flow from irrigated areas.

Yearly Runoff:

Water Year	Acre-Feet
1902	-
1903	87,300
1904	181,000
1905	921,000
1906	175,000
1907	508,000
1908	166,000

(continued)

TABLE C4-42: (continued)

Water Year	Acre-Feet
1909	548,000
1910	405,000
1911	93,100
1912	145,000
1913	167,000
1914	879,000
1915	664,000
1916	315,000
1917	575,000
1918	253,000
1919	241,000
1920	305,000
1921	788,000
1922	241,000
1923	556,000
1924	1,130,000
1925	153,000
1926*	395,000
1927	295,000
1928	316,000
1929	321,000
1930	306,000
1931	217,000
1932	115,000
1933	117,000
1934	117,100
1935	296,200
1936	87,880
1937	72,660
1938	165,200
1939	438,000
1940	61,790
1941	64,800
1942	1,092,000
1943	360,300
1944	259,900
1945	206,900
1946	258,800
1947	553,000
1948	408,600
1949	648,600
1950	195,800
1951	195,600
1952	337,700
1953	148,100
1954	101,000
1955	73,080
1956	55,400
1957	379,900

(continued)

TABLE C4-42: (continued)

Water Year	Acre-Feet
1958	657,500
1959	249,200
1960	202,600
1961	327,200
1962	614,600
1963	183,100
1964	102,500
1965	438,200
1966	374,900
1967	259,200
1968	201,800
1969	475,700
1970	816,600
1971	588,100
1972	200,400
1973	1,101,000
1974	487,200
1975	255,400
Average annual for 73 years of record	351,752

*Enactment date of the South Platte River Compact (March 8, 1926).
- Flows were not recorded for the entire water year.
[1]USGS, 1958, 64a, 69a, 71, 72, 73a, 73b, 74, 75.

APPENDIX D

LEGAL DOCUMENTS PERTINENT TO THE ALLOCATION OF WATER TO THE SOUTH PLATTE RIVER BASIN

INTRODUCTION

Besides the constraints of the water laws of the states of Wyoming and Colorado, the various interstate and international decrees, compacts and treaties found within this appendix affect the amount of water the South Platte River Basin can import from the North Platte River Basin, the Colorado River Basin, and the Arkansas River Basin.

This material is from "Colorado Water Laws - A Compilation of Statutes, Regulations, Compacts, and Selected Cases," compiled and edited by George E. Radosevich et al., 1975.

SECTION D1

LITIGATION CONCERNING THE WATERS OF THE NORTH PLATTE RIVER BASIN WHICH AFFECT THEIR AVAILABILITY FOR EXPORT TO THE SOUTH PLATTE RIVER BASIN

Exhibit DI-1: THE NORTH PLATTE RIVER DECREE AS EXCERPTED FROM NEBRASKA v. WYOMING 325 U.S. 589 (1945)

This cause having been heretofore submitted on the report of the Special Master and the exceptions of the parties thereto, and the Court being now fully advised in the premises:

It is ordered, adjudged, and decreed that:

I. The State of Colorado, its officers, attorneys, agents and employees, be and they are hereby severally enjoined–

(a) From diverting or permitting the diversion of water from the North Platte River and its tributaries for the irrigation of more than a total of 135,000 acres of land in Jackson County, Colorado, during any one irrigation season;

(b) From storing or permitting the storage of more than a total amount of 17,000 acre feet of water for irrigation purposes from the North Platte River and its tributaries in Jackson County, Colorado, between October 1 of any year and September 30 of the following year;

(c) From exporting out of the basin of the North Platte River and its tributaries in Jackson County, Colorado, to any other stream basin or basins more than 60,000 acre feet of water in any period of ten consecutive years reckoned in continuing progressive series beginning with October 1, 1945.

II. Exclusive of the Kendrick Project and Seminoe Reservoir the State of Wyoming its officers, attorneys, agents and employees, be and they are hereby severally enjoined–

(a) From diverting or permitting the diversion of water from the North Platte River above the Guernsey Reservoir and from the tributaries entering the North Platte River above the Pathfinder Dam for the irrigation of more than a total of 168,000 acres of land in Wyoming during any one irrigation season.

(b) From storing or permitting the storage of more than a total amount of 18,000 acre feet of water for irrigation purposes from the North Platte River and its tributaries above the Pathfinder Reservoir between October 1 of any year and September 30 of the following year.

III. The State of Wyoming, its officers, attorneys, agents and employees, be and they are hereby severally enjoined from storing or permitting the storage of water in Pathfinder, Guernsey, Seminoe and Alcova Reservoirs otherwise then in accordance with the relative storage rights, as among themselves, of such reservoirs, which are hereby defined and fixed as follows:

First, Pathfinder Reservoir;
Second, Guernsey Reservoir;
Third, Seminoe Reservoir; and
Fourth, Alcova Reservoir;

Provided, however, that water may be impounded in or released from Seminoe Reservoir, contrary to the foregoing rule of priority operation for use in the generation of electric power when and only when such storage or release will not materially interfere with the administration of water for irrigation purposes according to the priority decreed for the French Canal and the State Line Canals.

IV. The State of Wyoming, its officers, attorneys, agents and employees be and they are hereby severally enjoined from storing or permitting the storage of water in Pathfinder, Guernsey, Seminoe or Alcova Reservoirs, and from the diversion of natural flow water through the Casper Canal for the Kendrick Project between and including May 1 and September 30 of each year otherwise than in accordance with the rule of priority in relation to the appropriations of the Nebraska lands supplied by the French Canal and by the State Line Canals, which said Nebraska appropriations are hereby adjudged to be senior to said four reservoirs and said Casper Canal, and which said Nebraska appropriations are hereby identified and defined, and their diversion limitations in second feet and seasonal limitations in acre feet fixed as follows:

Lands	Canal	Limitation in Second Feet	Seasonal Limitation in Acre Feet
Tract of 1,025 acres	French	15	2,227
Mitchell Irrigation District	Mitchell	195	35,000
Gering Irrigation District	Gering	193	36,000
Farmers Irrigation District	Tri-State	748	183,050
Ramshorn Irrigation District	Ramshorn	14	3,000

V. The natural flow in the Guernsey Dam to Tri-State Dam section between and including May 1 and September 30 of each year, including the contribution of Spring Creek, be and the same hereby is apportioned between Wyoming and Nebraska on the basis of twenty-five per cent to Wyoming and seventy-five per cent to Nebraska, with the right granted Nebraska to designate from time to time the portion of its share which shall be delivered into the Inter–State, Fort Laramie, French and Mitchell Canals for use on the Nebraska lands served by these canals. The State of Nebraska, its officers, attorneys, agents and employees and the State of Wyoming, its officers, attorneys, agents and employees, are hereby enjoined and restrained from diversion or use contrary to this apportionment, provided that in the apportionment of water in this section the flow for each day, until ascertainable, shall be assumed to be the same as that of the preceding day, as shown by the measurements and computations for that day, and provided further, that unless and until Nebraska, Wyoming and the United States agree upon a modification thereof, or upon another formula, reservoir evaporation and transportation losses in the segregation of natural flow and storage shall be computed in accordance with the following formula taken from United States' Exhibit 204A:

Reservoir evaporation losses

Seminoe, Pathfinder and Alcova Reservoirs.—Evaporation will be computed daily based upon evaporation from Weather Bureau Standard 4 foot diameter Class "A" pan located at Pathfinder Reservoir. Daily evaporation will be multiplied by area of water surface of reservoir in acres and by co-efficient of 70 per cent to reduce pan record to open water surface.

Guernsey Reservoir.—Compute same as above except use pan evaporation at Whalen Dam.

River carriage losses

River carriage losses will be computed upon basis of area of river water surface as determined by aerial surveys made in 1939 and previous years and upon average monthly evaporation at Pathfinder Reservoir for the period 1921 to 1939, inclusive, using a co-efficient of 70 per cent to reduce pan records to open water surface. Daily evaporation losses in second-feet for various sections of the river are shown in the following table:

River Section	Area (Acres)	Daily Loss (Second-Feet)				
		May	June	July	August	Sept.
Alcova to Wendover	8,360	53	76	87	76	56
Guernsey Res. to Whalen	560	4	5	6	5	4
Whalen to State Line	2,430	16	22	25	22	16

Above table is based upon mean evaporation at Pathfinder as follows: May 0.561 ft.; June 0.767 ft.; July 0.910 ft.; Aug. 0.799 ft., Sept. 0.568 ft; Co-efficient of 70 per cent to reduce pan record to open water surface.

Above table does not contain computed loss for section of river from Pathfinder Dam to head of Alcova Reservoir (area 170 acres) because this area is less than submerged area of original river bed in Alcova Reservoir, and is, therefor, considered as off-set.

Likewise the area between Seminoe Dam and head of Pathfinder Reservoir is less than area of original river bed through Pathfinder Reservoir—considered as off-set. Evaporation losses will be divided between natural flow and storage water flowing in any section of river channel upon a proportional basis. This proportion will ordinarily be determined at the upper end of the section except under conditions of intervening accruals or diversions that materially change the ratio of storage to natural flow at the lower end of the section. In such event the average proportion for the section will be determined by using the mean ratio for the two ends of the section.

In the determination of transportation losses for the various sections of the stream, such time intervals for the passage of water from point to point shall be used as may be agreed upon by Nebraska, Wyoming and the United States, or in the absence of such agreement, as may be decided upon from day to day by the manager of the government reservoirs, with such adjustments to be made by said manager from time to time as may be necessary to make as accurate a segregation as is possible.

VI. This decree is intended to and does deal with and apportion only the natural flow of the North Platte River. Storage water shall not be affected by this decree and the owners of rights therein shall be permitted to distribute the same in accordance with any lawful contracts which they may have entered into or may in the future enter into without interference because of this decree.

VII. Such additional gauging stations and measuring devices at or near the Wyoming-Nebraska state line, if any, as may be necessary for making any apportionment herein decreed, shall be constructed and maintained at the joint and equal expense of Wyoming and Nebraska to the extent that the costs thereof are not paid by others.

VIII. The State of Wyoming, its officers, attorneys, agents and employees be and they are hereby severally enjoined from diverting or permitting the diversion of water from the North Platte River or its tributaries at or above Alcova Reservoir in lieu of or in exchange for return flow water from the Kendrick Project reaching the North Platte River below Alcova Reservoir.

IX. The State of Wyoming and the State of Colorado be and they hereby are each required to prepare and maintain complete and accurate records of the total area of land irrigated and the storage and exportation of the water of the North Platte River and its tributaries within those portions of their respective jurisdictions covered by the provisions of paragraphs I and II hereof, and such records shall be available for inspection at all reasonable times; provided, however, that such records shall not be required in reference to the water uses permitted by paragraph X hereof.

X. This decree shall not affect or restrict the use or diversion of water from the North Platte River and its tributaries in Colorado or Wyoming for ordinary and usual domestic, municipal and stock watering purposes and consumption.

XI. For the purposes of this decree:

(a) "Season" or "seasonal" refers to the irrigation season, May 1 to September 30, inclusive;

(b) The term "storage water" as applied to releases from reservoirs owned and operated by the United States is defined as any water which is released from reservoirs for use on lands under canals having storage contracts in addition to the water which is discharged through those reservoirs to meet natural flow uses permitted by this decree;

(c) "Natural flow water" shall be taken as referring to all water in the stream except storage water;

(d) Return flows of Kendrick Project shall be deemed to be "natural flow water" when they have reached the North Platte River, and subject to the same diversion and use as any other natural flow in the stream.

XII. This decree shall not affect:

(a) The relative rights of water users within any one of the States who are parties to this suit except as may be otherwise specifically provided herein;

(b) Such claims as the United States has to storage water under Wyoming law; nor will the decree in any way interfere with the ownership and operation by the United States of the various federal storage and power plants, works and facilities.

(c) The use or disposition of any additional supply or supplies of water which in the future may be imported into the basin of the North Platte River from the water shed of an entirely separate stream, and which presently do not enter said basin, or the return flow from any such supply or supplies.

(d) The apportionment heretofore made by this Court between the States of Wyoming and Colorado of the waters of the Laramie River, a tributary of the North Platte River;

(e) The apportionment made by the compact between the States of Nebraska and Colorado, apportioning the water of the South Platte River.

XIII. Any of the parties may apply at the foot of this decree for its amendment or for further relief. The Court retains jurisdiction of this suit for the purpose of any order, direction, or modification of the decree, or any supplementary decree, that may at any time be deemed proper in relation to the subject matter in controversy. Matters with reference to which further relief may hereafter be sought shall include, but shall not be limited to, the following:

(a) The question of the applicability and effect of the Act of August 9, 1937, 50 Stat. 564,595-596, upon the rights of Colorado and its water users when and if water hereafter is available for storage and use in connection with the Kendrick Project in Wyoming.

(b) The question of the effect upon the rights of upstream areas of the construction or threatened construction in downstream areas of any projects not now existing or recognized in this decree;

(c) The question of the effect of the construction or threatened construction of storage capacity not now existing on tributaries entering the North Platte River between Pathfinder Reservoir and Guernsey Reservoir;

(d) The question of the right to divert at or above the headgate of the Casper Canal any water in lieu of, or in exchange for, any water developed by artificial drainage to the river of sump areas on the Kendrick Project;

(e) Any question relating to the joint operation of Pathfinder, Guernsey, Seminoe and Alcova Reservoirs whenever changed conditions make such joint operation possible;

(f) Any change in conditions making modification of the decree or the granting of further relief necessary or appropriate.

XIV. The costs in this cause shall be apportioned and paid as follows: the State of Colorado one-fifth; the State of Wyoming two-fifths; and the State of Nebraska two-fifths. Payment of the fees and expenses of the Special Master has been provided by a previous order of this Court.

XV. The clerk of this Court shall transmit to the chief magistrates of the States of Colorado, Wyoming, and Nebraska, copies of this decree duly authenticated under the seal of this Court.

NOTES ON NEBRASKA v. WYOMING DECREE

On June 15, 1953, the Court, having received a joint motion of the parties to the above cause for approval of a stipulation dated January 14, 1953, and to modify and supplement the decree heretofore set out, entered an order (345 U.S. 981) approving the stipulation and modifying and supplementing the decree in the following respects:

"1. In paragraph I (a) of the decree the figure '145,000' is substituted for the figure '135,000'.

"2. Paragraph XIII is amended by striking the first sentence and substituting for it the following:

"Any of the parties may apply at the foot of this decree for its amendment or for further relief, except that for a period of five years from and after June 15, 1953, the State of Colorado shall not institute any proceedings for the amendment of the decree or for further relief. In the event that within said period of five years any other party applies for an amendment of the decree or for further relief, then the State of Colorado may assert any and all rights, claims or defenses available to it under the decree as amended.

"3. Two new paragraphs, as follows, are added to the decree:

"XVI. Whatever claims or defenses the parties or any of them may have in respect to the application, interpretation or construction of the Act of August 9, 1937 (50 Stat. 564-595) shall be determined without prejudice to any party arising because of any development of the Kendrick Project occurring subsequent to October1, 1951.

"XVII. When Glendo Dam and Reservoir are constructed, the following provisions shall be effective:

"(a) The construction and operation of the Glendo Project shall not impose any demand on areas at or above Seminoe Reservoir which will prejudice any rights that the States of Colorado or Wyoming might have to secure a modification of the decree permitting an expansion of water uses in the natural basin of the North Platte River in Colorado or above Seminoe Reservoir in Wyoming.

"(b) The construction and operation of Glendo Reservoir shall not affect the regimen of the natural flow of the North Platte River above Pathfinder Dam. The regimen of the natural flow of the North Platte River below Pathfinder Dam shall not be changed, except that not more than 40,000 acre feet of the natural flow of the North Platte River and its tributaries which cannot be stored in upstream reservoirs under the provisions of this decree may be stored in the Glendo Reservoir during any water year, in addition to evaporation losses on such storage, and further, the amount of such storage water that may be held in storage at any one time, including carryover storage, shall never exceed 100,000 acre feet. Such storage water shall be disposed of in accordance with contracts to be hereafter executed, and it may be used for the irrigation of lands in the basin of the North Platte River in western Nebraska to the extent of 25,000 acre feet annually, and for the irrigation of lands in the basin of the North Platte River in southeastern Wyoming below Guernsey Reservoir to the extent of 15,000 acre feet annually, provided that it shall not be used as a substitute for storage water contracted for under any existing permanent arrangements. The above limitation on storage of natural flow does not apply to flood water which may be temporarily stored in any capacity allocated for flood control in the Glendo Reservoir, nor to water originally stored in Pathfinder Reservoir which may be temporarily re-stored in Glendo Reservoir after its release from Pathfinder and before its delivery pursuant to contract; nor to water which may be impounded behind Glendo Dam, as provided in the Bureau of Reclamation Definite Plan Report for the Glendo Unit dated December 1952, for the purpose of creating a head for the development of water power.

"(c) Paragraph III of the decree is amended to read as follows:

"III. The State of Wyoming, its officers, attorneys, agents and employees, be and they are hereby severally enjoined from storing or permitting the storage of water in Pathfinder, Guernsey, Seminoe, Alcova and Glendo Reservoirs otherwise than in accordance with the relative storage rights, as among themselves, of such reservoirs, which are hereby defined and fixed as follows:

First, Pathfinder Reservoir;
Second, Guernsey Reservoir;
Third, Seminoe Reservoir;
Fourth, Alcova Reservoir; and
Fifth, Glendo Reservoir;

Provided, however that water may be impounded in or released from Seminoe Reservoir, contrary to the foregoing rule of priority operation for use in the generation of electric power when and only when such storage or release will not materially interfere with the administration of water for irrigation purposes according to the priority decreed for the French Canal and the State Line Canals.

"Storage rights of Glendo Reservoir shall be subject to the provisions of this paragraph III.

"(d) Paragraph IV of the decree is amended to read as follows:

"IV. The State of Wyoming, its officers, attorneys, agents and employees be and they are hereby severally enjoined from storing or permitting the storage of water in Pathfinder, Guernsey, Seminoe, Alcova and Glendo Reservoirs, and from the diversion of natural flow water through the Casper Canal for the Kendrick Project between and including May 1 and September 30 of each year otherwise than in accordance with the rule of priority in relation to the appropriations of the Nebraska lands supplied by the French Canal and by the State Line Canals, which said Nebraska appropriations are hereby adjudged to be senior to said five reservoirs and said Casper Canal, and which said Nebraska appropriations are hereby identified and defined, and their diversion limitation in second feet and seasonal limitations in acre-feet fixed as follows:

Lands	Canal	Limitation in Second-Feet	Seasonal Limitation in Acre-Feet
Tract of 1,025 acres	French	15	2,227
Mitchell Irrigation District	Mitchell	195	35,000
Gering Irrigation District	Gering	193	36,000
Farmers Irrigation District	Tri-State	748	183,050
Ramshorn Irrigation District	Ramshorn	14	3,000

"(e) Paragraph V of the decree is amended to read as follows:

"V. The natural flow in the Guernsey Dam to Tri-State Dam section between and including May 1 and September 30 of each year, including the contribution of Spring Creek, be and the same hereby is apportioned between Wyoming and Nebraska on the basis of twenty-five percent to Wyoming and seventy-five percent to Nebraska, with the right granted Nebraska to designate from time to time the portion of its share which shall be delivered into the Interstate, Fort Laramie, French and Mitchell Canals for use on the Nebraska lands served by these canals. The State of Nebraska, its officers, attorneys, agents and employees, and the State of Wyoming, its officers, attorneys, agents and employees, are hereby enjoined and restrained from diversion or use contrary to this apportionment, provided that in the apportionment of water in this section the flow for each day, until ascertainable, shall be assumed to be the same as that of the preceding day, as shown by the measurements and computations for that day, and provided further, that unless and until Nebraska, Wyoming and the United States agree upon a modification thereof, or upon another formula, reservoir evaporation and transportation losses in the segregation of natural flow and storage shall be computed in accordance with the following formula taken from United States' Exhibit 204A and the stipulation of the parties dated February 14, 1953, and filed on January 30, 1953:

Reservoir evaporation losses

Seminoe, Pathfinder and Alcova Reservoirs. —Evaporation will be computed daily based upon evaporation from Weather Bureau Standard 4 foot diameter Class A pan located at Pathfinder Reservoir. Daily evaporation will be multiplied by area of water surface of reservoir in acres and by co-efficient of 70 per cent to reduce pan record to open water surface.

Glendo and Guernsey Reservoirs.—Compute same as above except use pan evaporation at Whalen Dam.

River carriage losses

River carriage losses will be computed upon basis of area of river water surface as determined by aerial surveys made in 1939 and previous years and upon average monthly evaporation at Pathfinder Reservoir for the period of 1921 to 1939, inclusive, using a co-efficient of 70 per cent to reduce pan records to open water surface.

Daily evaporation losses in second-feet for various sections of the river are shown in the following table:

River Section	Area (Acres)	Daily Loss (Second Feet) May	June	July	Aug.	Sept.
Alcova to Glendo Reservoir	6,740	43	5	70	61	45
Guernsey Reservoir to Whalen	560	4	22	6	5	4
Whalen to State Line	2,430	16		25	22	16

Above table is based upon mean evaporation at Pathfinder as follows: May 0.561 ft.; June 0.767 ft.; July 0.910 ft.; Aug. 0.799 ft.; Sept. 0.568 ft. Co-efficient of 70 per cent to reduce pan record to open water surface.

Above table does not contain computed loss for section of river from Glendo Dam to head of Guernsey Reservoir (area 680 acres) because this area is less than submerged area of original river bed (940 acres) in Glendo Reservoir and is, therefore, considered as off-set.

Above table does not contain computed loss for section of river from Pathfinder Dam to head of Alcova Reservoir (area 170 acres) because this area is less than submerged area of original river bed in Alcova Reservoir and is, therefore, considered as off-set.

Likewise the area between Seminoe Dam and head of Pathfinder Reservoir is less than area of original river bed through Pathfinder Reservoir—considered as off-set. Evaporation losses will be divided between natural flow and storage water flowing in any section of river channel upon a proportional basis. This proportion will ordinarily be determined at the upper end of the section except under conditions of intervening accruals or diversions that materially change the ratio of storage to natural flow at the lower end of this section. In such event the average proportion for the section will be determined by using the mean ratio for the two ends of the section.

In the determination of transportation losses for the various sections of the stream, such time intervals for the passage of water from point to point shall be used as may be agreed upon by Nebraska, Wyoming and the United States, or in the absence of such agreement, as may be decided upon from day to day by the manager of the government reservoirs, with such adjustments to be made by said manager from time to time as may be necessary to make as accurate a segregation as is possible."

Reference to the decree as thus modified will be found in the Joint Resolution of July 16, 1954 (68 Stat. 486) which approved the definite plan report of the Secretary of the Interior for the Glendo unit of the Missouri River Basin project and directed that that unit be constructed and operated in accordance with the report and with the modified decree.

Exhibit DI-2: THE LARAMIE RIVER DECREE AS EXCERPTED FROM WYOMING v. COLORADO, 353 U.S. 953 (1957)

Upon consideration of the joint motion of counsel for the parties in this case to vacate the former decree (259 U.S. 496; 260 U.S. 1 (pp. 688f ante)), it is ordered that the joint motion be, and it is hereby granted and the former decree, as amended, is vacated and a new decree is entered to read as follows:

"IT IS ORDERED, ADJUDGED AND DECREED that:

"I. The State of Colorado, or anyone recognized by her as duly entitled thereto, shall have the right to divert from the Laramie river and its tributaries, for use in the State of Colorado, 49,375 acre-feet of water in each calendar year, which diversion and use shall be subject to the limitations and restrictions hereinafter set forth. The State of Wyoming, or anyone recognized by her as duly entitled thereto, shall have the right to divert and use all water flowing and remaining in the Laramie river and its tributaries after such diversion and use in Colorado.

"II. The State of Colorado, its officers, attorneys, agents and employees be, and they are severally enjoined—

"(a) from diverting or permitting the diversion of more than 19,875 acre-feet of water in any calendar year from the Laramie river and its tributaries for use in Colorado at any or all points outside of the basin of said river, which amount may be diverted by the present owners of transmountain water rights or by their successors in ownership, through any ditches, canals, tunnels or structures capable of carrying the same, as the owners of said water rights and of such structures may from time to time agree among themselves, or as may be determined by a court of competent jurisdiction;

"(b) from diverting or permitting the diversion of more than 29,500 acre-feet of water in any calendar year from the Laramie river and its tributaries for use in Colorado within the drainage basin of said river, of which amount not more than 1,800 acre-feet shall be diverted in any calendar year after July 31; provided, that if in any calendar year any part of all of said 19,875 acre-feet of water which may be diverted for use outside of the drainage basin of said river is not so diverted for use outside the drainage basin of said river, the amount not so diverted may be added to the amount which may be diverted hereunder for use in Colorado within the drainage basin of said river. Such water diverted for use in Colorado within the drainage basin of said river shall be diverted only through the headgates of ditches serving, and shall only be used to irrigate, those lands within the Laramie river basin in Colorado which are marked and designed by cross-hatching on Exhibit 'A' attached hereto and hereby made a part hereof, by the present owners of said lands and the water rights serving said lands or by their successors in ownership, and none of said waters shall be used for the irrigation of any lands not included within the boundaries of the lands sc indicated on Exhibit 'A'.

"III. Except as modified or restricted hereby, the relative rights to the use of Colorado's share of the Laramie river shall continue to be governed by the rules of appropriation and use as determined by the laws of Colorado, and shall be administered by its water officials.

"IV. This decree shall not prejudice or affect the right of the State of Colorado or the State of Wyoming, or of anyone recognized by either state as duly entitled thereto, to continue to exercise the right to divert and use water from Sand Creek, sometimes spoken of as a tributary of the Laramie river, in virtue of an existing and lawful appropriation of the waters of such creek.

"V. The Clerk of this Court shall transmit to the chief magistrates of the States of Wyoming and Colorado copies of this decree duly authenticated under the seal of this Court."

The motion of Ward Goodrich et al. for leave to intervene is denied.

SECTION D2

LITIGATION CONCERNING THE WATERS OF THE COLORADO RIVER BASIN WHICH AFFECT THEIR AVAILABILITY FOR EXPORT TO THE SOUTH PLATTE RIVER BASIN

Exhibit D2-1: COLORADO RIVER COMPACT

37-61-101. Colorado River Compact.-- The General Assembly hereby approves the compact, designated as the "Colorado River Compact", signed at the City of Santa Fe, State of New Mexico, on the 24th day of November, A.D. 1922, by Delph E. Carpenter, as the Commissioner for the State of Colorado, under authority of and in conformity with the provisions of an act of the General Assembly of the State of Colorado, approved April 2, 1921, entitled "An Act providing for the appointment of a Commissioner on behalf of the State of Colorado to negotiate a compact and agreement between the States of Arizona, California, Colorado, Nevada, New Mexico, Utah and Wyoming and between said States and the United States respecting the use and distribution of the waters of the Colorado River and the rights of said States and the United States thereto, and making an appropriation therefor.", the same being Chapter 246 of the Session Laws of Colorado, 1921, and signed by the Commissioners for the States of Arizona, California, Nevada, New Mexico, Utah, and Wyoming, under legislative authority, and signed by the Commissioners for said seven States and approved by the Representative of the United States of America under authority and in conformity with the provisions of an Act of the Congress of the United States, approved August 19, 1921, entitled "An Act to permit a compact or agreement between the States of Arizona, California, Colorado, Nevada, New Mexico, Utah and Wyoming, respecting the disposition and apportionment of the waters of the Colorado River, and for other purposes.", which said compact is as follows:

COLORADO RIVER COMPACT

The States of Arizona, California, Colorado, Nevada, New Mexico, Utah and Wyoming, having resolved to enter into a compact, under the Act of the Congress of the United States of America approved August 19, 1921, (42 Statutes at Large, page 171), and the Acts of the legislatures of the said states, have through their Governors appointed as their commissioners:
W. S. Norviel, for the State of Arizona;
W. F. McClure, for the State of California;
Delph E. Carpenter, for the State of Colorado;
J. G. Scrugham, for the State of Nevada;
Stephen B. Davis, Jr., for the State of New Mexico;
R. E. Caldwell, for the State of Utah;
Frank C. Emerson, for the State of Wyoming;
who, after negotiations participated in by Herbert Hoover appointed by the President as the representative of the United States of America, have agreed upon the following articles:

ARTICLE I

The major purposes of this compact are to provide for the equitable division and apportionment of the use of the waters of the Colorado River System; to establish the relative importance of different beneficial uses of water; to promote interstate comity; to remove causes of present and future controversies; and to secure the expeditious agricultural and industrial development of the Colorado River Basin, the storage of its waters and the protection of life and property from floods. To these ends the Colorado River Basin is divided into two Basins, and an apportionment of the use of part of the water of the Colorado River System is made to each of them with the provision that further equitable apportionments may be made.

ARTICLE II

As used in this Compact: -

(a) The term "Colorado River System" means that portion of the Colorado River and its tributaries within the United States of America.

(b) The term "Colorado River Basin" means all of the drainage area of the Colorado River System and all other territory within the Unived States of America to which the waters of the Colorado River System shall be beneficially applied.

(c) The term "States of the Upper Division" means the States of Colorado, New Mexico, Utah and Wyoming.

(d) The term "States of the Lower Division" means the States of Arizona, California and Nevada.

(e) The "Lee Ferry" means a point in the main stream of the Colorado River one mile below the mouth of the Paria River.

(f) The term "Upper Basin" means those parts of the States of Arizona, Colorado, New Mexico, Utah and Wyoming within and from which waters naturally drain into the Colorado River System above Lee Ferry, and also all parts of said States located without the drainage area of the Colorado River System which are now or shall hereafter be beneficially served by waters diverted from the System above Lee Ferry.

(g) The term "Lower Basin" means those parts of the States of Arizona, California, Nevada, New Mexico and Utah within and from which waters naturally drain into the Colorado River System below Lee Ferry, and also all parts of said States located without the drainage area of the Colorado River System which are now or shall hereafter be beneficially served by waters diverted from the System below Lee Ferry.

(h) The term "domesitc use" shall include the use of water for household, stock, municipal, mining, milling, industrial and other like purposes, but shall exclude the generation of electrical power.

ARTICLE III

(a) There is hereby apportioned from the Colorado River System in perpetuity to the Upper Basin and to the Lower Basin respectively the exclusive beneficial consumptive use of 7,500,000 acre feet of water per annum, which shall include all water necessary for the supply of any rights which may now exist.

(b) In addition to the apportionment in paragraph (a) the Lower Basin is hereby given the right to increase its beneficial consumptive use of such waters by one million acre per annum.

(c) If, as a matter of international comity, the United States of America shall hereafter recognize in the United States or Mexico any right to the use of any waters of the Colorado River System, such waters shall be supplied first from the waters which are surplus over and above the aggregate of the quantities specified in paragraphs (a) and (b); and if such surplus shall prove insufficient for this purpose, then, the burden of such deficiency shall be equally borne by the Upper Basin and the Lower Basin, and whenever necessary the States of the Upper Division shall deliver at Lee Ferry water to supply one-half of the deficiency so recognized in addition to that provided in paragraph (d).

(d) The states of the Upper Division will not cause the flow of the river at Lee Ferry to be depleted below an aggregate of 75,000,000 acre feet for any period of ten consecutive years reckoned in continuing progressive series beginning with the first day of October next succeeding the ratification of this compact.

(e) The States of the Upper Division shall not withhold water, and the States of the Lower Division shall not require the delivery of water, which cannot reasonably be applied to domestic and agricultural uses.

(f) Further equitable apportionment of the beneficial uses of the waters of the Colorado River System unapportioned by paragraphs (a), (b) and (c) may be made in the manner provided in paragraph (g) at any time after October first, 1963, if an when either basin shall have reached its total beneficial consumptive use as set out in paragraphs (a) and (b).

(g) In the event of the desire for a further apportionment as provided in paragraph (f) any two signatory States, acting through their Governors, may give joint notice of such desire to the Governors of the other signatory States and to the President of the United States of America, and it shall be the duty of the Governor of the signatory states and of the President of the United States of America forthwith to appoint representatives, whose duty it shall be to divide the apportion equitably between the Upper Basin and Lower Basin the beneficial use of the unapportioned water of the Colorado River System as mentioned in paragraph (f), subject to the Legislative ratification of the signatory States and the Congress of the United States of America.

ARTICLE IV

(a) Inasmuch as the Colorado River has ceased to be navigable for commerce and the reservation of its waters for navigation would seriously limit the development of its Basin, the use of its waters for purpose of navigation shall be subservient to the uses of such waters for domestic, agricultural and power purposes. If the Congress shall not consent to this paragraph, the other provisions of this compact shall nevertheless remain binding.

(b) Subject to the provisions of this compact, water of the Colorado River System may be impounded and used for the generation of electrical power, but such impounding and use shall be subservient to the use and consumption of such water for agricultural and domestic purposes and shall not interfere with or prevent use for such dominant purposes.

(c) The provisions of this article shall not apply to or interfere with the regulation and control by any state within its boundaries of the appropriation, use and distribution of water.

ARTICLE V

The Chief Official of each signatory State charged with the administration of water rights, together with the Director of the United States Reclamation Service and the Director of the United States Geological Survey shall co-operate, ex officio:

(a) To promote the systematic determination and coordination of the facts as to flow, appropriation, consumption and use of water in the Colorado River Basin, and the interchange of available information in such matters.

(b) To secure the ascertainment and publication of the annual flow of the Colorado River at Lee Ferry.

(c) To perform such other duties as may be assigned by mutual consent of the signatories from time to time.

ARTICLE VI

Should any claim or controversy arise between any two or more of the signatory States: (a) with respect to the waters of the Colorado River System not covered by the terms of this compact; (b) over the meaning or performance of any of the terms of this compact; (c) as to the allocation of the burdens incident to the performance of any article of this compact or the delivery of waters as herein provided; (d) as to the construction or operation of works within the Colorado River Basin to be situated in two or more States, or to be constructed in one State for the benefit of another State; or (e) as to the diversion of water in one State for the benefit of another State; the Governors of the States affected, upon the request of one of them, shall forthwith appoint Commissioners with poer to consider and adjust such claim or controversy, subject to ratification by the Legislatures of the States so affected.

Nothing herein contained shall prevent the adjustment of any such claim or controversy by any present method or by direct future legislative action of the interested States.

ARTICLE VII

Nothing in this compact shall be construed as affecting the obligations of the United States of America to Indian tribes.

ARTICLE VIII

Present perfected rights to the beneficial use of waters of the Colorado River System are unimpaired by this compact. Whenever storage capacity of 5,000,000 acre feet shall have been provided on the main Colorado River within or for the benefit of the Lower Basin, then claims of such rights, if any, by appropriators or users of waters in the Lower Basin, against appropriators or users of water in the Upper Basin shall attach to and be satisfied from water that may be stored not in conflict with Article III.

All other rights to beneficial use of waters of the Colorado River System shall be satisfied solely from the water apportioned to that Basin in which they are situate.

ARTICLE IX

Nothing in this compact shall be construed to limit or prevent any State from instituting or maintaining any action or proceeding, legal or equitable, for the protection of any right under this compact or the enforcement of any of its provisions.

ARTICLE X

This compact may be terminated at any time by the unanimous agreement of the signatory States. In the event of such termination all rights established under it shall continue unimpaired.

ARTICLE XI

This compact shall become binding and obligatory when it shall have been approved by the Legislatures of each of the signatory States and by the Congress of the United States. Notice of approval by the Legislatures shall be given by the Governor of each signatory State to the Governors of other signatory States and to the President of the United States, and the President of the United States is requested to give notice to the Governors of the signatory States of approval by the Congress of the United States.

In Witness Whereof, The Commissioners have signed this compact in a single original, which shall be deposited in the archives of the Department of State of the United States of America and of which a duly certified copy shall be forwarded to the Governor of each of the signatory States.

Done at the City of Santa Fe, New Mexico, this Twenty-fourth day of November, A.D. One Thousand Nine Hundred and Twenty-Two.

W. S. Norviel,
W. F. McClure,
Delph E. Carpenter,
J. G. Scrugham,
Stephen B. David, Jr.,
R. E. Caldwell,
Frank E. Emerson.

Approved:
Herbert Hoover.

37-61-102. Compact effective on approval.-- That said compact shall not be binding and obligatory on any of the parties thereto unless and until the same has been approved by the legislature of each of the said states and by the congress of the United States, and the governor of the state of Colorado shall give notice of the approval of said compact by the general assembly of the state of Colorado to the governors of each of the remaining signatory states and to the president of the United States, in conformity with article XI of said compact.

37-61-103. Approval waived.-- That the provisions of the first paragraph of article XI of the Colorado River Compact, making said compact effective when it has been approved by the legislature of each of the signatory states, are hereby waived and said compact shall become binding and obligatory upon the state of Colorado and upon the other signatory states, which have ratified or may hereafter ratify it, whenever at least six of the signatory states have consented thereto and the congress of the United States has given its consent and approval, but this article shall be of no force or effect until a similar act or resolution has been passed or adopted by the legislatures of the states of California, Nevada, New Mexico, Utah, and Wyoming.

37-61-104. Certified copies of compact.-- That certified copies of this article be forwarded by the governor of the state of Colorado to the president of the United States, the secretary of state of the United States, and the governors of the states of Arizona, California, Nevada, New Mexico, Utah, and Wyoming.

Exhibit D2-2: UPPER COLORADO RIVER COMPACT

37-62-101. Upper Colorado River compact.-- The general assembly hereby ratifies the compact among the states of Colorado, New Mexico, Utah, Wyoming, and Arizona, designated as the "Upper Colorado river basin compact" and signed in the city of Santa Fe, state of New Mexico, on the 11th day of October, A.D. 1948, by Clifford H. Stone, commissioner for the state of Colorado, Fred E. Wilson, commissioner for the state of New Mexico, Edward H. Watson, commissioner for the state of Utah, L. C. Bishop, commissioner for the state of Wyoming, Charles A. Carson, commissioner for the state of Arizona, and approved by Harry W. Bashore, representative of the United States of America. Said compact is as follows:

ARTICLE I

(a) The major purposes of this compact are to provide for the equitable division and apportionment of the use of the waters of the Colorado river system, the use of which was apportioned in perpetuity to the upper basin by the Colorado river compact; to establish the obligations of each state of the upper division with respect to the deliveries of water required to be made at Lee Ferry by the Colorado river compact; to promote interstate comity; to remove causes of present and future controversaries; to secure the expeditious agricultural and industrial development of the upper basin, the storage of water and to protect life and property from floods.

(b) It is recognized that the Colorado river compact is in full force and effect and all of the provisions hereof are subject thereto.

ARTICLE II

As used in this compact:

(a) The term "Colorado river system" means that portion of the Colorado river and its tributaries within the United States of America.

(b) The term "Colorado river basin" means all of the drainage area of the Colorado river system and all other territory within the United States of America to which the waters of the Colorado river system shall be beneficially applied.

(c) The term "states of the upper division" means the states of Colorado, New Mexico, Utah and Wyoming.

(d) The term "states of the lower division" means the states of Arizona, California and Nevada.

(e) The term "Lee ferry" means a point in the main stream of the Colorado river one mile below the mouth of the Paria river.

(f) The term "upper basin" means those parts of the states of Arizona, Colorado, New Mexico, Utah and Wyoming within and from which waters naturally drain into the Colorado river system above Lee ferry, and also all parts of said states located without the drainage area of the Colorado river system which are now or shall hereafter be beneficially served by waters diverted from the Colorado river system above Lee ferry.

(g) The term "Lower basin" means those parts of the states of Arizona, California, Nevada, New Mexico and Utah within and from which waters naturally drain into the Colorado river system below Lee ferry, and also all parts of said states located without the drainage area of the Colorado river system which are now or shall hereafter be beneficially served by waters diverted from the Colorado river system below Lee ferry.

(h) The term "Colorado river compact" means the agreement concerning the apportionment of the use of the waters of the Colorado river system dated November 24, 1922, executed by commissioners for the states of Arizona, California, Colorado, Nevada, New Mexico, Utah and Wyoming, approved by Herbert Hoover, representative of the United States of America, and proclaimed effective by the President of the United States of America, June 25, 1929.

(i) The term "Upper Colorado river system" means that portion of the Colorado river system above Lee ferry.

(j) The term "Commission" means the administrative agency created by article VIII of this compact.

(k) The term "water year" means that period of twelve months ending September 30 of each year.

(l) The term "acre-foot" means the quantity of water required to cover an acre to the depth of one foot and is equivalent to 43,560 cubic feet.

(m) The term "domestic use" shall include the use of water for household, stock municipal, mining, milling, industrial and other like purposes, but shall exclude the generation of electrical power.

(n) The term "virgin flow" means the flow of any stream undepleted by the activities of man.

ARTICLE III

(a) Subject to the provisions and limitations contained in the Colorado river compact and in this compact, there is hereby apportioned from the upper Colorado river system in perpetuity to the states of Arizona, Colorado, New Mexico, Utah and Wyoming, respectively, the consumptive use of water as follows:

(1) To the state of Arizona the consumptive use of 50,000 acre-fee of water per annum.

(2) To the states of Colorado, New Mexico, Utah and Wyoming, respectively, the consumptive use per annum of the quantites resulting from the application of the following percentages to the total quantity of consumptive use per annum appropriated in perpetuity to and available for use each year by upper basin under the Colorado river compact and remaining after the deduction of the use, not to exceed 50,000 acre-feet per annum, made in the state of Arizona.

State of Colorado	51.75 per cent,
State of New Mexico	11.25 per cent,
State of Utah	23.00 per cent,
State of Wyoming.	14.00 per cent.

(b) The apportionment made to the respective states by paragraph (a) of this article is based upon, and shall be applied in conformity with, the following principles and each of them:

(1) The apportionment is of any and all man-made depletions;

(2) Beneficial use is the basis, the measure and the limit of the right to use;

(3) No state shall exceed the apportioned use in any water year when the effect of such excess use, as determined by the commission, is to deprive another signatory state of its apportioned use during the water year; provided, that this subparagraph (b) (3) shall not be construed as:

(i) Altering the apportionment of use, or obligations to make deliveries as provided in article XI, XII, XIII or XIV of this compact;

(ii) Purporting to apportion among the signatory states of such uses of water as the upper basin may be entitled to under paragraphs (f) and (g) of article III of the Colorado river compact; or

(iii) Countenancing average uses by any signatory state in excess of its apportionment.

(4) The apportionment to each state includes all water necessary for the supply of any rights which now exist.

(c) No apportionment is hereby made, or intended to be made of such use of water as the upper basin may be entitled to under paragraphs (f) and (g) of article III of the Colorado river compact.

(d) The apportionment made by this article shall not be taken as any basis for the allocation among the signatory states of any benefits resulting from the generation of power.

ARTICLE IV

In the event curtailment of use of water by the states of the upper division at any time shall become necessary in order that the flow at Lee ferry shall not be depleted below that required by article III of the Colorado river compact, the extent of curtailment by each state of the consumptive use of water apportioned to it by article III of this compact shall be in such quantities and as such times as shall be determined by the commission upon the application of the following principles:

(a) The extent and times of curtailment shall be such as to assure full compliance with article III of the Colorado river compact;

(b) If any state or states of the upper division, in the ten years immediately preceding the water year in which curtailment is necessary, shall have consumptively used more water than it was or they were, as the case may be, entitled to use under the apportionment made by article III of this compact, such state or states shall be required to supply at Lee ferry a quantity of water equal it its, or the aggregate of their, overdraft or the proportionate part of such overdraft, as may be necessary to assure compliance with article III of the Colorado river compact, before demand is made on any other state of the upper division;

(c) Except as provided in subparagraph (b) of this article, the extent of curtailment by each state of the upper division of the consumptive use of water apportioned to it by article III of this compact shall be such as to result in the delivery at Lee ferry of a quantity of water which bears the same relation to the total required curtailment of use by the states of the upper division as the consumptive use of the upper Colorado river system water which was made by each such state during the water year immediately preceding the year in which the curtailment becomes necessary bears to the total consumptive use of such water in the states of the upper division during the same water year; provided, that in determining such relation the uses of water under rights perfected prior to November 24, 1922, shall be excluded.

ARTICLE V

(a) All losses of water occurring from or as the result of the storage of water in reservoirs constructed prior to the signing of this compact shall be charged to the state in which such reservoir or reservoirs are located. Water stored in reservoirs covered by this paragraph (a) shall be for the exclusive use of and shall be charged to the state in which the reservoir or reservoirs are located.

(b) All losses of water occurring from or as a result of the storage of water in reservoirs constructed after the signing of this compact shall be charged as follows:

(1) If the commission finds that the reservoir is used, in whole or in part, to assist the states of the upper division in meeting their obligations to deliver water at Lee ferry imposed by article III of the Colorado river compact, the commission shall make findings, which in no event shall be contrary to the laws of the United States of America under which any reservoir is constructed, as to the reservoir capacity allocated for that purpose. The whole or that proportion, as the case may be, of reservoir losses as found by the commission to be reasonably and properly chargeable to the reservoir or reservoir capacity utilized to assure deliveries at Lee ferry shall be charged to the states of the upper division in the proportion which the consumptive use of water in each state of the upper division during the water year in which the charge is made bears to the total consumptive use of water in all states of the upper division during the same water year. Water stored in reservoirs or in reservoir capacity covered by this subparagraph (b) (1) shall be for the common benefit of all of the states of the upper division.

(2) If the commission finds that the reservoir is used, in whole or in part, to supply water for use in a state of the upper division, the commission shall make findings, which in no event shall be contrary to the laws of the United States of America under which any reservoir is constructed, as to the reservoir or reservoir capacity utilized to supply water for use and the state in which such water will be used. The whole or that proportion, as the case may be, of reservoir losses as found by the commission to be reasonably and properly chargeable to the state in which such water will be used shall be borne by that state. As determined by the commission, water stored in reservoirs covered by this subparagraph (b) (2) shall be earmarked for and charged to the state in which the water will be used.

(c) In the event the commission finds that a reservoir site is available both to assure deliveries at Lee ferry and to store water for consumptive use in a state of the upper division, the storage of water for consumptive use shall be given preference. Any reservoir or reservoir capacity hereafter used to assure deliveries at Lee ferry shall by order of the commission be used to store water for consumptive use in a state, provided the commission finds that such storage is reasonably necessary to permit such state to make the use of the water apportioned to it by this compact.

ARTICLE VI

The commission shall determine the quantity of the consumptive use of water, which use is apportioned by article III hereof, for the upper basin and for each state of the upper basin by the inflow-outflow method in terms of man-made depletions of the virgin flow at Lee ferry, unless the commission, by unanimous action, shall adopt a different method of determination.

ARTICLE VII

The consumptive use of water by the United States of America or any of its agencies, instrumentalities or wards shall be charged as a use by the state in which the use is made; provided, that such consumptive use incident to the diversion, impounding, or conveyance of water in one state for use in another shall be charged to such latter state.

ARTICLE VIII

(a) There is hereby created an interstate administrative agency to be known as the "Upper Colorado river commission." The commission shall be composed of one commissioner representing each of the states of the upper division, namely, the states of Colorado, New Mexico, Utah and Wyoming, designated or appointed in accordance with the laws of each such state and, if designated by the President, one commissioner representing the United States of America. The President is hereby requested to designate a commissioner. If so designated the commissioner representing the United States of America shall be the presiding officer of the commission and shall be entitled to the same powers and rights as the commissioner of any state. Any four members of the commission shall constitute a quorum.

(b) The salaries and personal expenses of each commissioner shall be paid by the government which he represents. All other expenses which are incurred by the commission incident to the administration of this compact, and which are not paid by the United States of America, shall be borne by the four states according to the percentage of sonsumptive use apportioned to each. On or before December 1 of each year, the commission shall adopt and transmit to the governors of the four states and to the President a budget covering an estimate of its expenses for the following year, and of the amount payable by each state. Each state shall pay the amount due by it to the commission on or before April 1 of the year following. The payment of the expenses of the commission and of its employees shall not be subject to the audit and accounting procedures of any of the four states; however, all receipts and disbursements of funds handled by the commission shall be audited yearly by a qualified independent public accountant and the report of the audit shall be included in and become a part of the annual report of the commission.

(c) The commission shall appoint a secretary, who shall not be a member of the commission, or an employee of any signatory state or of the United States of America while so acting. He shall serve for such term and receive such salary and perform such duties as the commission may direct. The commission may employ such engineering legal, clerical and other personnel as, in its judgment, may be necessary for the performance of its functions under this compact. In the hiring of employees, the commission shall not be bound by the civil service laws of any state.

(d) The commission, so far as consistent with this compact, shall have the power to:

(1) Adopt rules and regulations;

(2) Locate, establish, construct, abandon, operate and maintain water guaging stations;

(3) Make estimates to forecast water run-off on the Colorado river and any of its tributaries;

(4) Engage in co-operative studies of water supplies of the Colorado river and its tributaries;

(5) Collect, analyze, correlate, preserve and report on data as to the stream flows, storage, diversions and use of the waters of the Colorado river, and any of its tributaries;

(6) Make findings as to the quantity of water of the upper Colorado river system used each year in the upper Colorado river basin and in each state thereof;

(7) Make findings as to the quantity of water deliveries at Lee ferry during each water year;

(8) Make findings as to the necessity for and the extent of the curtailment of use, required, if any, pursuant to article IV hereof;

(9) Make findings as to the quantity of reservoir losses and as to the share thereof chargeable under article V hereof to each of the states;

(10) Make findings of fact in the event of the occurrence of extraordinary drought or serious accident to the irrigation system in the upper basin, whereby deliveries by the upper basin of water which it may be required to deliver in order to aid in fulfilling obligations of the United States of America to the United Mexican States arising under the treaty between the United States of America and the United Mexican States, dated February 3, 1944 (Treaty Series 994) become difficult, and report such findings to the governors of the upper basin states, the President of the United States of America, the United States section of the international boundary and water commission, and such other federal officials and agencies as it may deem appropriate to the end that the water allotted to Mexico under division III of such treaty may be reduced in accordance with the terms of such treaty;

(11) Acquire and hold such personal and real property as may be necessary for the performance of its duties hereunder and to dispose of the same when no longer required;

(12) Perform all functions required of it by this compact and do all things necessary, proper or convenient in the performance of its duties hereunder, either independently or in co-operation with any state or federal agency;

(13) Make and transmit annually to the governors of the signatory states and the President of the United States of America, with the estimated budget, a report covering the activities of the commission for the preceding water year.

(e) Except as otherwise provided in this compact the concurrence of four members of the commission shall be required in any action taken by it.

(f) The commission and its secretary shall make available to the governor of each of the signatory states any information within its possession at any time, and shall always provide free access to its records by the governors of each of the states, or their representatives or authorized representatives of the United States of America.

(g) Findings of fact made by the commission shall not be conclusive in any court, or before any agency or tribunal, but shall constitute prima facie evidence of the facts found.

(h) The organization meeting of the commission shall be held within four months from the effective date of this compact.

ARTICLE IX

(a) No state shall deny the right of the United States of America and, subject to the conditions hereinafter contained, no state shall deny the right of another signatory state, any person, or entity of any signatory state to acquire rights to the use of water, or to construct or participate in the construction and use of diversion works and storage reservoirs with appurtenant works, canals and conduits in one state for the purpose of diverting, conveying, storing, regulating and releasing water to satisfy the provisions of the Colorado river compact relating to the obligation of the states of the upper division to make deliveries of water at Lee ferry, or for the purpose of diverting, conveying, storing or regulating water in an upper signatory state for consumptive use in a lower signatory state, when such use is within the apportionment to such lower state made by this compact. Such rights shall be subject to the rights of water users, in a state in which such reservoir or works are located, to receive and use water, the use of which is within the apportionment to such state by this compact.

(b) Any signatory state, any person or any entity of any signatory state shall have the right to acquire such property rights as are necessary to the use of water in conformity with this compact in any other signatory state by donation, purchase or through the exercise of the power of eminent domain. Any signatory state, upon the written request of the governor of any other signatory state, for the benefit of whose water users property is to be acquired in the state to which such written request is made, shall proceed expeditiously to acquire the desired property either by purchase at a price satisfactory to the requesting state, or, if such purchase cannot be made, then through the exercise of its power of eminent domain and shall convey such property to the requesting state or such entity as may be designated by the requesting state; provided, that all costs of acquisition and expenses of every kind and nature whatsoever incurred in obtaining the requested property shall be paid by the requesting state at the time and in the manner prescribed by the state requested to acquire the property.

(c) Should any facility be constructed in a signatory state by and for the benefit of another signatory state or states or the water users thereof, as above provided, the construction, repair, replacement, maintenance and operation of such facility shall be subject to the laws of the state in which the facility is located, except that, in the case of a reservoir constructed in one state for the benefit of another state or states, the water administration officials of the state in which the facility is located shall permit the storage and release of any water which, as determined by findings of the commission, falls within the apportionment of the state or states for whose benefit the facility is constructed. In the case of a regulating reservoir for the joint benefit of all states in making Lee ferry deliveries, the water administration officials of the state in which the facility is located, in permitting the storage and release of water, shall comply with the findings and orders of the commission.

(d) In the event property is acquired by a signatory state in another signatory state for the use and benefit of the former, the users of water made available by such facilities, as a condition precedent to the use thereof, shall pay to the political subdivisions of the state in which such works are located, each and every year during which such rights are enjoyed for such purposes, a sum of money equivalent to the average annual amount of taxes levied and assessed against the land and improvements theron during the ten years preceding the acquisition of such land. Said payments shall be in full reimbursement for the loss of taxes in such political subdivisions of the state, and in lieu of any and all taxes on said property, improvements and rights. The signatory states recommend to the President and the congress that, in the event the United States of America shall acquire property in one of the signatory states for the benefit of another signatory state, or its water users, provision be made for like payment in reimbursement of loss of taxes.

ARTICLE X

(a) The signatory states recognize La Plata river compact entered into between the states of Colorado and New Mexico, dated November 27, 1922, approved by the congress on January 29, 1925 (43 Stat. 796), and this compact shall not affect the apportionment therein made.

(b) All consumptive use of water of La Plata river and its tributaries shall be charged under the apportionment of article III hereof to the state in which the use is made; provided, that consumptive use incident to the diversion, impounding or conveyance of water in one state for use in the other shall be charged to the latter state.

ARTICLE XI

Subject to the provisions of this compact, the consumptive use of the water of the Little Snake river and its tributaries is hereby apportioned between the states of Colorado and Wyoming in such quantities as shall result from the application of the following principles and procedures:

(a) Water used under rights existing prior to the signing of this compact.

(1) Water diverted from any tributary of the Little Snake river or from the main stem of the Little Snake river above a point one hundred feet above the confluence of Savery creek and the Little Snake river shall be administered without regard to rights covering the diversion of water from any down-stream points.

(2) Water diverted from the main stem of the Little Snake river below a point one hundred feet below the confluence of Savery creek and the Little Snake river shall be administered on the basis of an interstate priority schedule prepared by the commission in conformity with priority dates established by the laws of the respective states.

(b) Water used under rights initiated subsequent to the signing of this compact.

(1) Direct flow diversions shall be so administered that, in time of shortage, the curtailment of use on each acre of land irrigated thereunder shall be as nearly equal as may be possible in both of the states.

(2) The storage of water by projects located in either state, whether of supplemental supply or of water used to irrigate land not irrigated at the date of the signing of this compact, shall be so administered that in times of water shortage the curtailment of storage of water available for each acre of land irrigated thereunder shall be as nearly equal as may be possible in both states.

(c) Water users under the apportionment made by this article shall be in accordance with the principle that beneficial use shall be the basis, measure and limit of the right to use.

(d) The states of Colorado and Wyoming each assent to diversions and storage of water in one state for use in the other state, subject to compliance with article IX of this compact.

(e) In the event of the importation of water to the Little Snake river basin from any other river basin, the state making the importation shall have the exclusive use of such imported water unless by written agreement, made by the representatives of the states of Colorado and Wyoming on the commission, it is otherwise provided.

(f) Water use projects initiated after the signing of this compact, to the greatest extent possible, shall permit the full use within the basin in the most feasible manner of the waters of the Little Snake river and its tributaries, without regard to the state line; and, so far as is practicable, shall result in an equal division between the states of the use of water not used under rights existing prior to the signing of this compact.

(g) All consumptive use of the waters of the Little Snake river and its tributaries shall be charged under the apportionment of article III hereof to the state in which the use is made; provided, that consumptive use incident to the diversion, impounding or conveyance of water in one state for use in the other shall be charged to the latter state.

ARTICLE XII

Subject to the provisions of this compact, the consumptive use of the waters of Henry's fork, a tributary of Green river originating in the state of Utah and flowing into the state of Wyoming and thence into the Green river in the state of Utah; Beaver creek, originating in the state of Utah and flowing into Henry's fork in the state of Wyoming; Burnt fork, a tributary of Henry's fork, originating in the state of Utah and flowing into Henry's fork in the state of Wyoming; Birch creek, a tributary of Henry's fork originating in the state of Utah and flowing into Henry's fork in the state of Wyoming; and Sheep creek, a tributary of Green river in the state of Utah and their tributaries, are hereby apportioned between the states of Utah and Wyoming in such quantities as will result from the application of the following principles and procedures:

(a) Waters used under rights existing prior to the signing of this compact.

Waters diverted from Henry's fork, Beaver creek, Burnt fork, Birch creek and their tributaries, shall be administered without regard to the state line on the basis of an interstate priority schedule to be prepared by the states affected and approved by the commission in conformity with the actual priority of right of use, the water requirements of the land irrigated and the acreage irrigated in connection therewith.

(b) Waters used under rights from Henry's fork, Beaver creek, Burnt fork, Birch creek and their tributaries, initiated after the signing of this compact shall be divided fifty per cent to the state of Wyoming and fifty per cent to the state of Utah and each state may use said waters as and where it deems advisable.

(c) The state of Wyoming assents to the exclusive use by the state of Utah of the water of Sheep creek, except that the lands, if any, presently irrigated in the state of Wyoming from the water of Sheep creek shall be supplied with water from Sheep creek in order of priority and in such quantities as are in conformity with the laws of the state of Utah.

(d) In the event of the importation of water to Henry's fork, or any of its tributaries, from any other river basin, the state making the importation shall have the exclusive use of such imported water unless by written agreement made by the representatives of the states of Utah and Wyoming on the commission, it is otherwise provided.

(e) All consumptive use of waters of Henry's fork, Beaver creek, Burnt fork, Birch creek, Sheep creek, and their tributaries shall be charged under the apportionment of article III hereof to the state in which the use is made; provided, that consumptive use incident to the diversion, impounding or conveyance of water in one state for use in the other shall be charged to the latter state.

(f) The states of Utah and Wyoming each assent to the diversion and storage of water in one state for use in the other state, subject to compliance with article IX of this compact. It shall be the duty of the water administrative officials of the state where the water is stored to release said stored water to the other state upon demand. If either the state of Utah or the state of Wyoming shall construct a reservoir in the other state for use in its own state, the water users of the state in which said facilities are constructed may purchase at cost a portion of the capacity of said reservoir sufficient for the irrigation of their lands thereunder.

(g) In order to measure the flow of water diverted, each state shall cause suitable measuring devices to be constructed, maintained and operated at or near the point of diversion into each ditch.

(h) The state engineers of the two states jointly shall appoint a special water commissioner who shall have authority to administer the water in both states in accordance with the terms of this article. The salary and expenses of such special water commissioner shall be paid, thirty per cent by the state of Utah and seventy per cent by the state of Wyoming.

ARTICLE XIII

Subject to the provisions of this compact, the rights to the consumptive use of the water of the Yampa river, a tributary entering the Green river in the state of Colorado, are hereby apportioned between the states of Colorado and Utah in accordance with the following principles:

(a) The state of Colorado will not cause the flow of the Yampa river at the Maybell gauging station to be depleted below an aggregate of 5,000,000 acre-feet for any period of ten consecutive years reckoned in continuing progressive series beginning with the first day of October next succeeding the ratification and approval of this compact. In the event any diversion is made from the Yampa river or from tributaries entering the Yampa river above the Maybell gauging station for the benefit of any water use project in the state of Utah, then the gross amount of all such diversions for use in the state of Utah, less any returns from such diversions to the river above Maybell, shall be added to the actual flow at the Maybell gauging station to determine the total flow at the Maybell gauging station.

(b) All consumptive use of the waters of the Yampa river and its tributaries shall be charged under the apportionment of article III hereof to the state in which the use is made; provided, that consumptive use incident to the diversion, impounding or conveyance of water in one state for use in the other shall be charged to the latter state.

ARTICLE XIV

Subject to the provisions of this compact, the consumptive use of the waters of the San Juan river and its tributaries is hereby apportioned between the states of Colorado and New Mexico as follows:

The state of Colorado agrees to deliver to the state of New Mexico from the San Juan river and its tributaries which rise in the state of Colorado a quantity of water which shall be sufficient, together with water originating in the San Juan basin in the state of New Mexico, to enable the state of New Mexico to make full use of the water apportioned to the state of New Mexico by article III of this compact, subject, however, to the following:

(a) A first and prior right shall be recognized as to:

(a) All uses of water made in either state at the time of the signing of this compact; and

(2) All uses of water contemplated by projects authorized, at the time of the signing of this compact under the laws of the United States of America whether or not such projects are eventually constructed by the United States of America or by some other entity.

(b) The state of Colorado assents to diversions and storage of water in the state of Colorado for use in the state of New Mexico, subject to compliance with article IX of this compact.

(c) The uses of the waters of the San Juan river and any of its tributaries within either state which are dependent upon a common source of water and which are not covered by (a) hereof, shall in times of water shortages be reduced in such quantity that the resulting consumptive use in each state will bear the same proportionate relation to the consumptive use made in each state during times of average water supply as determined by the commission; provided, that any preferential uses of water to which Indians are entitled under article XIX shall be excluded in determining the amount of curtailment to be made under this paragraph.

(d) The curtailment of water use by either state in order to make deliveries at Lee ferry as required by article IV of this compact shall be independent of any and all conditions imposed by this article and shall be made by each state, as and when required, without regard to any provision of this article.

(e) All consumptive use of the waters of the San Juan river and its tributaries shall be charged under the apportionment of article III hereof to the state in which the use is made; provided, that consumptive use incident to the diversion, impounding or conveyance of water in one state for use in the other shall be charged to the latter state.

ARTICLE XV

(a) Subject to the provisions of the Colorado river compact and of this compact, water of the upper Colorado river system may be impounded and used for the generation of electrical power, but such impounding and use shall be subservient to the use and consumption of such water for agricultural and domestic purposes and shall not interfere with or prevent use for such dominant purposes.

(b) The provisions of this compact shall not apply to or interfere with the right or power of any signatory state to regulate within its boundaries the appropriation, use and control of water, the consumptive use of which is apportioned and available to such state by this compact.

ARTICLE XVI

The failure of any state to use the water, or any part thereof, the use of which is apportioned to it under the terms of this compact, shall not constitute a relinquishment of the right to such use to the lower basin or to any other state, nor shall it constitute a forfeiture or abandonment of the right to such use.

ARTICLE XVII

The use of any water now or hereafter imported into the natural drainage basin of the upper Colorado river system shall not be charged to any state under the apportionment of the consumptive use made by this compact.

ARTICLE XVIII

(a) The state of Arizona reserves its rights and interest under the Colorado river compact as a state of the lower division and as a state of the lower basin.

(b) The state of New Mexico and the state of Utah reserve their respective rights and interests under the Colorado river compact as states of the lower basin.

ARTICLE XIX

Nothing in this compact shall be construed as:

(a) Affecting the obligations of the United States of America to Indian tribes;

(b) Affecting the obligations of the United States of America under the treaty with the United Mexican States (Treaty Series 994);

(c) Affecting any rights or powers of the United States of America, its agencies or instrumentalities, in or to the waters of the upper Colorado river system, or its capacity to acquire rights in and to the use of said water;

(d) Subjecting any property of the United States of America, its agencies or instrumentalities, to taxation by any state or subdivision therof, or creating any obligation on the part of the United States of America, its agencies or instrumentalities, by reason of the acquisition, construction or operation of any property or works of whatever kind, to make any payment to any state or political subdivision thereof, state agency, municipality or entity whatsoever, in reimbursement for the loss of taxes;

(e) Subjecting any property of the United States of America, its agencies or instrumentalities, to the laws of any state to an extent other than the extent to which such laws would apply without regard to this compact.

ARTICLE XX

This compact may be terminated at any time by the unanimous agreement of the signatory states. In the event of such termination, all rights established under it shall continue unimpaired.

ARTICLE XXI

This compact shall become binding and obligatory when it shall have been ratified by the legislatures of each of the signatory states and approved by the congress of the United States of America. Notice of ratification by the legislatures of the signatory states shall be given by the governor of each signatory state to the governor of each of the other signatory states and to the President of the United States of America, and the President is hereby requested to give notice to the governor of each of the signatory states of approval by the congress of the United States of America.

IN WITNESS WHEREOF, the commissioners have executed six counterparts hereof each of which shall be and constitute an original, one of which shall be deposited in the archives of the department of state of the United States of America, and one of which shall be forwarded to the governor of each of the signatory states.

Done at the city of Santa Fe, state of New Mexico, this 11th day of October, 1948.

Charles A. Carlson,
Commissioner for the
State of Arizona.
Clifford H. Stone,
Commissioner for the
State of Colorado.
Fred E. Wilson,
Commissioner for the
State of New Mexico.

Exhibit D2-3: MEXICAN TREATY ON RIO GRANDE, TIJUANA AND COLORADO RIVERS

Mexican Treaty Ratified by U.S. Senate April 18, 1945, Effective Nov. 8, 1945

Treaty Series No. 994

The Government of the United States of America and the Government of the United Mexican States: animated by the sincere spirit of cordiality and friendly cooperation which happily governs the relations between them; taking into account the fact that Articles VI and VII of the Treaty of Peace, Friendship and Limits between the United States of America and the United Mexican States signed at Guadalupe Hidalgo on February 2, 1848, and Article IV of the boundary treaty between the two countries signed at the City of Mexico December 30, 1853 regulate the use of the waters of the Rio Grande (Rio Bravo) and the Colorado River for purposes of navigation only; considering that the utilization of these waters for other purposes is desirable in the interest of both countries, and desiring, moreover, to fix and delimit the rights of the two countries with respect to the waters of the Colorado and Tijuana Rivers, and of the Rio Grande (Rio Bravo) from Fort Quitman, Texas, United States of America, to the Gulf of Mexico, in order to obtain the most complete and satisfactory utilization thereof, have resolved to conclude a treaty and for this purpose have named as their plenipotentiaries:

The President of the United States of America:

Cordell Hull, Secretary of State of the United States of America, George S. Meseersmith, Ambassador Extraordinary and Plenipotentiary of the United States of America in Mexico, and Lawrence M. Lawson, United States Commissioner, International Boundary Commission, United States and Mexico; and

The President of the United Mexican States:

Francisco Castillo Najera, Ambassador Extraordinary and Plenipotentiary of the United Mexican States in Washington, and Rafael Fernandez MacGregor, Mexican Commissioner, International Boundary Commission, United States and Mexico; who, having communicated to each other their respective Full Powers and having found them in good and due form, have agreed upon the following:

1—PRELIMINARY PROVISIONS

Article 1

For the purposes of this Treaty it shall be understood that:

(a) "The United States" means the United States of America.

(b) "Mexico" means the United Mexican States.

(c) "The Commission" means the International Boundary and Water Commission, United States and Mexico, as described in Article 2 of this Treaty.

(d) "To divert" means the deliberate act of taking water from any channel in order to convey it elsewhere for storage, or to utilize it for domestic, agricultural, stock-raising or industrial purposes whether this be done by means of dams across the channel, partition weirs, lateral intakes, pumps or any other methods.

(e) "Point of diversion" means the place where the act of diverting the water is effected.

(f) "Conservation capacity of storage reservoirs" means that part of their total capacity devoted to holding and conserving the water for disposal thereof as and when required, that is, capacity additional to that provided for silt retention and flood control.

(g) "Flood discharges and spills" means the voluntary or involuntary discharge of water for flood control as distinguished from releases for other purposes.

(h) "Return flow" means that portion of diverted water that eventually finds its way back to the source from which it was diverted.

(i) "Release" means the deliberate discharge of stored water for conveyance elsewhere or for direct utilization.

(j) "Consumptive use" means the use of water by evaporation, plant transpiration or other manner whereby the water is consumed and does not return to its source of supply. In general it is measured by the amount of water diverted less the part thereof which returns to the stream.

(k) "Lowest major international dam or reservoir" means the major international dam or reservoir situated farthest downstream.

(l) "Highest major international dam or reservoir" means the major international dam or reservoir situated farthest upstream.

Article 2

The International Boundary Commission established pursuant to the provisions of the Convention between the United States and Mexico signed in Washington, March 1, 1889 to facilitate the carrying out of the principles contained in the Treaty of November 12, 1884 and to avoid difficulties occasioned by reason of the changes which take place in the beds of the Rio Grande (Rio Bravo) and the Colorado River shall hereafter be known as the International Boundary and Water Commission, United States and Mexico, which shall continue to function for the entire period during which the present Treaty shall continue in force. Accordingly, the term of the Convention of March 1, 1889 shall be considered to be indefinitely extended, and the Convention of November 21, 1900 between the United States and Mexico regarding that Convention shall be considered completely terminated.

The application of the present Treaty, the regulation and exercise of the rights and obligations which the two Governments assume thereunder, and the settlement of all disputes to which its observance and execution may give rise are hereby entrusted to the International Boundary and Water Commission, which shall function in conformity with the powers and limitations set forth in this Treaty.

The Commission shall in all respects have the status of an international body, and shall consist of a United States Section and a Mexican Section. The head of each Section shall be an Engineer Commissioner. Wherever there are provisions in this Treaty for joint action or joint agreement by the two Governments, or for the furnishing of reports, studies or plans to the two Governments, or similar provisions, it shall be understood that the particular matter in question shall be handled by or through the Department of State of the United States and the Ministry of Foreign Relations of Mexico.

The Commission or either of its two Sections may employ such assistants and engineering and legal advisers as it may deem necessary. Each Government shall accord diplomatic status to the Commissioner, designated by the other Government. The Commissioner, two principal engineers, a legal adviser, and a secretary, designated by each Government as members of it Section of the Commission, shall be entitled in the territory of the other country to the priveleges and immunities appertaining to diplomatic officers. The Commission and its personnel may freely carry out their observations, studies and field work in the territory of either country.

The jurisdiction of the Commission shall extend to the limitrophe ports of the Rio Grande (Rio Bravo) and the Colorado River, to the land boundary between the two countries, and to works located upon their common boundary, each Section of the Commission retaining jurisdiction over the part of the works located within the limits of its own country. Neither Section shall assume jurisdiction or control over works located within the limits of the country of the other without the express consent of the Government of the latter. The works constructed, acquired or used in fulfillment of the provisions of this Treaty and located wholly within the territorial limits of either county, although these works may be international in character, shall remain, except as herein otherwise specifically provided, under the exclusive jurisdiction and control of the Section of the Commission in whose country the works may be situated.

The duties and powers vested in the Commission by this Treaty shall be in addition to those vested in the International Boundary Commission by the Convention of March 1, 1889 and other pertinent treaties and agreements in force between the two countries except as the provisions of any of them may be modified by the present Treaty.

Each Government shall bear the expenses incurred in the maintenance of its Section of the Commission. The joint expenses, which may be incurred as agreed upon by the Commission, shall be borne equally by the two Governments.

Article 3

In matters in which the Commission may be called upon to make provisions for the joint use of international waters, the following order of preferences shall serve as guide:

1. Domestic and municipal uses.
2. Agriculture and stock-raising.
3. Electrical power.
4. Other industrial uses.
5. Navigation.
6. Fishing and hunting.
7. Any other beneficial uses which may be determined by the Commission.

All of the foregoing uses shall be subject to any sanitary measures or works which may be mutually agreed upon by the two Governments, which hereby agree to give preferential attention to the solution of all border sanitation problems.

II--RIO GRANDE (RIO BRAVO)

Articles 4-10 are not included as this river lies outside the interest of this study.

III–COLORADO RIVER

Article 10

Of the waters of the Colorado River, from any and all sources, there are allotted to Mexico:

(a) A guaranteed annual quantity of 1,500,000 acre-feet (1,850,234,000 cubic meters) to be delivered in accordance with the provisions of Article 15 of this Treaty.

(b) Any other quantities arriving at the Mexican points of diversion, with the understanding that in any year in which, as determined by the United States Section, there exists a surplus of water of the Colorado River in excess of the amount necessary to supply users in the United States and the guaranteed quantity of 1,500,000 acre-feet (1,850,234,000 cubic meters) annually to Mexico, the United States undertakes to deliver to Mexico, in the manner set out in Article 15 of this Treaty, additional waters of the Colorado River system to provide a total quantity not to exceed 1,700,000 acre-feet (2,096,931,000 cubic meters) a year. Mexico shall acquire no right beyond that provided by this subparagraph by the use of the waters of the Colorado River System, for any purpose whatsoever, in excess of 1,500,000 acre-feet (1,850,234,000 cubic meters) annually.

In the event of extraordinary drought or serious accident to the irrigation system in the United States, thereby making it difficult for the United States to deliver the guaranteed quantity of 1,500,000 acre-feet (1,850,234,000 cubic meters) a year, the water allotted to Mexico under subparagraph (a) of this Article will be reduced in the same proportion as consumptive uses in the United States are reduced.

Article 11

(a) The United States shall deliver all waters allotted to Mexico wherever these waters may arrive in the bed of the limitrophe section of the Colorado River, with the exceptions hereinafter provided. Such waters shall be made up of the waters of the said river, whatever their origin, subject to the provisions of the following paragraphs of this Article.

(b) Of the waters of the Colorado River allotted to Mexico by subparagraph (a) of Article 10 of this Treaty, the United States shall deliver, wherever such waters may arrive in the limitrophe section of the river, 1,000,000 acre-feet (1,233,489,000 cubic meters) annually from the time the Davis dam and reservoir are placed in operation until January 1, 1980 and thereafter 1,125,000 acre-feet (1,387,675,000 cubic meters) annually, except that, should the main diversion structure referred to in subparagraph (a) of Article 12 of this Treaty be located entirely in Mexico and should Mexico so request, the United States shall deliver a quantity of water not exceeding 25,000 acre-feet (30,837,000 cubic meters) annually unless a larger quantity may be mutually agreed upon, at a point, to be likewise mutually agreed upon, on the international land boundary near San Luis, Sonora, in which event the quantities of 1,000,000 acre-feet (1,233,489,000 cubic meters) and 1,125,000 acre-feet (1,387,675,000 cubic meters) provided hereinabove as deliverable in the limitrophe section of the river shall be reduced by the quantities to be delivered in the year concerned near San Luis, Sonora.

(c) During the period from the time the Davis dam and reservoir are placed in operation until January 1, 1980, the United States shall also deliver to Mexico annually, of the water allotted to it 500,000 acre-feet (616,745,000 cubic meters), and thereafter the United States shall deliver annually 375,000 acre-feet (462,558,000 cubic meters), at the international boundary line, by means of the All-American Canal and a canal connecting the lower end of the Pilot Knob Wasteway with the Alamo Canal or with any other Mexican canal which may be substituted for the Alamo Canal. In either event the deliveries shall be made at an operating water surface elevation not higher than that of the Alamo Canal at the point where it crossed the international boundary line in the year 1943.

(d) All the deliveries of water specified above shall be made subject to the provisions of Article 15 of this Treaty.

Article 12

The two Governments agree to construct the following works:

(a) Mexico shall construct at its expense, within a period of five years from the date of the entry into force of this Treaty, a main diversion structure below the point where the northernmost part of the international land boundary line intersects the Colorado River. If such diversion structure is located in the limitrophe section of the river, its location, design and construction shall be subject to the approval of the Commission. The Commission shall thereafter maintain and operate the structure at the expense of Mexico. Regardless of where such diversion structure is located, there shall simultaneously be constructed such levees, interior drainage facilities and other works, or improvements to existing works, as in the opinion of the Commission shall be necessary to protect lands within the United States against damage from such floods and seepage as might result from the construction, operation and maintenance of this diversion structure. These protective works shall be constructed, operated and maintained at the expense of Mexico by the respective Sections of the Commission, or under their supervision, each within the territory of its own country.

(b) The United States, within a period of five years from the date of the entry into force of this Treaty, shall construct in its own territory and at its expense, and thereafter operate and maintain at its expense, the Davis storage dam and reservoir, a part of the capacity of which shall be used to make possible the regulation at the boundary of the waters to be delivered to Mexico in accordance with the provisions of Article 15 of this Treaty.

(c) The United States shall construct or acquire in its own territory the works that may be necessary to convey a part of the waters of the Colorado River allotted to Mexico to the Mexican diversion points on the international land boundary line referred to in this Treaty. Among these works shall be included: the canal and other works necessary to convey water from the lower end of the Pilot Knob Wasteway to the international boundary, and should Mexico request it, a canal to connect the main diversion structure referred to in subparagraph (a) of this Article, if this diversion structure should be built in the limitrophe section of the river, with the Mexican system of canals at point to be agreed upon by the Commission on the international land boundary near San Luis, Sonora. Such works shall be constructed or acquired and operated and maintained by the United States Section at the expense of Mexico. Mexico shall also pay the costs of any sites or rights of way required for such works.

(d) The Commission shall construct, operate and maintain in the limitrophe section of the Colorado River, and each Section shall construct, operate and maintain in the territory of its own country on the Colorado River below Imperial Dam and on all other carrying facilities used for the delivery of water to Mexico, all necessary gaging stations and other measuring devices for the purpose of keeping a complete record of the waters delivered to Mexico and of the flows of the river. All data obtained as to such deliveries and flows shall be periodically compiled and exchanged between the two Sections.

Article 13

The Commission shall study, investigate and prepare plans for flood control on the Lower Colorado River between Imperial Dam and the Gulf of California, in both the United States and Mexico, and shall, in a Minute, report to the two Governments the works which should be built, the estimated cost thereof, and the part of the works to be constructed by each Government. The two Governments agree to construct, through their respective Sections of the Commission, such works as may be recommended by the Commission and approved by the two Governments, each Government to pay the costs of the works constructed by it. The Commission shall likewise recommend the parts of the works to be operated and maintained jointly by the Commission and the parts to be operated and maintained by each Section. The two Governments agree to pay in equal shares the cost of joint operation and maintenance, and each Government agrees to pay the cost of operation and maintenance of the works assigned to it for such purpose.

Article 14

In consideration of the use of the All-American Canal for the delivery to Mexico, in the manner provided in Article 11 and 15 of this Treaty, of a part of its allotment of the waters of the Colorado River, Mexico shall pay to the United States:

(a) A proportion of the costs actually incurred in the construction of Imperial Dam and the Imperial Dam-Pilot Knob section of the All-American Canal, this proportion and the method and terms of repayment to be determined by the two Governments, which, for this purpose, shall take into consideration the proportionate uses of these facilities by the two countries, these determinations to be made as soon as Davis dam and reservoir are placed in operation.

(b) Annually, a proportionate part of the total costs of maintenance and operation of such facilities, these costs to be prorated between the two countries in proportion to the amount of water delivered annually through such facilities for use in each of the two countries.

In the event that revenues from the sale of hydroelectric power which may be generated at Pilot Knob become available for the amortization of part or all of the costs of the facilities named in subparagraph (a) of this Article, the part that Mexico should pay of the costs of said facilities shall be reduced or repaid in the same proportion as the balance of the total costs are reduced or repaid. It is understood that any such revenue shall not become available until the cost of any works which may be constructed for the generation of hydroelectric power at said location has been fully amortized from the revenues derived therefrom.

Article 15

A. The water allotted in subparagraph (a) of Article 10 of this Treaty shall be delivered to Mexico at the points of delivery specified in Article 11, in accordance with the following two annual schedules of deliveries by months, which the Mexican Section shall formulate and present to the Commission before the beginning of each calendar year:

SCHEDULE I

Schedule I shall cover the delivery, in the limitrophe section of the Colorado River, of 1,000,000 acre-feet (1,233,489,000 cubic meters) of water each year from the date Davis dam and reservoir are placed in operation until January 1, 1980 and the delivery of 1,125,000 acre-feet (1,387,675,000 cubic meters) of water each year thereafter. This schedule shall be formulated subject to the following limitations:

With reference to the 1,000,000 acre-feet (1,233,489,000 cubic meters) quantity:

(a) During the months of January, February, October, November and December the prescribed rate of delivery shall be not less than 600 cubic feet (17.0 cubic meters) nor more than 3,500 cubic feet (99.1 cubic meters) per second.

(b) During the remaining months of the year the prescribed rate of delivery shall be not less than 1,000 cubic feet (28.3 cubic meters) nor more than 3,500 cubic feet (99.1 cubic meters) per second.

With reference to the 1,125,000 acre-feet (1,387,675,000 cubic meter) quantity:

(a) During the months of January, February, October, November and December the prescribed rate of delivery shall be not less than 675 cubic feet (19.1 cubic meters) nor more than 4,000 cubic feet (113.3 cubic meters) per second.

(b) During the remaining months of the year the prescribed rate of delivery shall be not less than 1,125 cubic feet (31.9 cubic meters), nor more than 4,000 cubic feet (113.3 cubic meters) per second.

Should deliveries of water be made at a point on the land boundary near San Luis, Sonora, as provided for in Article II, such deliveries shall be made under a sub-schedule to be formulated and furnished by the Mexican Section. The quantities and monthly rates of deliveries under such sub-schedule shall be in proportion to those specified for Schedule I, unless otherwiseagreed upon by the Commission.

SCHEDULE II

Schedule II shall cover the delivery at the boundary line by means of the All-American Canal of 500,000 acre-feet (616,745,000 meters) of water each year from the date Davis dam and reservoir are placed in operation until January 1, 1980 and the delivery of 375,000 acre-feet (462,558,000 cubic meters) of water each year thereafter. The schedule shall be formulated subject to the following limitations:

With reference to the 500,000 acre-feet (616,745,000 cubic meter) quantity:

(a) During the months of January, February, October, November and December the prescribed rate of delivery shall be not less than 300 cubic feet (8.5 cubic meters) nor more than 2,000 cubic feet (56.6 cubic meters) per second.

(b) During the remaining months of the year the prescribed rate of delivery shall be not less than 500 cubic feet (14.2 cubic meters) nor more than 2,000 cubic feet (56.6 cubic meters) per second.

With reference to the 375,000 acre-feet (462,558,000 cubic meter) quantity:

(a) During the months of January, February, October, November and December the prescribed rate of delivery shall be not less than 225 cubic feet (6.4 cubic meters) nor more than 1,500 cubic feet (42.5 cubic meters) per second.

(b) During the remaining months of the year the prescribed rate of delivery shall be not less than 375 cubic feet (10.6 cubic meters) nor more than 1,500 cubic feet (42.5 cubic meters) per second.

B. The United States shall be under no obligation to deliver, through the All-American Canal, more than 500,000 acre-feet (616,745,000 cubic meters) annually from the date Davis dam and reservoir are placed in operation until January 1, 1980 or more than 375,000 acre-feet (462,558,000 cubic meters) annually thereafter. If by mutual agreement, any part of the quantities of water specified in this paragraph are delivered to Mexico at points on the land boundary otherwise than through the All-American Canal, the above quantities of water and the rates of deliveries set out under Schedule II of this Article shall be correspondingly diminished.

C. The United States shall have the option of delivering, at the point on the land boundary mentioned in subparagraph (c) of Article 11, any part or all of the water to be delivered at that point under Schedule II of this Article during the months of January, February, October, November and December of each year, from any source whatsoever, with the understanding that the total specified annual quantities to be delivered through the All-American Canal shall not be reduced because of the exercise of this option, unless such reduction be requested by the Mexican Section, provided that the exercise of this option shall not have the effect of increasing the total amount of scheduled water to be delivered to Mexico.

D. In any year in which there shall exist in the river, water in excess of that necessary to satisfy the requirements in the United States and the guaranteed quantity of 1,500,000 acre-feet (1,850,234,000 cubic meters) allotted to Mexico, the United States hereby declares its intention to cooperate with Mexico in attempting to supply additional quantities of water through the All-American Canal as such additional quantities are desired by Mexico, if such use of the Canal and facilities will not be detrimental to the United States, provided that the delivery of any additional quantities through the All-American Canal shall not have the effect of increasing the total scheduled deliveries to Mexico. Mexico hereby declares its intention to cooperate with the United States by attempting to curtail deliveries of water through the All-American Canal in years of limited supply, if such curtailment can be accomplished without detriment to Mexico and is necessary to allow full use of all available water supplies, provided that such curtailment shall not have the effect of reducing the total scheduled deliveries of water to Mexico.

E. In any year in which there shall exist in the river, water in excess of that necessary to satisfy the requirements in the United States and the guaranteed quantity of 1,500,000 acre-feet (1,850,234,000 cubic meters) allotted to Mexico, the United States Section shall so inform the Mexican Section in order that the latter may schedule such surplus water to complete a quantity up to a maximum of 1,700,000 acre-feet (2,096,931,000 cubic meters). In this circumstance the total quantities to be delivered under Schedules I and II shall be increased in proportion to their respective total quantities and the two schedules thus increased shall be subject to the same limitations as those established for each under paragraph A of this Article.

F. Subject to the limitations as to rates of deliveries and total quantities set out in Schedules I and II, Mexico shall have the right, upon thirty days notice in advance to the United States Section, to increase or decrease each monthly quantity prescribed by those schedules by not more than 20 % of the monthly quantity.

G. The total quantity of water to be delivered under Schedule I of paragraph A of this Article may be increased in any year if the amount to be delivered under Schedule II is correspondingly reduced and if the limitations as to rates of delivery under each schedule are correspondingly increased and reduced.

IV--TIJUANA RIVER

Article 16 is not included as this river lies outside the interest of this study.

V–GENERAL PROVISIONS

Article 17

The use of the channels of the international rivers for the discharge of flood or other excess waters shall be free and not subject to limitation by either country, and neither country shall have any claim against the other in respect of any damage caused by such use. Each Government agrees to furnish the other Government, as far in advance as practicable, any information it may have in regard to such extraordinary discharges of water from reservoirs and flood flows on its own territory as may produce floods on the territory of the other.

Each Government declares its intention to operate its storage dams in such manner, consistent with the normal operations of its hydraulic systems, as to avoid, as far as feasible, material damage in the territory of the other.

Article 18

Public use of the water surface of lakes formed by international dams shall, when not harmful to the services rendered by such dams, be free and common to both countries, subject to the police regulations of each country in its territory, to such general regulations as may appropriately be prescribed and enforced by the Commission with the approval of the two Governments for the purpose of the application of the provisions of this Treaty, and to such regulations as may appropriately be prescribed and enforced for the same purpose by each Section of the Commission with respect to the areas and borders of such parts of those lakes as lie within its territory. Neither Government shall use for military purposes such water surface situated within the territory of the other country except by express agreement between the two Governments.

Article 19

The two Governments shall conclude such special agreements as may be necessary to regulate the generation, development and disposition of electric power at international plants, including the necessary provisions for the export of electric current.

Article 20

The two Governments shall, through their respective Sections of the Commission, carry out the construction of works allotted to them. For this purpose the respective Sections of the Commission may make use of any competent public or private agencies in accordance with the laws of the respective countries. With respect to such works as either Section of the Commission may have to execute on the territory of the other, it shall, in the execution of such works, observe the laws of the place where such works are located or carried out, with the exceptions hereinafter stated.

All materials, implements, equipment and repair parts intended for the construction, operation and maintenance of such works shall be exempt from import and export customs duties. The whole of the personnel employed either directly or indirectly on the construction, operation or maintenance of the works may pass freely from one country to the other for the purpose of going to and from the place of location of the works, without any immigration restrictions, passports or labor requirements. Each Government shall furnish, through his own Section of the Commission, convenient means of identification to the personnel employed by it on the aforesaid works and verification certificates covering all materials, implements, equipment and repair parts intended for the works.

Each Government shall assume responsibility for and shall adjust exclusively in accordance with its own laws all claims arising within its territory in connection with the construction, operation or maintenance of the whole or any part of the works herein agreed upon, or of any works which may, in the execution of this Treaty, be agreed upon in the future.

Article 21

The construction of the international dams and the formation of artificial lakes shall produce no change in the fluvial international boundary, which shall continue to be governed by existing treaties and conventions in force between the two countries.

The commission shall, with the approval of the two Governments, establish in the artificial lakes, by buoys or by other suitable markers, a practicable and convenient line to provide for the exercise of the jurisdiction and control vested by this Treaty in the Commission and its respective Sections. Such line shall also mark the boundary for the application of the customs and police regulations of each country.

Article 22

The provisions of the Convention between the United States and Mexico for the rectification of the Rio Grande (Rio Bravo) in the El Paso-Juarez Valley signed on February 1, 1933, shall govern, so far as delimitation of the boundary, distribution of jurisdiction and sovereignty, and relations with private owners are concerned, in any places where works for the artificial channeling, canalization or rectification of the Rio Grande (Rio Bravo) and the Colorado River are carried out.

Article 23

The two Governments recognize the public interest attached to the works required for the execution and performance of this Treaty and agree to acquire, in accordance with their respective domestic laws, any private property that may be required for the construction of the said works, including the main structures and their appurtenances and the construction materials therefor, and for the operation and maintenance thereof, at the cost of the country within which the property is situated, except as may be otherwise specifically provided in this Treaty.

Each Section of the Commission shall determine the extent and location of any private property to be acquired within its own country and shall make the necessary requests upon its Government for the acquisition of such property.

The Commission shall determine the cases in which it shall become necessary to locate works for the conveyance of water or electrical energy and for the servicing of any such works, for the benefit of either of the two countries, in the territory of the other country, in order that such works can be built pursuant to agreement between the two Governments. Such works shall be subject to the jurisdiction and supervision of the Section of the Commission within whose country they are located.

Construction of the works built in pursuance of the provisions of this Treaty shall not confer upon either of the two countries any rights either of property or of jurisdiction over any part whatsoever of the territory of the other. These works shall be part of the territory and be the property of the country wherein they are situated. However, in the case of any incidents occuring on works constructed across the limitrophe part of a river and with supports on both banks, the jurisdiction of each country shall be limited by the center line of such works, which shall be marked by the Commission, without thereby changing the international boundary.

Each Government shall retain, through its own Section of the Commission and within the limits and to the extent necessary to effectuate the provisions of this Treaty, direct ownership, control and jurisdiction within its own territory and in accordance with its own laws, over all real property—including that within the channel of any river rights of way and rights in rem, that it may be necessary to enter upon and occupy for the construction, operation or maintenance of all the works constructed, acquired or used pursuant to this Treaty. Furthermore, each Government shall similarly acquire and retain in its own possession the title, control and jurisdiction over such works.

Article 24

The International Boundary and Water Commission shall have, in addition to the powers and duties otherwise specifically provided in this Treaty, the following powers and duties:

(a) To initiate and carry on investigations and develop plans for the works which are to be constructed or established in accordance with the provisions of this and other treaties or agreements in force between the two Governments dealing with boundaries and international waters; to determine, as to such works, their location, size, kind and characteristic specifications; to estimate the cost of such works; and to recommend the division of such costs between the two Governments, the arrangements for the furnishing of the necessary funds, and the dates for the beginning of the works, to the extent that the matters mentioned in this subparagraph are not otherwise covered by specific provisions of this or any other Treaty.

(b) To construct the works agreed upon or to supervise their construction and to operate and maintain such works or to supervise their operation and maintenance, in accordance with the respective domestic laws of each country. Each Section shall have, to the extent necessary to give effect to the provisions of this Treaty, jurisdiction over the works constructed exclusively in the territory of its country whenever such works shall be connected with or shall directly affect the execution of the provisions of this Treaty.

(c) In general to exercise and discharge the specific powers and duties entrusted to the Commission by this and other treaties and agreements in force between the two countries, and to carry into execution and prevent the violation of the provisions of those treaties and agreements. The authorities of each country shall aid and support the exercise and discharge of these powers and duties, and each Commissioner shall invoke when necessary the jurisdiction of the courts or other appropriate agencies of his country to aid in the execution and enforcement of these powers and duties.

(d) To settle all differences that may arise between the two Governments with respect to the interpretation or application of this Treaty, subject to the approval of the two Governments. In any case in which the Commissioners do not reach an agreement, they shall so inform their respective governments reporting their respective opinions and the grounds therefor and the points upon which they differ, for discussion and adjustment of the difference through diplomatic channels and for application, where proper, of the general or special agreements which the two Governments have concluded for the settlement of controversies.

(e) To furnish the information requested of the Commissioners jointly by the two Governments on matters within their jurisdiction. In the event that the request is made by one Government alone, the Commissioner of the other Government must have the express authorization of his Government in order to comply with such request.

(f) The Commission shall construct, operate and maintain upon the limitrophe parts of the international streams, and each Section shall severally construct, operate and maintain upon the parts of the international streams and their tributaries within the boundaries of its own country, such stream gaging stations as may be needed to provide the hydrographic data necessary or convenient for the proper functioning of this Treaty. The data so obtained shall be compiled and periodically exchanged between the two sections.

(g) The Commission shall submit annually a joint report to the two Governments on the matters in its charge. The Commission shall also submit to the two Governments joint reports on general or any particular matters at such other times as it may deem necessary or as may be requested by the two Governments.

Article 25

Except as otherwise specifically provided in this Treaty, Articles III and VII of the Convention of March 1, 1889 shall govern the proceedings of the Commission in carrying out the provisions of this Treaty. Supplementary thereto the Commission shall establish a body of rules and regulations to govern its procedure, consistent with the provisions of this Treaty and of Article III and VII of the Convention of March 1, 1889 and subject to approval of both Governments.

Decisions of the Commission shall be recorded in the form of Minutes done in duplicate in the English and Spanish languages, signed by each Commissioner and attested by the Secretaries, and copies thereof forwarded to each Government within three days after being signed. Except where the specific approval of the two Governments is required by any provision of this Treaty, if one of the Governments fails to communicate to the Commission its approval or disapproval of a decision of the Commission within thirty days reckoned from the date of the Minute in which it shall have been pronounced, the Minute in question and the decisions which it contains shall be considered to be approved by that Government. The Commissioners, within the limits of their respective jurisdictions, shall execute the decisions of the Commission that are approved by both Governments.

If either Government disapproves a decision of the Commission, the two Governments shall take cognizance of the matter, and if an agreement regarding such matter is reached between the two Governments, the agreement shall be communicated to the Commissioners, who shall take such further proceedings as may be necessary to carry out such agreement.

VI–TRANSITORY PROVISIONS

Article 26

During a period of eight years from the date of the entry into force of this Treaty, or until the beginning of operation of the lowest major international reservoir on the Rio Grande (Rio Bravo), should it be placed in operation prior to the expiration of said period, Mexico will cooperate with the United States to relieve, in times of drought, any lack of water needed to irrigate the lands now under irrigation in the Lower Rio Grande Valley in the United States, and for this purpose Mexico will release water from El Azucar reservoir on the San Juan River and allow that water to run through its system of canals back into the San Juan River in order that the United States may divert such water from the Rio Grande (Rio Bravo).

Such releases shall be made on condition that they do not affect the Mexican irrigation system, provided that Mexico shall, in any event, except in cases of extraordinary drought or serious accident to its hydraulic works, release and make available to the United States for its use the quantities requested, under the following conditions: that during the said eight years there shall be made available a total of 160,000 acre-feet (197,358,000 cubic meters) and up to 40,000 acre-feet (49,340,000 cubic meters) in any one year; that the water shall be made available as requested at rates not exceeding 750 cubic feet (21.2 cubic meters) per second; that when the rates of flow requested and made available have been more than 500 cubic feet (14.2 cubic meters) per second the period of release shall not extend beyond fifteen consecutive days; and that at least thirty days must lapse between any two periods of release during which rates of flow in excess of 500 cubic feet (14.2 cubic meters) per second have been requested and made available. In addition to the guaranteed flow, Mexico shall release from El Azucar reservoir and conduct through its canal system and the San Juan River, for use in the United States during periods of drought and after satisfying the needs of Mexican users, any excess water that does not in the opinion of the Mexican Section have to be stored and that may be needed for the irrigation of lands which were under irrigation during the year 1943 in the lower Rio Grande Valley in the United States.

Article 27

The provisions of Article 10,11, and 15 of this Treaty shall not be applied during a period of five years from the date of the entry into force of this Treaty, or until the Davis dam and the major Mexican diversion structure on the Colorado River are placed in operation, should these works be placed in operation prior to the expiration of said period. In the meantime Mexico may construct and operate at its expense a temporary diversion structure in the bed of the Colorado River in territory of the United States for the purpose of diverting water into the Alamo Canal, provided that the plans for such structure and the construction and operation thereof shall be subject to the approval of the United States Section. During this period of time the United States will make available in the river at such diversion structure river flow not currently required in the United States, and the United States will cooperate with Mexico to the end that the latter may satisfy its irrigation requirements within the limits of those requirements for lands irrigated in Mexico from the Colorado River during the year 1943.

VII–FINAL PROVISIONS

Article 28

This Treaty shall be ratified and the ratifications thereof shall be exchanged in Washington. It shall enter into force on the day of the exchange of ratifications and shall continue in force until terminated by another Treaty concluded for that purpose between the two Governments.

In witness whereof the respective Plenipotentiaries have signed this Treaty and have hereunto affixed their seals.

Done in duplicate in the English and Spanish languages, in Washington on this third day of February, 1944.

For the Government of the United States of America:

Cordell Hull (seal)
George S. Messersmith (seal)
Lawrence M. Lawson (seal)

For the Government of the United Mexican States:

F. Castillo Najera (seal)
Rafael Fernandez MacGregor (seal)

PROTOCOL

(Protocol, signed November 14, 1944, supplementary to treaty between United States and Mexico relating to waters of the Colorado and Tijuana Rivers and of the Rio Grande Signed February 3, 1944.)

The Government of the United States of America and the Government of the United Mexican States agree and understand that:

Wherever, by virtue of the provisions of the Treaty between the United States of America and the United Mexican States, signed in Washington on February 3, 1944, relating to the utilization of the waters of the Colorado and Tijuana Rivers and of the Rio Grande from Fort Quitman, Texas, to the Gulf of Mexico, specific functions are imposed on, or exclusive jurisdiction is vested in, either of the Sections of the International Boundary and Water Commission, which involve the construction or use of works for storage or conveyance of water, flood control, stream gauging, or for any other purpose, which are situated wholly within the territory of the county of that Section, and which are to be used only partly for the performance of treaty provisions such jurisdiction shall be exercised, and such functions, including the construction, operation and maintenance of the said works, shall be performed and carried out by the Federal agencies of that country which now or hereafter may be authorized by domestic law to construct, or to operate and maintain, such works. Such functions or jurisdictions shall be exercised in conformity with the provisions of the Treaty and in cooperation with the respective Section of the Commission, to the end that all international obligations and functions may be coordinated and fulfilled.

The works to be constructed or used on or along the boundary, and those to be constructed or used exclusively for the discharge of treaty stipulations, shall be under the jurisdiction of the commission or of the respective Section, in accordance with the provisions of the Treaty. In carrying out the construction of such works the Sections of the Commission may utilize the services of public or private organizations in accordance with the laws of their respective countries.

This Protocol, which shall be regarded as an integral part of the aforementioned Treaty signed in Washington on February 3, 1944, shall be ratified and the ratifications thereof shall be exchanged in Washington. This Protocol shall be effective beginning with the day of the entry into force of the Treaty and shall continue effective so long as the Treaty remains in force.

In witness whereof the respective Plenipotentiaries have signed this Protocol and have hereunto affixed their seals.

Done in duplicate, in English and Spanish languages, in Washington, this fourteenth day of November, 1944.

For the Government of the United States of America

E.R. Stettigius, Jr. (seal)
Acting Secretary of State of the United States of America

For the Government of the United Mexican States:

F. Castillo Najera (seal)
Ambassador Extraordinary and Plenipotentiary of the
United Mexican States in Washington

SECTION D3

LITIGATION CONCERNING THE WATERS OF THE ARKANSAS RIVER BASIN WHICH AFFECT THEIR AVAILABILITY FOR EXPORT TO THE SOUTH PLATTE RIVER BASIN

Exhibit D3-1: ARKANSAS RIVER COMPACT

37-69-101. Arkansas River compact.-- The general assembly hereby ratifies the compact between the state of Colorado and the state of Kansas designated as the "Arkansas river compact" signed in the city of Denver, state of Colorado, on the 14th day of December, A. D. 1948, by Henry C. Vidal, Gail L. Ireland, and Harry B. Mendenhall, commissioners for the state of Colorado, and George S. Knapp, Edward F. Arn, William E. Leavitt, and Roland H. Tate, commissioners for the state of Kansas, and approved by Hans Kramer, representative of the United States of America. Said compact is as follows:

ARKANSAS RIVER COMPACT

The state of Colorado and the state of Kansas, parties signatory to this compact (hereinafter referred to as "Colorado" and "Kansas," respectively, or individually as a "state," or collectively as the "states") having resolved to conclude a compact with respect to the waters of the Arkansas river, and being moved by considerations of interstate comity, having appointed commissioners as follows:

Henry C. Vidal, Gail L. Ireland, and Harry B. Mendenhall, for Colorado; and George S. Knapp, Edward F. Arn, William E. Leavitt, and Roland H. Tate, for Kansas; and the consent of the congress of the United States to negotiate and enter into an interstate compact not later than January 1, 1950, having been granted by Public Law 34, 79th Congress, 1st Session, and pursuant thereto the President having designated Hans Kramer as the representative of the United States, the said commissioners for Colorado and Kansas, after negotiations participated in by the representative of the United States, have agreed as follows:

ARTICLE I

The major purposes of this compact are to:

A. Settle existing disputes and remove causes of future controversy between the states of Colorado and Kansas, and between citizens of one and citizens of the other state, concerning the waters of the Arkansas river and their control, conservation and utilization for irrigation and other beneficial purposes.

B. Equitably divide and apportion between the states of Colorado and Kansas the waters of the Arkansas river and their utilization as well as the benefits arising from the construction, operation and maintenance by the United States of John Martin reservoir project for water conservation purposes.

ARTICLE II

The provisions of this compact are based on (1) the physical and other conditions peculiar to the Arkansas river and its natural drainage basin, and the nature and location of irrigation and other developments and facilities in connection therewith; (2) the opinion of the United States supreme court entered December 6, 1943, in the case of Colorado v. Kansas (320 U. S. 383) concerning the relative rights of the respective states in and to the use of waters of the Arkansas river; and (3) the experience derived under various interim executive agreements between the two states apportioning the waters released from the John Martin reservoir as operated by the corps of engineers.

ARTICLE III

As used in this compact:

A. The word "stateline" means the geographical boundary line between Colorado and Kansas.

B. The term "waters of the Arkansas river" means the waters originating in the natural drainage basin of the Arkansas river, including its tributaries, upstream from the stateline, and excluding waters brought into the Arkansas river basin from other river basins.

C. The term "stateline flow" means the flow of waters of the Arkansas river as determined by gauging stations located at or near the stateline. The flow as determined by such stations, whether located in Colorado or Kansas, shall be deemed to be the actual stateline flow.

D. "John Martin reservoir project" is the official name of the facility formerly known as Caddoa reservoir project, authorized by the Flood Control Act of 1936, as amended, for construction, operation and maintenance by the war department, corps of engineers, later designated at the corps of engineers, department of the army, and herein referred to as the "corps of engineers." "John Martin reservoir" is the water storage space created by "John Martin dam".

E. The "flood control storage" is that portion of the total storage space in John Martin reservoir allocated to flood control purposes.

F. The "conservation pool" is that portion of the total storage space in John Martin reservoir lying below the flood control storage.

G. The "ditches of Colorado water district 67" are those ditches and canals which divert water from the Arkansas river or its tributaries downstream from John Martin dam for irrigation use in Colorado.

H. The term "river flow" means the sum of the flows of the Arkansas and the Purgatoire rivers into John Martin reservoir as determined by gauging stations appropriately located above said reservoir.

I. The term "the administration" means the Arkansas river compact administration established under article VIII.

ARTICLE IV

Both states recognize that:

A. This compact deals only with the waters of the Arkansas river as defined in article III.

B. This compact is not concerned with the rights, if any, of the state of New Mexico or its citizens in and to the use in New Mexico of waters of Trinchera creek or other tributaries of the Purgatoire river, a tributary of the Arkansas river.

C. (1) John Martin dam will be operated by the corps of engineers to store and release the waters of the Arkansas river in and from John Martin reservoir for its authorized purposes.

(2) The bottom of the flood control storage is presently fixed by the chief of engineers, U. S. Army, at elevation 3,851 feet above mean sea level. The flood control storage will be operate for flood control purposes and to those ends will impound or regulate the streamflow volumes that are in excess of the then available storage capacity of the conservation pool. Releases from the flood control storage may be made at times and rates determined by the corps of engineers to be necessary or advisable without regard to ditch diversion capacities or requirements in either or both states.

(3) The conservation pool will be operated for the benefit of water users in Colorado and Kansas, both upstream and downstream from John Martin dam, as provided in this compact. The maintenance of John Martin dam and appurtenance works may at times require the corps of engineers to release waters then impounded in the conservation pool or to prohibit the storage of water therein until such maintenance work is completed. Flood control operation may also involve temporary utilization of conservation storage.

D. This compact is not intended to impede or prevent future beneficial development of the Arkansas river basin in Colorado and Kansas by federal or state agencies, by private enterprise, or by combinations thereof, which may involve construction of dams, reservoirs and other works for the purposes of water utilization and control, as well as the improved or prolonged functioning of existing works: Provided, that the waters of the Arkansas river, as defined in article III, shall not be materially depleted in usable quantity or availability for use to the water users in Colorado and Kansas under this compact by such future development or construction.

ARTICLE V

Colorado and Kansas hereby agree upon the following basis of apportionment of the waters of the Arkansas river:

A. Winter storage in John Martin reservoir shall commence on November 1st of each year and continue to and include the next succeeding March 31st. During said period all water entering said reservoir up to the limit of the then available conservation capacity shall be stored: Provided, that Colorado may demand releases of water equivalent to the river flow, but such releases shall not exceed 100 c.f.s. (cubic feet per second) and water so released shall be used without avoidable waste.

B. Summer storage in John Martin reservoir shall commence on April 1st of each year and continue to and include the next succeeding October 31st. During said period, except when Colorado water users are operating under decreed priorities as provided in paragraphs F and G of this article, all water entering said reservoir up to the limit of the then available conservation capacity shall be stored: Provided, that Colorado may demand releases of water equivalent to the river flow up to 500 c.f.s., and Kansas may demand releases of water equivalent to that portion of the river flow between 500 c.f.s. and 750 c.f.s., irrespective of releases demanded by Colorado.

C. Releases of water stored pursuant to the provisions of paragraphs A and B of this article shall be made upon demands by Colorado and Kansas concurrently or separately at any time during the summer storage period. Unless increases to meet extraordinary conditions are authorized by the administration, separate releases of stored water to Colorado shall not exceed 750 c.f.s., separate releases of stored water to Kansas shall not exceed 500 c.f.s., and concurrent releases of stored water shall not exceed a total of 1250 c.f.s.: Provided, that when water stored in the conservation pool is reduced to a quantity less than 20,000 acre-feet, separate releases of stored water to Colorado shall not exceed 600 c.f.s., and separate releases of stored water to Kansas shall not exceed 400 c.f.s., and concurrent releases of stored water shall not exceed 1,000 c.f.s.

D. Releases authorized by paragraphs A, B, and C of this article, except when all Colorado water users are operating under decree priorities as provided in paragraphs F and G of this article, shall not impose any call on Colorado water users that divert waters of the Arkansas river upstream from John Martin dam.

E. (1) Releases of stored water and releases of river flow may be made simultaneously upon the demands of either or both states.

(2) Water released upon concurrent or separate demands shall be applied promptly to beneficial use unless storage thereof downstream is authorized by the administration.

(3) Releases of river flow and of stored water to Colorado shall be measured by gauging stations located at or near John Martin dam and the releases to which Kansas is entitled shall be satisfied by an equivalent in state line flow.

(4) When water is released from John Martin reservoir appropriate allowances as determined by the administration shall be made for the intervals of time required for such water to arrive at the points of diversion in Colorado and at the state line.

(5) There shall be no allowance or accumulation of credits or debits for or against either state.

(6) Storage, releases from storage and releases of river flow authorized in this article shall be accomplished pursuant to procedures prescribed by the administration under the provisions of article VIII.

F. In the event the administration finds that within a period of fourteen days the water in the conservation pool will be or is liable to be exhausted, the administration shall forthwith notify the state engineer of Colorado, or his duly authorized representative, that commencing upon a day certain within said fourteen day period, unless a change of conditions justifies cancellation or modification of such notice, Colorado shall administer the decreed rights of water users in Colorado water district 67 as against each other and as against all rights now or hereafter decreed to water users diverting upstream from John Martin dam on the basis of relative priorities in the same manner in which their respective priority rights were administered by Colorado before John Martin reservoir began to operate and as though John Martin dam had not been constructed. Such priority administration by Colorado shall be continued until the administration finds that water is again available in the conservation pool for release as provided in this compact, and timely notice of such finding shall be given by the administration to the state engineer of Colorado or his duly authorized representative; provided, that except as controlled by the operation of the preceding provisions of this paragraph and other applicable provisions of this compact, when there is water in the conservation pool the water users upstream from John Martin reservoir shall not be affected by the decrees to the ditches in Colorado water district 67. Except when administration in Colorado is on a priority basis the water diversions in Colorado water district 67 shall be administered by Colorado in accordance with distribution agreements made from time to time between the water users in such district and filed with the administration and with the state engineer of Colorado or, in the absence of such agreement, upon the basis of the respective priority decrees, as against each other, in said district.

G. During periods when Colorado reverts to administration of decree priorities, Kansas shall not be entitled to any portion of the river flow entering John Martin reservoir. Waters of the Arkansas river originating in Colorado which may flow across the state line during such periods are hereby apportioned to Kansas.

H. If the usable quantity and availability for use of the waters of the Arkansas river to water users in Colorado water district 67 and Kansas will be thereby materially depleted or adversely affected, (1) priority rights now decreed to the ditches of Colorado water district 67 shall not hereafter be transferred to other water districts in Colorado or to points of diversion or places of use upstream from John Martin dam; and (2) the ditch diversion rights from the Arkansas river in Colorado water district 67 and of Kansas ditches between the state line and Garden City shall not hereafter be increased beyond the total present rights of said ditches, without the administration, in either case (1) or (2), making findings of fact that no such depletion or adverse effect will result from such proposed transfer or increase. Notice of legal proceedings for any such proposed transfer or increase shall be given to the administration in the manner and within the time provided by the laws of Colorado or Kansas in such cases.

ARTICLE VI

A. (1) Nothing in this compact shall be construed as impairing the jurisdiction of Kansas over the waters of the Arkansas river that originate in Kansas and over the waters that flow from Colorado across the state line into Kansas.

(2) Except as otherwise provided, nothing in this compact shall be construed as supplanting the administration by Colorado of the rights of appropriators of waters of the Arkansas river in said state as decreed to said appropriators by the courts of Colorado, nor as interfering with the distribution among said appropriators by Colorado, nor as curtailing the diversion and use for irrigation and other beneficial purposes in Colorado of the waters of the Arkansas river.

B. Inasmuch as the Frontier canal diverts waters of the Arkansas river in Colorado west of the state line for irrigation uses in Kansas only, Colorado concedes to Kansas and Kansas hereby assumes exclusive administrative control over the operation of the Frontier canal and its headworks for such purposes, to the same extent as though said works were located entirely within the state of Kansas. Water carried across the state line in Frontier canal or any other similarly situated canal shall be considered to be part of the state line flow.

ARTICLE VII

A. Each state shall be subject to the terms of this compact. Where the name of the state or the term "state" is used in this compact these shall be construed to include any person or entity of any nature whatsoever using, claiming or in any manner asserting any right to the use of the waters of the Arkansas river under the authority of that state.

B. This compact establishes no general principle or precedent with respect to any other interstate stream.

C. Wherever any state or federal official agency is referred to in this compact such reference shall apply to the comparable official or agency succeeding to their duties and functions.

ARTICLE VIII

A. To administer the provisions of this compact there is hereby created an interstate agency to be known as the Arkansas river compact administration herein designated as "the administration".

B. The administration shall have power to:

(1) Adopt, amend and revoke by-laws, rules and regulations consistent with the provisions of this compact;

(2) Prescribe procedures for the administration of this compact: Provided, that where such procedures involve the operation of John Martin reservoir project they shall be subject to the approval of the district engineer in charge of said project;

(3) Perform all functions required to implement this compact and to do all things necessary, proper or convenient in the performance of its duties.

C. The membership of the administration shall consist of three representatives from each state who shall be appointed by the respective governors for a term not to exceed four years. One Colorado representative shall be a resident of and water right owner in water district 14 or 17, one Colorado representative shall be a resident of and water right owner in water district 67, and one Colorado representative shall be the director of the Colorado water conservation board. Two Kansas representatives shall be residents of and water right owners in the counties of Finey, Kearny or Hamilton, and one Kansas representative shall be the chief state official charged with the administration of water rights in Kansas. The President of the United States is hereby requested to designate a representative of the United States, and if a representative is so designated he shall be an ex officio member and act as chairman of the administration without vote.

D. The state representatives shall be appointed by the respective governors within thirty days after the effective date of this compact The administration shall meet and organize within sixty days after such effective date. A quorum for any meeting shall consist of four members of the administration: Provided, that at least two members are present from each state. Each state shall have but one vote in the administration and every decision, authorization or other action shall require unanimous vote. In case of a divided vote on any matter within the purview of the administration, the administration may, by subsequent unanimous vote, refer the matter for arbitration to the representative of the United States or other arbitrator or arbitrators, in which event the decision made by such arbitrator or arbitrators shall be binding upon the administration.

E. (1) The salaries, if any, and the personal expenses of each member shall be paid by the government which he represents. All other expenses incident to the administration of this compact which are not paid by the United States shall be borne by the states on the basis of 60 per cent by Colorado and 40 per cent by Kansas.

(2) In each even numbered year the administration shall adopt and transmit to the governor of each state its budget covering anticipated expenses for the forthcoming biennium and the amount thereof payable by each state. Each state shall appropriate and pay the amount due by it to the administration.

(3) The administration shall keep accurate accounts of all receipts and disbursements and shall include a statement thereof, together with a certificate of audit by a certified public accountant, in its annual report. Each state shall have the right to make an examination and audit of the accounts of the administration at any time.

F. Each state shall provide such available facilities, equipment and other assistance as the administration may need to carry out its duties. To supplement such available assistance the administration may employ engineering, legal, clerical and other aid as in its judgment may be necessary for the performance of its functions. Such employees shall be paid by and be responsible to the administration, and shall not be considered to be employees of either state.

G. (1) The administration shall co-operate with the chief official of each state charged with the administration of water rights and with federal agencies in the systematic determination and correlation of the facts as to the flow and diversion of the waters of the Arkansas river and as to the operation and siltation of John Martin Reservoir and other related structures. The administration shall co-operate in the procurement, interchange, compilation and publication of all factual data bearing upon the administration of this compact without, in general, duplicating measurements, observations or publications made by state or federal agencies. State officials shall furnish pertinent factual data to the administration upon its request. The administration shall, with the collaboration of the appropriate federal and state agencies, determine as may be necessary from time to time, the location of gauging stations required for the proper administration of this compact and shall designate the official records of such stations for its official use.

(2) The director, U. S. geological survey, the commissioner of reclamation and the chief of engineers, U. S. Army, are hereby requested to collaborate with the administration and with appropriate state officials in the systematic determination and correlation of data referred to in paragraph G (1) of this article and in the execution of other duties of such officials which may be necessary for the proper administration of this compact.

(3) If deemed necessary for the administration of this compact, the administration may require the installation and maintenance, at the expense of water users, of measuring devices of approved type in any ditch or group of ditches diverting water from the Arkansas river in Colorado or Kansas. The chief official of each state charged with the administration of water rights shall supervise the execution of the administration's requirements for such installations.

H. Violation of any of the provisions of this compact or other actions prejudicial thereto which come to the attention of the administration shall be promptly investigated by it. When deemed advisable as the result of such investigation, the administration may report its findings and recommendations to the state official who is charged with the administration of water rights for appropriate action, it being the intent of this compact that enforcement of its terms shall be accomplished in general through the state agencies and officials charged with the administration of water rights.

I. Findings of fact made by the administration shall not be conclusive in any court or before any agency or tribunal but shall constitute prima facie evidence of the facts found.

J. The administration shall report annually to the governors of the states and to the President of the United States as to matters within its purview.

ARTICLE IX

A. This compact shall become effective when ratified by the legislature of each state and when consented to by the congress of the United States by legislation providing substantially, among other things, as follows:

Nothing contained in this act or in the compact herein consented to shall be construed as impairing or affecting the sovereignty of the United States or any of its rights or jurisdiction in and over the area or waters which are the subject of such compact: Provided, that the chief of engineers is hereby authorized to operate the conservation features of the John Martin reservoir project in a manner conforming to such compact with such exceptions as he and the administration created pursuant to the compact may jointly approve.

B. This compact shall remain in effect until modified or terminated by unanimous action of the states and in the event of modification or termination all rights then established or recognized by this compact shall continue unimpaired.

IN WITNESS WHEREOF, the commissioners have signed this compact in triplicate original, one of which shall be forwarded to the secretary of state of the United States of America and one of which shall be forwarded to the governor of each signatory state.

Done in the city and county of Denver, in the state of Colorado, on the fourteenth day of December, in the year of our Lord one thousand nine hundred and forty-eight.

Henry C. Vidal,
Gail L. Ireland,
Harry B. Mendenhall,
Commissioners for Colorado.

Attest:
Warden L. Noe, Secretary.

George S. Knapp,
Edward F. Arn,
William E. Leavitt,
Roland H. Tate,
Commissioners for Kansas.

Approved:
Hans Kramer,
Representative of the
United States.

37-69-102. When compact effective.-- Said compact shall not become effective unless and until the same has been ratified by the legislature of each of the signatory states and consented to by the congress of the United States. The governor of the state of Colorado shall give notice of the ratification of the said compact to the governor of the state of Kansas and to the president of the United States.

37-69-103. Interstate agency created by compact.-- It is hereby recognized, found, determined, and declared that the compact creates an interstate agency which is known as the Arkansas river compact administration and which is an independent entity whose members and employees are not officers and employees of either of the states signatory to the compact.

37-69-104. Appointment of members of compact administration.-- After the said compact becomes effective the Colorado members of the Arkansas river compact administration shall be appointed by the governor, shall serve until revocation of their appointment by the governor, and, on behalf of the Arkansas river compact administration, the state of Colorado shall pay the necessary expenses and also compensation of said members in an amount which shall be fixed by the governor and when so fixed shall be changed only by action of the governor.

37-69-105. Payment of expenses of compact administration.-- The Colorado share of the expenses of the Arkansas river compact administration and the expenses and compensation of the Colorado members of that administration shall be paid out of funds appropriated by the general assembly to the Colorado water conservation board and warrants shall be drawn against such appropriation upon vouchers signed by the governor and the director of the Colorado water conservation board.

37-69-106. Administrative code inapplicable.-- The provisions of articles 2, 3, 31, 35, and 36 of title 24, C.R.S. 1973, shall be inapplicable to any acts or proceedings taken to carry out the purposes of said compact.

SECTION D4

LITIGATION CONCERNING THE WATERS OF THE SOUTH PLATTE RIVER BASIN WHICH AFFECT THEIR AVAILABILITY FOR USE WITHIN COLORADO

Exhibit D4-1: SOUTH PLATTE RIVER COMPACT

37-65-101. South Platte River Compact.-- The General Assembly hereby approves the compact, designated as the "South Platte River Compact", between the states of Colorado and Nebraska, signed at the City of Lincoln, State of Nebraska, on the 27th day of April, A.D. 1923, by Delph E. Carpenter as the Commissioner for the State of Colorado, under authority of Chapter 243, Session Laws of Colorado, 1921, and Chapter 190, Session Laws of Colorado, 1923, and by Robert H. Willis as the Commissioner for the State of Nebraska, thereunto duly authorized, which said compact is as follows:

SOUTH PLATTE RIVER COMPACT BETWEEN THE STATES OF COLORADO AND NEBRASKA

The State of Colorado and the State of Nebraska, desiring to remove all causes of present and future controversy between said States, and between citizens of one against citizens of the other, with respect to the waters of the South Platte River, and being moved by considerations of interstate comity, have resolved to conclude a compact for these purposes and, through their respective Governors, have named as their commissioners:

Delph E. Carpenter, for the State of Colorado; and Robert H. Willis, for the State of Nebraska; who have agreed upon the following articles:

ARTICLE I

In this compact:

1. The State of Colorado and the State of Nebraska are designated, respectively, as "Colorado" and "Nebraska".

2. The provisions hereof respecting each signatory State, shall include and bind its citizens and corporations and all others engaged or interested in the diversion and use of the waters of the South Platte River in that State.

3. The term "Upper Section" means that part of the South Platte River in the State of Colorado above and westerly from the west boundary of Washington County, Colorado.

4. The term "Lower Section" means that part of the South Platte River in the State of Colorado between the west boundary of Washington County and the intersection of said river with the boundary line common to the signatory States.

5. The term "Interstate Station" means that streams gauging station described in Article II.

6. The term "flow of the river" at the Interstate Station means the measured flow of the river at said station plus all increment to said flow entering the river between the Interstate Station and the diversion works of the Western Irrigation District in Nebraska.

ARTICLE II

1. Colorado and Nebraska, at their joint expense, shall maintain a stream gauging station upon the South Platte River at the river bridge near the town of Julesburg, Colorado, or at a convenient point between said bridge and the diversion works of the canal of the Western Irrigation District in Nebraska, for the purpose of ascertaining and recording the amount of water flowing in said river from Colorado into Nebraska and to said diversion works at all times between the first day of April and the fifteenth day of October of each year. The location of said station may be changed from year to year as the river channels and water flow conditions of the river may require.

2. The State Engineer of Colorado and the Secretary of the Department of Public Works of Nebraska shall make provision for the co-operative gauging at and the details of operation of said station and for the exchange and publication of records and data. Said state officials shall ascertain the rate of flow of the South Platte River through the Lower Section in Colorado and the time required for increases or decreases of flow, at points within said Lower Section, to reach the Interstate Station. In carrying out the provisions of Article IV of this compact, Colorado shall always be allowed sufficient time for any increase in flow (less permissible diversions) to pass down the river and be recorded at the Interstate Station.

ARTICLE III

The waters of Lodgepole Creek, a tributary of the South Platte River flowing through Nebraska and entering said river within Colorado, hereafter shall be divided and apportioned between the signatory States as follows:

1. The point of division of the waters of Lodgepole Creek shall be located on said creek two miles north of the boundary line common to the signatory states.

2. Nebraska shall have the full and unmolested use and benefit of all waters flowing in Lodgepole Creek above the point of diversion and Colorado waives all present and future claims to the use of said waters. Colorado shall have the exclusive use and benefit of all waters flowing at or below the point of division.

3. Nebraska may use the channel of Lodgepole Creek below the point of division and the channel of the South Platte River between the mouth of Lodgepole Creek and the Interstate Station, for the carriage of any waters of Lodgepole Creek which may be stored in Nebraska above the point of division and which Nebraska may desire to deliver to ditches from the South Platte River in Nebraska, and any such waters so carried shall be free from interference by diversions in Colorado and shall not be included as a part of the flow of the South Platte River to be delivered by Colorado at the Interstate Station in compliance with Article IV of this compact, provided, however, that such runs of stored water shall be made in amounts of not less than ten cubic feet per second of time and for periods of not less than twenty-four hours.

ARTICLE IV

The waters of the South Platte River hereafter shall be divided and apportioned between the signatory States as follows:

1. At all times between the fifteenth day of October of any year and the first day of April of the next succeeding year, Colorado shall have the full and uninterrupted use and benefit of the waters of the river flowing within the boundaries of the State, except as otherwise provided by Article VI.

2. Between the first day of April and the fifteenth day of October of each year, Colorado shall not permit diversions from the Lower Section of the river, to supply Colorado appropriations having adjudicated dates of priority subsequent to the fourteenth day of June, 1897, to an extent that will diminish the flow of the river at the Interstate Station, on any day, below a mean flow of 120 cubic feet of water per second of time, except as limited in paragraph three (3) of this Article.

3. Nebraska shall not be entitled to receive and Colorado shall not be required to deliver, on any day, any part of the flow of the river to pass the Interstate Station, as provided by paragraph (2) of this Article, not then necessary for beneficial use by those entitled to divert water from said river within Nebraska.

4. The flow of the river at the Interstate Station shall be used by Nebraska to supply the needs of present perfected rights to the use of water from the river within said State before permitting diversions from the river by other claimants.

5. It is recognized that variable climatic conditions, the regulation and administration of the stream in Colorado, and other causes, will produce diurnal and other unavoidable variations and fluctuations in the flow of the river at the Interstate Station, and it is agreed that, in the performance of the provisions of said paragraph two (2), minor or compensating irregularities and fluctuations in the flow at the Interstate Station shall be permitted; but where any deficiency of the mean daily flow at the Interstate Station may have been occasioned by neglect, error or failure in the performance of duty by the Colorado water officials having charge of the administration of diversions from the Lower Section of the river in that state, each such deficiency shall be made up, within the next succeeding period of seventy-two hours, by delivery of additional flow at the Interstate Station, over and above the amount specified in paragraph two (2) of this Article, sufficient to compensate for such deficiency.

6. Reductions in diversions from the Lower Section of the river, necessary to the performance of paragraph two (2) of this Article by Colorado, shall not impair the rights of appropriators in Colorado (not to include the proposed Nebraska canal described in Article VI), whose supply has been so reduced, to demand and receive equivalent amounts of water from other parts of the stream in that State according to its Constitution, laws, and the decisions of its courts.

7. Subject to compliance with the provisions of this Article, Colorado shall have and enjoy the otherwise full and uninterrupted use and benefit of the waters of the river which hereafter may flow within the boundaries of that State from the first day of April to the fifteenth day of October in each year, but Nebraska shall be permitted to divert, under and subject to the provisions and conditions of Article VI, any surplus waters which otherwise would flow past the Interstate Station.

ARTICLE V

1. Colorado shall have the right to maintain, operate, and extend, within Nebraska, the Peterson Canal and other canals of the Julesburg Irrigation District which now are or may hereafter be used for the carriage of water from the South Platte River for the irrigation of lands in both states, and Colorado shall continue

to exercise control and jurisdiction of said canals and the carriage and delivery of water thereby. This Article shall not excuse Nebraska water users from making reports to Nebraska officials in compliance with the Nebraska laws.

2. Colorado waives any objection to the delivery of water for irrigation of lands in Nebraska by the canals mentioned in paragraph one (1) of this Article, and agrees that all interests in said canals and the use of waters carried thereby, now or hereafter acquired by owners of lands in Nebraska, shall be afforded the same recognition and protection as are the interests of similar land owners served by said canals within Colorado; provided, however, that Colorado reserves to those in control of said canals the right to enforce the collection of charges or assessments, hereafter levied or made against such interest of owners of the lands in Nebraska, by withholding the delivery of water until the payment of such charges or assessments; provided, however, such charges or assessments shall be the same as those levied against similar interests of owners of lands in Colorado.

3. Nebraska grants to Colorado the right to acquire by purchase, prescription, or the exercise of eminent domain, such rights-of-way, easements or lands as may be necessary for the construction, maintenance, operation, and protection of those parts of the above mentioned canals which now or hereafter may extend into Nebraska.

ARTICLE VI

It is the desire of Nebraska to permit its citizens to cause a canal to be constructed and operated for the diversion of water from the South Platte River within Colorado for irrigation of lands in Nebraska; that said canal may commence on the south bank of said river at a point southwesterly from the town of Ovid, Colorado, and may run thence easterly through Colorado along or near the line of survey of the formerly proposed "Perkins County Canal" (sometimes known as the "South Divide Canal") and into Nebraska, and that said project shall be permitted to divert waters of the river as hereinafter provided. With respect to such proposed canal it is agreed:

1. Colorado consents that Nebraska and its citizens may hereafter construct, maintain, and operate such a canal and thereby may divert water from the South Platte River within Colorado for use in Nebraska, in the manner and at the time in this Article provided, and grants to Nebraska and its citizens the right to acquire by purchase, prescription, or the exercise of eminent domain such rights-of-way, easements or lands as may be necessary for the construction, maintenance, and operation of said canal; subject, however, to the reservations and limitations and upon the conditions expressed in this Article which are and shall be limitations upon and reservations and conditions running with the rights and privileges hereby granted, and which shall be expressed in all permits issued by Nebraska with respect to said canal.

2. The net future flow of the Lower Section of the South Platte River, which may remain after supplying all present and future appropriations from the Upper Section, and after supplying all appropriations from the Lower Section perfected prior to the seventeenth day of December 1921, and after supplying the additional future appropriations in the Lower Section for the benefit of which a prior and preferred use of thirty-five thousand acre-feet of water is reserved by subparagraph (a) of this Article, may be diverted by said canal between the fifteenth day of October of any year and the first day of April of the next succeeding year subject to the following reservations, limitations and conditions:

(a) In addition to the water now diverted from the Lower Section of the river by present perfected appropriations, Colorado hereby reserves the prior, preferred and superior right to store, use and to have in storage in readiness for use on and after the first day of April in each year, an aggregate of thirty-five thousand acre-feet of water to be diverted from the flow of the river in the Lower Section between the fifteenth day of October of each year and the first day of April of the next succeeding year, without regard to the manner or time of making such future uses, and diversions of water by said Nebraska canal shall in no manner impair or interfere with the exercise by Colorado of the right of future use of the water hereby reserved.

(b) Subject at all times to the reservation made by subparagraph (a) and to the other provisions of this Article, said proposed canal shall be entitled to divert five hundred cubic feet of water per second of time from the flow of the river in the Lower Sections, as of priority of appropriation of date December 17, 1921, only between the fifteenth day of October of any year and the first day of April of the next succeeding year upon the express condition that the right to so divert water is and shall be limited exclusively to said annual period and shall not constitute the basis for any claim to water necessary to supply all present and future appropriations in the Upper Section or present appropriations in the Lower Section and those hereafter to be made therein as provided in subparagraph (a).

3. Neither this compact nor the construction and operation of such a canal nor the diversion, carriage and application of water thereby shall vest in Nebraska, or in those in charge or control of said canal or in the users of water therefrom, any prior, preferred or superior servitude upon or claim or right to the use of any water of the South Platte River in Colorado from the first day of April to the fifteenth day of October of any year or against any present or future appropriator or use of water from said river in Colorado during said period of every year, and Nebraska specifically waives any such claims and agrees that the same shall never be made or asserted. Any surplus waters of the river, which otherwise would flow past the Interstate Station during such period of any year after supplying all present and future diversions by Colorado, may be diverted by such a canal, subject to the other provisions and conditions of this Article.

4. Diversion of water by said canal shall not diminish the flow necessary to pass the Interstate Station to satisfy superior claims of users of water from the river in Nebraska.

5. No appropriations of water from the South Platte River by any other canal within Colorado shall be transferred to said canal or be claimed or asserted for diversion and carriage for use on lands in Nebraska.

6. Nebraska shall have the right to regulate diversions of water by said canal for the purposes of protecting other diversions from the South Platte River within Nebraska and of avoiding violations of the provisions of Article IV; but Colorado reserves the right at all times to regulate and control the diversions by said canal to the extent necessary for the protection of all appropriations and diversions within Colorado or necessary to maintain the flow at the Interstate Stations as provided by Article IV of this compact.

ARTICLE VII

Nebraska agrees that compliance by Colorado with the provisions of this compact and the delivery of water in accordance with its terms shall relieve Colorado from any further or additional demand or claim by Nebraska upon the waters of the South Platte River within Colorado.

ARTICLE VIII

Whenever any official of either State is designated herein to perform any duty under this compact, such designation shall be interpreted to include the state official or officials upon whom the duties now performed by such official may hereafter devolve, and it shall be the duty of the officials of the State of Colorado charged with the duty of the distribution of the waters of the South Platte River for irrigation purposes, to make deliveries of water at the Interstate Station in compliance with this compact without necessity of enactment of special statutes for such purposes by the General Assembly of the State of Colorado.

ARTICLE IX

The physical and other conditions peculiar to the South Platte River and to the territory drained and served thereby constitute the basis for this compact and neither of the signatory States hereby concedes the establishment of any general principle or precedent with respect to other interstate streams.

ARTICLE X

This compact may be modified or terminated at any time by mutual consent of the signatory States, but, if so terminated and Nebraska or its citizens shall seek to enforce any claims of vested rights in the waters of the South Platte River, the statutes of limitation shall not run in favor of Colorado or its citizens with reference to claims of the Western Irrigation District to the water of the South Platte River from the sixteenth day of April, 1916, and as to all other present claims from the date of the approval of this compact to the date of such termination, and the State of Colorado and its citizens who may be made defendants in any action brought for such purpose shall not be permitted to plead the statutes of limitation for such period of time.

ARTICLE XI

This compact shall become operative when approved by the Legislature of each of the signatory States and by the Congress of the United States. Notice of approval by the Legislature shall be given by the Governor of each State to the Governor of the other State and to the President of the United States, and the President of the United States is requested to give notice to the Governors of the signatory States of the approval by the Congress of the United States.

IN WITNESS WHEREOF, the Commissioners have signed this compact in duplicate originals, one of which shall be deposited with the Secretary of State of each of the Signatory States.

Done at Lincoln, in the State of Nebraska, this 27th day of April, in the year of our Lord One Thousand Nine Hundred and Twenty-three.

Delph E. Carpenter,

Robert H. Willis.