Upper Colorado Region

Comprehensive Framework Study

Appendix X
Irrigation and Drainage

per Colorado Region State-Federal Inter-Agency Group / Pacific Southwest
r - Agency Committee / Water Resources Council June 1971

UPPER COLORADO REGION

COMPREHENSIVE FRAMEWORK STUDY

APPENDIX X

IRRIGATION AND DRAINAGE

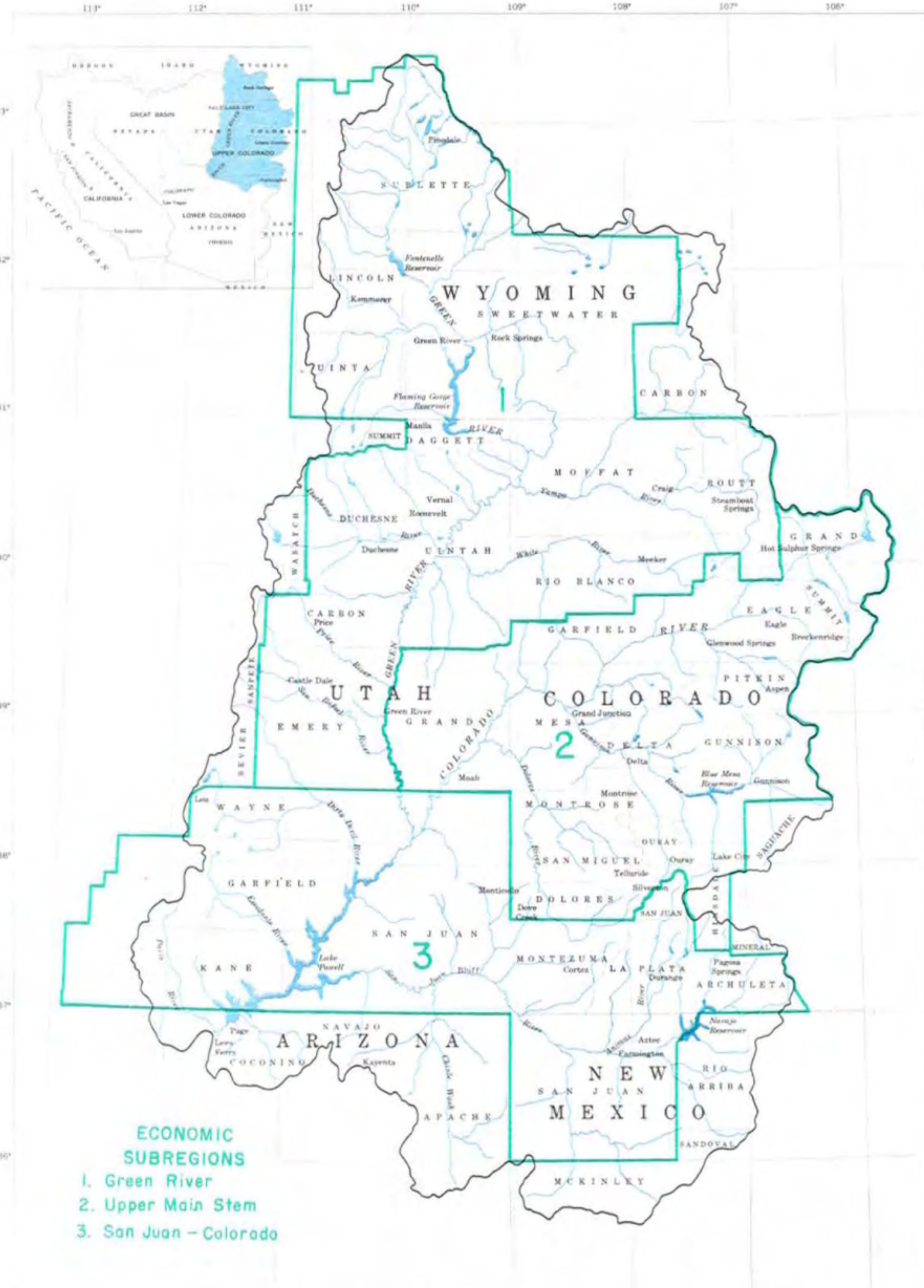
JUNE 1971

This report of the Upper Colorado Region State-Federal Interagency Group was prepared at field level and presents a framework program for the development and management of the water and related land resources of the Upper Colorado Region. This report is subject to review by the interested Federal agencies at the departmental level, by the Governors of the affected states, and by the Water Resources Council prior to its transmittal to the Congress for its consideration.

LIST OF DOCUMENTS
COMPREHENSIVE FRAMEWORK STUDIES

UPPER COLORADO REGION

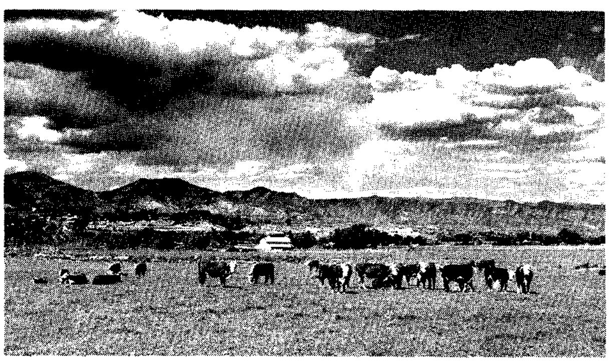
COMPREHENSIVE FRAMEWORK STUDY



UPPER COLORADO REGION
COMPREHENSIVE FRAMEWORK STUDY

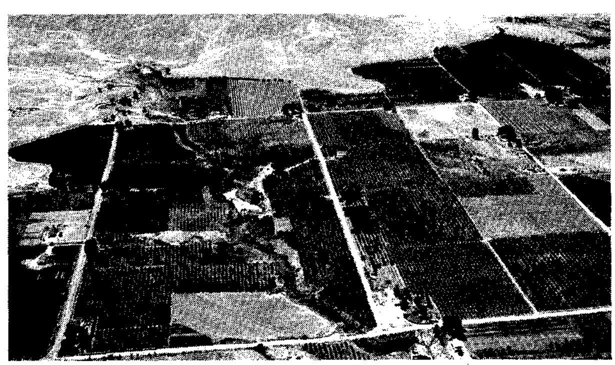
SOURCE OF WATER

RESERVOIR STORAGE



FEED FOR LIVESTOCK

DIVERSIFIED FARMING



Water and land are important resources of the Upper Colorado Region. Water from melting snow is stored in reservoirs and diverted for irrigation of parched crop lands downstream.

SUMMARY

A total of 1,621,500 acres or 2 percent of the land area of the region was irrigated in 1965 and 7,058,600 acres of potentially irrigable land (10 percent of area) are suitable for irrigation. The annual modified outflow of water from the region for 1965 development conditions averaged 12,064,000 acre-feet.

"Regionally Interpreted" OBERS objectives were used as a basis for the framework plan and appraised crop production needs consistent with livestock output projections by utilizing the region's resources and determined land acreage and water requirements for irrigation, as follows:

	1965	1980	2000	2020
Irrigated land (1,000 acres)	1,622	1,794	1,954	2,122
On-site water depletions (1,000 acre-feet)	2,128	2,653	2,982	3,294

To satisfy "RI" OBERS framework plan requirements for irrigation by 2020, 587,400 acres of new land will need to be developed--including 86,800 acres to replace irrigated land abandoned or converted to other uses. A total of 421,100 acres of short-supply irrigated land will be provided supplemental water.

Alternate levels of irrigation development in the region are as follows:

Level of development	Irrigated acreage (1,000 acres)		On-site depletions (1,000 acre-feet)	
	1965	2020	1965	2020
OBERS, "As published"	1,622	1,551	2,128	1/ 2,200
"Regionally Interpreted" OBERS	1,622	2,122	2,128	3,294
State alternative (6.5 MAF)	1,622	2,118	2,128	3,297
State alternative (8.16 MAF)	1,622	2,354	2,128	3,658
State alternative (water available)	1,622	2,579	2,128	4,089

1/ Estimated.

Sufficient land and water for irrigation are available within the region to meet all needs projected in the development levels. The latter alternative will require augmentation of water to meet Colorado River Compact requirements. For larger developments, land is available but substantial augmentation would be required to satisfy demands within the region as well as downstream.

Installation cost for irrigation, including system improvement, drainage, and irrigation's prorated share of storage and major distribution systems, will total $857 million by 2020 under the "RI" OBERS framework plan.

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PART I

INTRODUCTION

Purpose and Scope

The specific purposes of the Irrigation and Drainage Appendix are to: (1) identify all presently irrigated and potentially irrigable lands, (2) determine the adequacy of water supplied to presently irrigated lands and water requirements of potentially irrigable lands, (3) show projected acreage of irrigated lands and the amount of water required to meet the production needs in the Upper Colorado Region for the years 1980, 2000, and 2020, including programs and costs for irrigation and drainage, and (4) present alternate levels of development.

Appendix X includes irrigation data for the region according to the following principal parts:

Part I. Introduction.--A brief discussion of the appendix and its scope and limitations.

Part II. Present status of irrigated land.--A summary of presently irrigated acres by source and adequacy of water supply, irrigation practices, water utilization, water quality, water rights, drainage, and irrigation's contribution to the economy of the region.

Part III. Irrigation potential.--A summary of the potentially irrigable lands, water requirements, and availability of irrigation water.

Part IV. Future demands.--A summary of projected demands for irrigated land, water requirements, water quality, land use and crop production, drainage requirements, and costs for irrigation for the years 1980, 2000, and 2020.

Part V. Alternate levels of development.--A summary of the OBERS "as published" for determining irrigated acreage requirements and various State alternative levels of irrigation development based upon water supply.

The Office of Business Economics (OBE) has provided population projections in the region for the target years 1980, 2000, and 2020. The Economic Research Service (ERS) has provided data for the agricultural sectors of the regional and subregional economy consistent with the population projections. The combined projections have been designated as "OBERS." A "Regional Interpretation" has been applied in determining crop production needs consistent with livestock output projections and a corresponding irrigated acreage requirement. Hereafter, when the term

"OBERS" is used in connection with water and land needs or demands for irrigation, it will be on the basis of this "Regional Interpretation," except as stated otherwise in Part V.

The Water Resource Planning Act was passed on July 22, 1965, by Public Law 89-80, 89th Congress, 1st Session. The Water Resource Council was established on April 10, 1966, as a result of this act. By letter of October 10, 1966, the Water Resource Council requested the Pacific Southwest Interagency Committee (PSIAC) to coordinate comprehensive studies in the Pacific Southwest, including the Upper Colorado Region. Authorization for preparation of this appendix followed.

Methodology, Definitions, and Assumptions

One of the basic factors considered in Appendix X was the inventory of land resources of the region to determine the total irrigated and potentially irrigable acreage. This was accomplished as a joint effort of several Federal agencies and appropriate States. Criteria for irrigation land classification were established by the Irrigation and Land Classification Seminar held in Salt Lake City, Utah, on July 18-19, 1967, and subsequent studies by an ad hoc Task Force of the Coordinated Planning Subcommittee.(1)

Presently irrigated land was inventoried as of the base year, 1965. By definition, irrigated land is land receiving water by artificial means for agricultural purposes by gravity, sprinkler, or subirrigation. It excludes lands watered by water spreading, such as range improvement. Responsibility for inventorying irrigated acreage in the region was assigned to the Land Use and Management Work Group. Methodology and assumptions used in the study are described in Appendix VI--Land Resources and Use.

The Irrigation and Drainage Work Group was responsible for inventorying potentially irrigable land in the region. The Bureau of Reclamation furnished basic data for the study from its land classification surveys. Additional information was solicited from other Federal and State agencies involved in surveys of agricultural lands, including the New Mexico Soils Task Force Group, Bureau of Indian Affairs, Committee on Arable Land Resources of Utah, and the Soil Conservation Service. These data were used directly or were interpreted and adjusted to show their suitability for irrigation development. The lands were identified on Geological Survey topographic work maps, scale 1:250,000, transferred to a regional map, scale 1:1,000,000 and subsequently printed on three subregional maps for the appendix. By definition, potentially irrigable land is land having soil, topography, drainage, and climatic conditions suitable for irrigation development. It may or may not be located where water supply is or can be made available at costs presently conducive to development. It comprises land in classes 1 to 4 which, if occurring in adequately sized units and properly provided with essential improvements in leveling, irrigation structures, and drainage, have sufficient productive capacity to support sustained irrigation.

Studies concerning water utilization and irrigation practices were made by the Soil Conservation Service in cooperation with appropriate State and Federal agencies. Data from all available sources were utilized and adjusted to regional, State, and subregional boundaries for the 1965 level of development. Consumptive use rates were estimated on an annual basis by the Blaney-Criddle method and on the basis of the latest data on local seasonal crop coefficients.1/ The region was divided into 61 evaluation areas for determining local consumptive irrigation requirements. The average water supply, irrigated acreages, and crop distributions were evaluated for each area. The U.S. Census of Agriculture for 1959 has the most consistent data regarding the total amount of water diverted for irrigation. Actual return flow measurements are available only at scattered locations and were considered inadequate for study purposes.

Definitions pertaining to water utilization for irrigation, as used in the appendix, are listed below.

Full supply irrigated land is irrigated land with a full and adequate water supply. Short supply irrigated land is irrigated land with a short and inadequate water supply. Surface sources of water include streams, lakes, reservoirs, and drainage ditches. Ground water sources relate to wells (pumped or flowing) and water taken directly from springs. Other definitions, methodology, and assumptions concerning water utilization for irrigation are presented in Appendix V--Water Resources--and in the "Framework Study Glossary" of the Pacific Southwest.

Water quality is a term used to describe the chemical and physical characteristics of water regarding its suitability for irrigation. Basic data for this section of the appendix were furnished by the Water Quality, Pollution Control, and Health Factors Work Group from current studies made of the Colorado River system. The effects of irrigation return flow on water quality are covered in Appendix XV--Water Quality, Pollution Control, and Health Factors.

Water right is a legally protected right, granted by State law to divert water and put it to beneficial use. Water rights as they pertain to irrigation are summarized briefly in this appendix from data furnished by appropriate States and by the Legal and Institutional Environments Work Group.

Drainage, as it pertains to irrigation, is the act, process, or mode of relieving lands of excess water and salt. Drainage water collected by a drainage system may derive from surface water or from water passing through soil and may be of a quality suitable for reuse, or it may be of

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1/ Refer to Appendix V, Water Resources, for further detail concerning water utilization criteria.

no further economic use at the time and place of its occurrence. Drainage data for this appendix were collected from various sources, including such Federal agencies as the Soil Conservation Service, Bureau of Reclamation, and Bureau of Indian Affairs.

The section dealing with the economic aspects of irrigated lands in regard to crop and livestock production, value of their products, and other benefits generated by irrigation, including economic projections of the region's agricultural requirements for allocating future irrigation development, was prepared by the Economics Work Group in cooperation with other appropriate task forces and work groups, Federal agencies, and State agencies. Data pertaining to characteristics of irrigated farms, livestock numbers, and value of crops, livestock, and livestock products were derived from U.S. Census of Agriculture, 1964. They are for economic subregions and region. Data concerning land use and crop production on irrigated lands were derived from task force studies based on Hydrologic Subregions and region for 1965.

Relationship to Overall Study

The basic objective of the formulation of framework plans is to provide a broad guide to the best use, or combination of uses, of water and related land resources of the region to meet foreseeable short- and long-term needs. The Irrigation and Drainage Appendix is one of several appendixes dealing with a particular phase of water and related land development, use, or management. It follows the general plan of analyzing the present situation and future requirements for irrigation to provide food and fiber for the target years 1980, 2000, and 2020. Together with the other appendixes, it provides basic data necessary to the formulation of framework plans and subsequent preparation of the main report.

History and Background

Irrigation has played an important role in the development of the Upper Colorado Region. Irrigation farming constituted the primary means of livelihood for early settlements which were established convenient to readily available irrigation water and good farming land. Most of the region climatically adapted to crop production has such scanty rainfall that many cultivated crops cannot be grown without irrigation. Forage crops, consisting largely of alfalfa and grass hay, irrigated pasture, small grains, and crop residues, occupy an important position among the different types of crops produced on irrigated lands in the region. These forage crops provide the winter base for the utilization of thousands of acres of adjacent rangeland for livestock production throughout the region.

Prehistoric Indians farmed the San Juan-Colorado Subregion from the eighth to the close of the 13th century A.D. raising such crops as beans, corn, and squash. This farming was dependent upon natural precipitation supplemented by intensive soil and moisture conservation practices such as small check dams and diversion of natural run-off areas to irrigate the crops. Although the subregion was traversed by early Spanish expeditions which reported it to be "a land dry and arid with a vegetation of cactus and desert plants," settlement by non-Indians did not take place until the discovery of gold in the San Juan Mountains in the early 1870's. There is a saying that Colorado was populated by men who "came to dig gold and remained to pitch hay."(2) Shortly before this time modern irrigation began in other portions of the Intermountain Region. Mormon pioneers, after reaching the Valley of the Great Salt Lake in 1847, began migrating into surrounding areas of western Wyoming and eastern Utah. The first agricultural settlement in what is now the State of Wyoming was made in 1853 on the Smiths Fork about 9 miles above Fort Bridger.(3) This was followed by settlement and establishment of communities along almost every permanent stream large enough to support irrigation throughout the region during the remainder of the 19th century.

Development of lands in Colorado began in earnest in 1874 when the Ute Indians ceded to the Federal Government some 3 million acres of their reservation which was immediately opened for settlement. Land was cleared and farming began with the construction of small privately financed water diversions and minor storage facilities by individuals or cooperative organizations. Private developments were supplemented by construction of Federal projects following passage of the Reclamation Act of 1902.

Settlement of irrigated farms in the San Juan Basin of New Mexico and Arizona began in the late 1870's. It was somewhat more gradual than in Colorado. Non-Indian agricultural development has been concentrated along the San Juan River in the Farmington, N. Mex., Area where diversified irrigation development has taken place. The Navajo Indian Reservation established in 1868 makes up a large portion of the region's land potential in New Mexico and Arizona. Since establishment of the reservation, scattered tracts of land have been developed for irrigation. These tracts are located primarily on intermittent streams.

Although in past decades stockraising and agriculture have been the mainstay of the Navajo economy, farm produce has been raised and utilized primarily for subsistence and barter purposes. Early efforts to improve agriculture were designed to increase productivity for subsistence purposes, and as agricultural works were developed, the acreages assigned to individual families remained small--usually 10 to 20 acres. Lands along the San Juan River have an adequate water supply; however, lands in other portions of the area are consistently short of water during the late summer months and throughout much of the irrigation season in years of subnormal runoff.

Irrigation started in Utah's Uinta Basin with the establishment of the Uintah Indian Reservation in 1866. Non-Indian settlers began to arrive in 1877. In 1905, after the Uintah Indian Reservation lands were allotted to the Indians in severalty, the remaining lands were returned to public domain and opened to settlement. Settlement began during the same period in other areas of eastern Utah wherever water and land were available. Long irrigation seasons and fertile soil favored crop production in the southern Utah area. Flooding frequently destroyed temporary diversion structures, however, thus disrupting the water supply for the small parcels of land served.

The earliest established communities in the region were isolated and, therefore, self-sustaining. Crops produced consisted of wheat, oats, corn, beans, and potatoes, but with the advent of better transportation methods and with the abundance of free rangeland close at hand, livestock production became the principal agricultural enterprise. Early irrigation systems were simple, consisting of rock and earth diversion dams with ditches to convey water to easily reached lands. In time, more sophisticated irrigation systems were introduced, utilizing community ditches and small privately financed irrigation companies whose works diverted directly from the perennial streams.

As streamflows became more fully utilized, it became evident that there was not enough water for late season use although there were usually excess flows during early spring runoff. Near the end of the 19th century storage of water in reservoirs was initiated by irrigation companies and many small reservoirs were constructed.

The building of large reservoirs on major streams was generally too difficult and expensive for the irrigation companies. An increased number of these large and expensive projects have been financed and constructed during the past 60 years by the Federal Government. In recent years these projects have become more complex and multipurpose in use, providing for irrigation, hydroelectric power, flood control, fish and wildlife enhancement, outdoor recreation, municipal and industrial use, sediment control, and area redevelopment. By 1965, irrigation developments included the following projects: Grand Valley, Collbran, Uncompahgre, Paonia, Colorado-Big Thompson, Smith Fork, Fruitgrowers, Mancos, Pine River, Pine River Indian Irrigation, and Florida in Colorado; Eden Project in Wyoming; Moon Lake, Scofield, and Vernal Unit of the Central Utah Project in Utah; Navajo (Dam), Hammond, and Hogback Extension Projects in New Mexico; and numerous small Indian and private developments throughout the region, comprising an additional 63,000 acres.

Although the region has some 7 million acres of additional land suitable for irrigation development, there is insufficient water for all of this land. Additional water developments are planned to meet the growing demands of the region by providing more regulatory storage, further development of ground water, greater use in pumping and transfer of water between drainage basins, and the possibility of increasing precipitation through weather modification. The availability of water supply in relation to available land varies throughout the region. In some areas the surface supply is already fully utilized. In other areas some additional water is available to meet consumptive uses, but development has not taken place because of isolation of potentially irrigable areas or because of other physical or economic considerations.

PART II

PRESENT STATUS OF IRRIGATION

Irrigated Lands (1965)

The land area of the Upper Colorado Region comprises portions of five Rocky Mountain States, totaling 72,234,000 acres. A total of 1,621,500 acres or about 2 percent of the land area was irrigated in 1965. The irrigated lands are shown in Table 1 below and on three subregional maps on the following pages.

Table 1 - Irrigated acreage--1965
(Unit--1,000 acres)

Hydrologic Subregion and State	Irrigated cropland: Full supply land	Irrigated cropland: Short supply land	Irrigated cropland: Total	Idle land 1/	Total
Green River					
Colorado	69.2	44.9	114.1	3.3	117.4
Utah	162.2	101.9	264.1	19.7	283.8
Wyoming	130.5	151.5	282.0	29.1	311.1
Subtotal	361.9	298.3	660.2	52.1	712.3
Upper Main Stem					
Colorado	418.4	157.2	575.6	34.3	609.9
Utah	3.5	4.8	8.3	.2	8.5
Subtotal	421.9	162.0	583.9	34.5	618.4
San Juan-Colorado					
Colorado	107.7	60.6	168.3	18.4	186.7
Utah	16.6	18.6	35.2	5.1	40.3
New Mexico	38.5	6.3	44.8	8.1	52.9
Arizona	1.2	3.5	4.7	6.2	10.9
Subtotal	164.0	89.0	253.0	37.8	290.8
Region					
Wyoming	130.5	151.5	282.0	29.1	311.1
Utah	182.3	125.3	307.6	25.0	332.6
Colorado	595.3	262.7	858.0	56.0	914.0
Arizona	1.2	3.5	4.7	6.2	10.9
New Mexico	38.5	6.3	44.8	8.1	52.9
Total	947.8	549.3	1,497.1	124.4	1,621.5

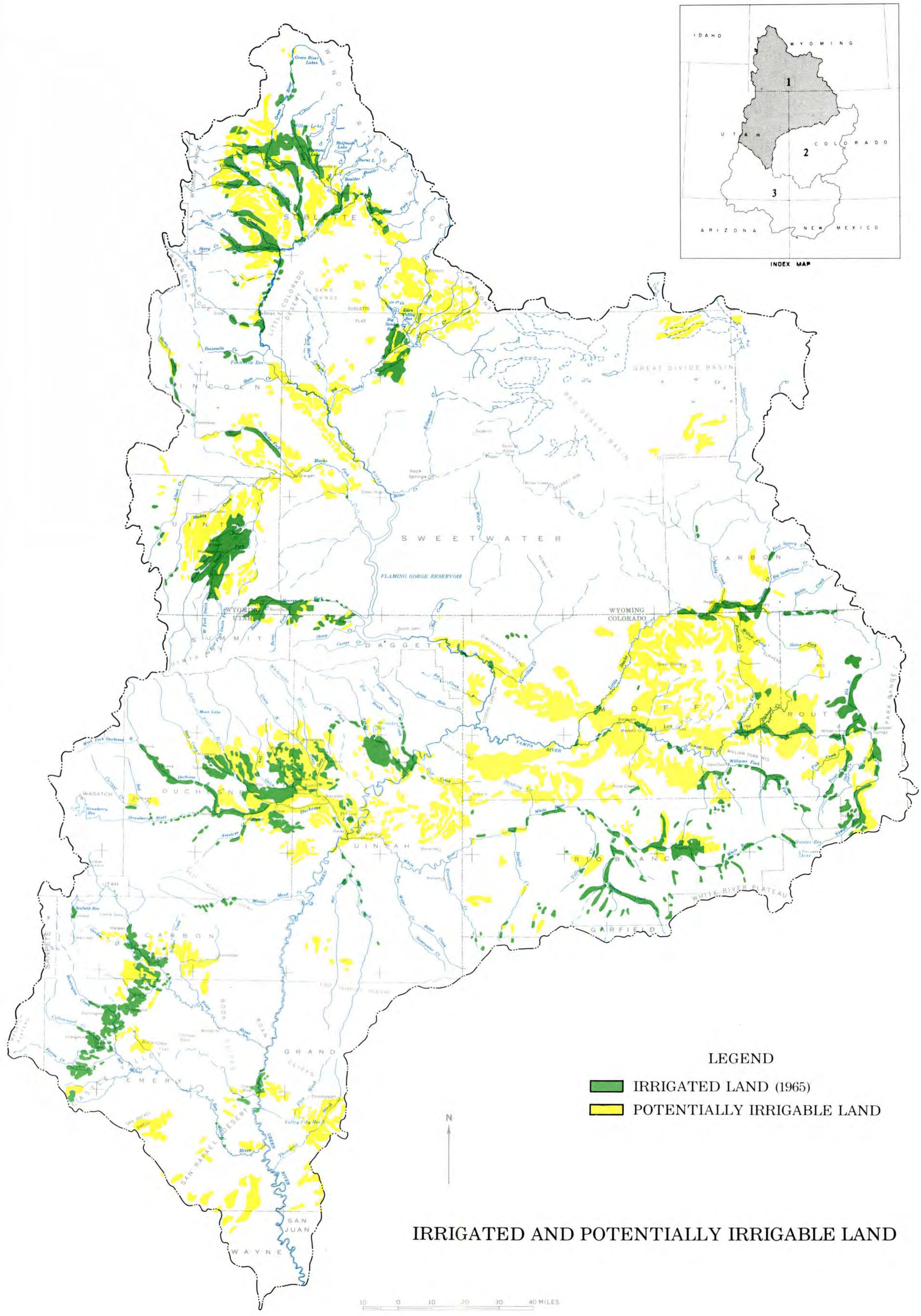
1/ Idle land is tabulated separately as it is land which is not irrigated in an average year.

As indicated in Table 1, 712,300 acres or 44 percent of the total irrigated land is in the Green River Subregion, of which 80 percent is in

UPPER COLORADO REGION

COMPREHENSIVE FRAMEWORK STUDY

GREEN RIVER SUBREGION



LEGEND

IRRIGATED LAND (1965)

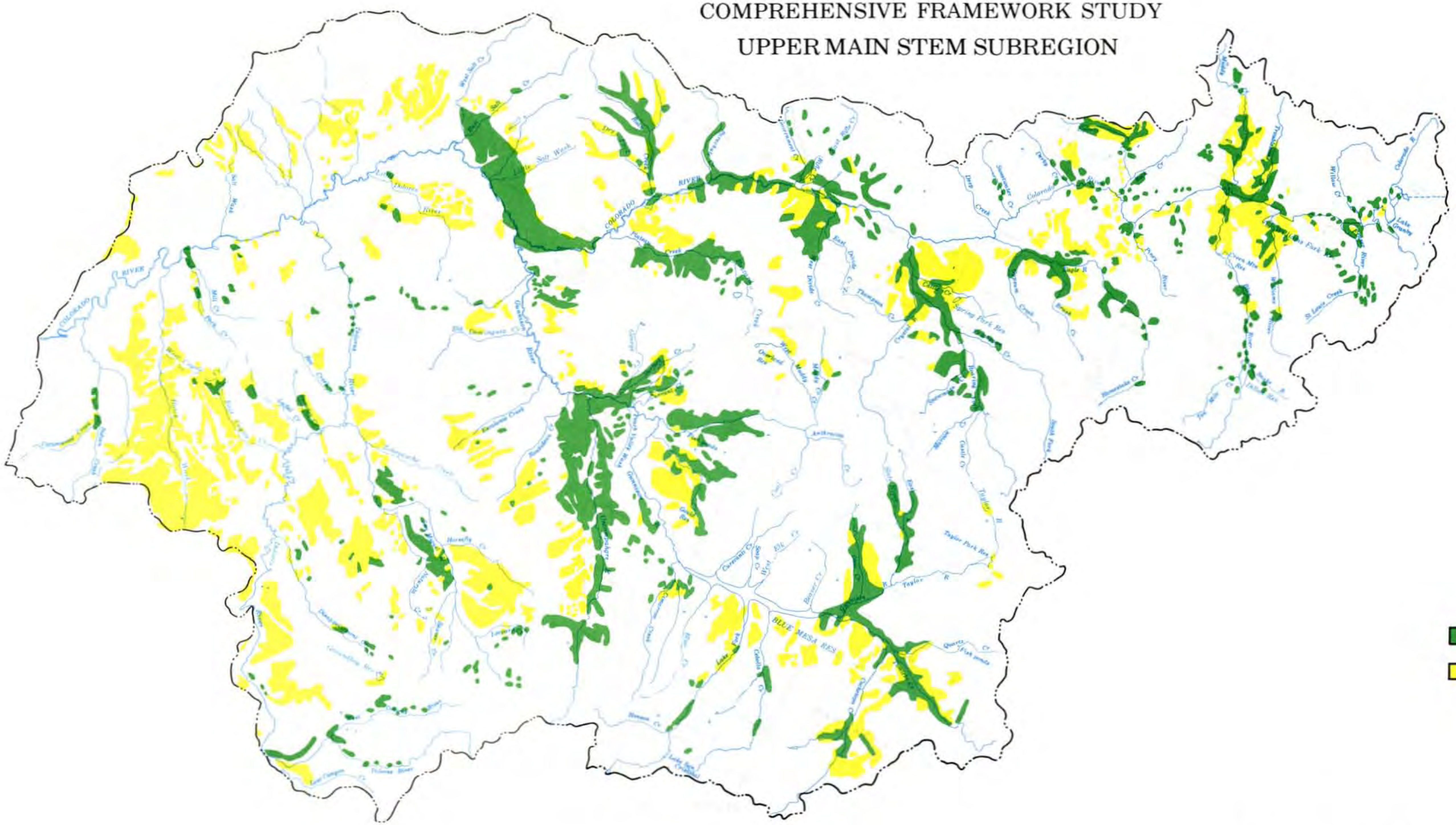
POTENTIALLY IRRIGABLE LAND

IRRIGATED AND POTENTIALLY IRRIGABLE LAND

UPPER COLORADO REGION

COMPREHENSIVE FRAMEWORK STUDY

UPPER MAIN STEM SUBREGION



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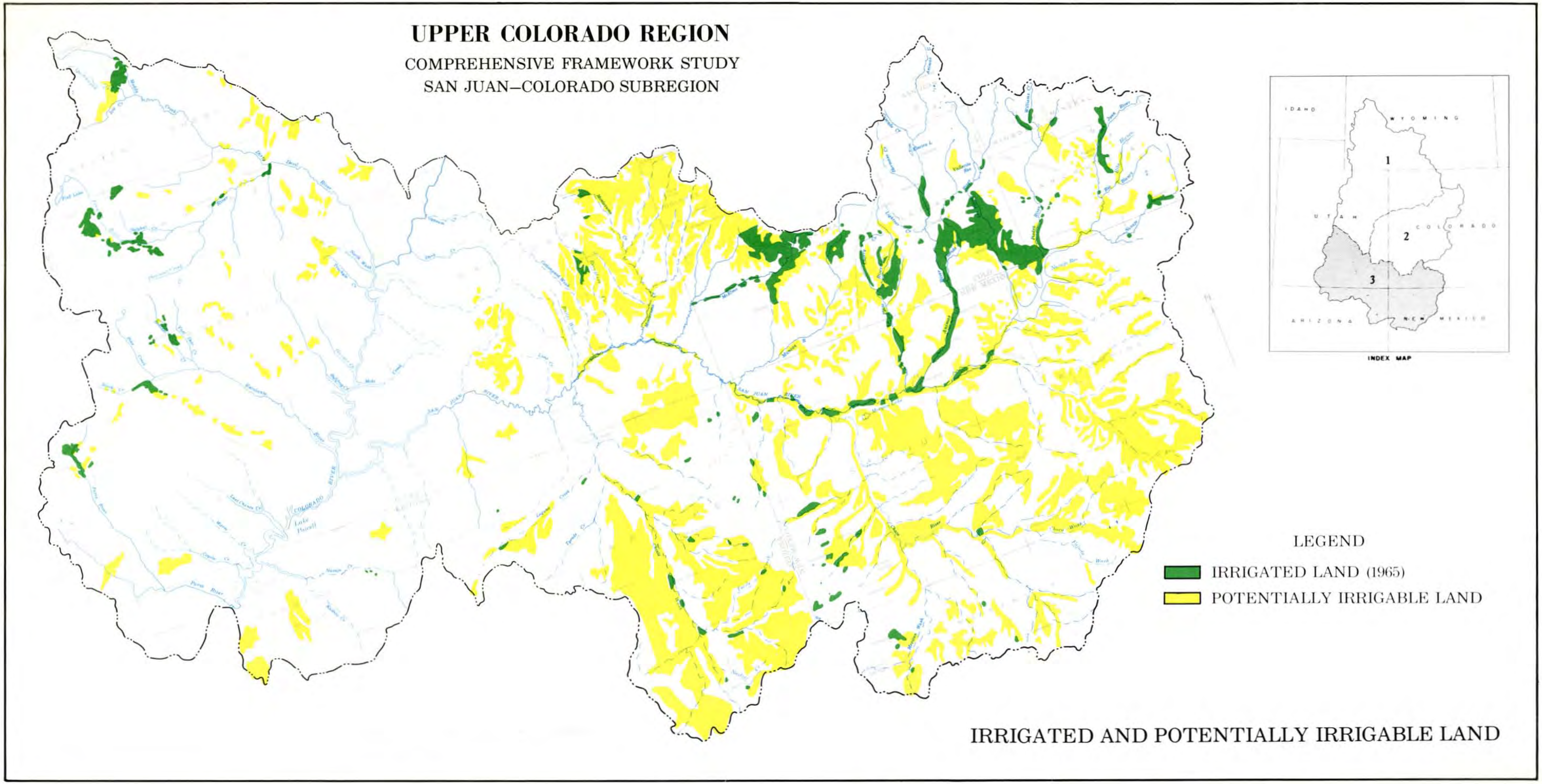
LEGEND

IRRIGATED LAND (1965)

POTENTIALLY IRRIGABLE LAND

IRRIGATED AND POTENTIALLY IRRIGABLE LAND


UPPER COLORADO REGION
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COLORADO RIVER
Lake Powell
LEGEND
IRRIGATED LAND (1965)
POTENTIALLY IRRIGABLE LAND
IRRIGATED AND POTENTIALLY IRRIGABLE LAND

Wyoming and Utah. The next largest acreage, 618,400 acres or 38 percent, is in the Upper Main Stem Subregion, of which 98 percent is in Colorado. The remaining 18 percent of the irrigation development, comprising 290,800 acres, is in the San Juan-Colorado Subregion, of which 65 percent is in Colorado.

Of the total acreage irrigated in 1965, 1,600,400 acres or 99 percent is irrigated entirely from surface flows. The remaining 1 percent, comprising 21,100 acres, is supplied partially or fully from ground water. Table 2 shows the breakdown of presently irrigated acreage from ground water.

Table 2 - Area irrigated from ground water
(Unit--1,000 acres)

State	Full use	Partial use 1/	Total
Wyoming	1.3	1.2	2.5
Utah	4.0	6.9	10.9
Colorado	3.0	4.7	7.7
Total	8.3	12.8	21.1

1/ Supplemental to surface supplies.
Source: U.S. Census of Agriculture, 1959.

Included in the total irrigated acreage of the region are 124,400 acres of idle land which are not irrigated in an average year because of water shortage or for other reasons. Lands actually cropped and which utilize water for irrigation total 1,497,100 acres. Of this total 947,800 acres or 63 percent has a full water supply and 549,300 acres or 37 percent has a short supply. Water shortages, for the most part, occur during the summer months, as most irrigation is by direct diversion from streams which recede after the spring runoff has passed. Supplemental late-season water is provided by reservoir storage. A total of about 308 reservoirs with an active capacity of 3,272,800 acre-feet, have been constructed by Federal and non-Federal entities to provide storage regulation for irrigation in the Region, as of 1965. Only 9 percent of the irrigated land was provided supplemental water through reservoir storage by Federal projects in 1965.

Some 80 percent of the irrigated acreage in the region produces alfalfa, grass hay, and pasture used to complement livestock grazing on the vastly larger areas of range and forest land. These crops are supplemented by small grains and other annuals produced on the remaining irrigated croplands. At lower elevations, such as in the vicinities of Montrose, Delta, Paonia, and Grand Junction, Colo., and Farmington, N. Mex., the farming is more diversified with fruits, vegetables, and feed crops produced.

Peach orchards in the Upper Main Stem Subregion of Colorado.

The short growing season that prevails over much of the region and an inadequate late summer water supply limit the kinds of crops that can be grown successfully.

The crop distribution on irrigated lands is summarized by States in Table 3. A more complete distribution by subregions is presented in Table 16.

Table 3 - Crop distribution on irrigated lands--1965
(Unit--1,000 acres)

Principal crops	Arizona	Colorado	New Mexico	Utah	Wyoming	Total
Grass hay and pasture	0.4	571.4	15.2	186.3	245.5	1,018.8
Alfalfa	.4	167.7	17.3	83.4	29.5	298.3
Small grain		47.6	2.1	25.4	7.0	82.1
Other crops	3.9	71.3	10.2	12.5		97.9
Total cropland	4.7	858.0	44.8	307.6	282.0	1,497.1
Idle	6.2	56.0	8.1	25.0	29.1	124.4
Total irrigated	10.9	914.0	52.9	332.6	311.1	1,621.5

As shown on the subregional maps, most irrigation development has taken place along the upper reaches of the major streams adjacent to high mountain ranges. Little development has taken place in the Lower Main Stem Areas where the streams are deeply entrenched in canyons 500 to 1,500 feet below and several miles distant from lands suitable for irrigation.

Most of the 311,100 acres of irrigated land in the Wyoming portion of the Green River Subregion lie in the headwaters of the Green River and its tributaries at elevations ranging from 6,500 to 8,500 feet. Land receiving sparse precipitation requires irrigation for successful crop production. The short growing season and cool summers combine to limit crops to forage and small grains. The frost-free period (32° F.) varies from about 20 days at Big Piney to 105 days at Green River, Wyo. For the predominant crops grown, alfalfa and grass for hay and pasture, the growing season varies from about 70 days to 130 days at those stations.

Irrigated soils in the headwaters of the Green River are composed primarily of alluvial materials derived from glacial deposits originating in the adjacent mountains. Some are derived from underlying shales, sandstones, and mudstones of local geologic formations. The irrigated lands occur primarily along river and creek bottoms, with smaller acreages lying on benches or terraces 20 to 40 feet above streambeds. Soil textures vary from sandy loams on the benches to clays in some reaches of the river bottoms. Most soils are underlain with several feet of sand and gravel, which provide natural drainage at elevated positions and allow little accumulation of harmful salts. Low-lying lands along stream channels are irrigated by wild flooding, causing water table buildup during the early part of the irrigation season. About 90 percent of these higher elevation lands in the Upper Green River Basin of Wyoming produces forage from meadow hay and pasture. Alfalfa is the principal crop raised on other lands such as in the Eden Project Area.

A total of 332,600 acres of land is presently irrigated in the Utah portion of the region. These lands are located largely in the Uinta Basin but include scattered developments along the east slope of the Wasatch Range for a distance of about 100 miles. Small, widely scattered tracts also lie in southeastern Utah in Grand and San Juan Counties, served largely from intermittent streams.

Crop production in the Utah segment of the region is almost entirely dependent on irrigation as the rainfall is sparse, ranging from about 6 to 12 inches over most of the area. Elevations of irrigated lands range from 4,000 to 8,000 feet, and the frost-free period (32° F.) ranges from about 90 to 190 days. Principal crops are alfalfa, small grains, native and improved pasture, and corn for silage. Only in the Monticello Area of southeastern Utah are winter wheat and dry beans grown in quantity without irrigation.

The irrigated lands in the Uinta Basin of Utah are composed mainly of deep, medium to moderately fine-textured soils on gravelly stream terraces and alluvial fans and moderately deep and shallow soils with strong lime horizons and hardpans on old gravelly benches and mesas. Relatively small parcels are surrounded by nonirrigable lands, mesa escarpments, and eroded sandstone and shale hills.

Lands along the east flank of the Wasatch Range of eastern Utah within the drainages of the Price, San Rafael, Dirty Devil, Fremont, Escalante, and Paria Rivers have mainly deep, moderately fine to medium-textured alluvial soils occurring along the stream valleys in relatively small parcels surrounded by nonirrigable shale hills and mesa remnants. Those in Carbon and Emery Counties are derived primarily from Mancos shale. These are characteristically grayish-brown, slowly permeable, erodible soils associated with severe salinity and drainage problems.

The small parcels of irrigated lands in Grand and San Juan Counties of southeastern Utah have many different soils. In the vicinity of Monticello, Blanding, and La Sal there are deep, reddish-brown, medium and moderately coarse-textured soils of aeolian origin on an undulating topography. Other soils consist of alluviums of variable textures occurring along stream valleys and on fans and pediments.

The Colorado segment of the region presently includes 914,000 acres of irrigated land. This land varies in elevation from about 4,500 feet in Grand Valley to 9,000 feet in the headwaters of the Gunnison River and other tributaries of the Colorado River. The frost-free period (32° F.) ranges from about 20 days on the higher lands to about 185 days at lower elevations, averaging about 110 days. For grass hay and pasture production at higher elevations, the growing season is approximately 70 days. Precipitation ranges from about 25 inches at higher elevations to about 10 inches at lower elevations, averaging about 15 inches.

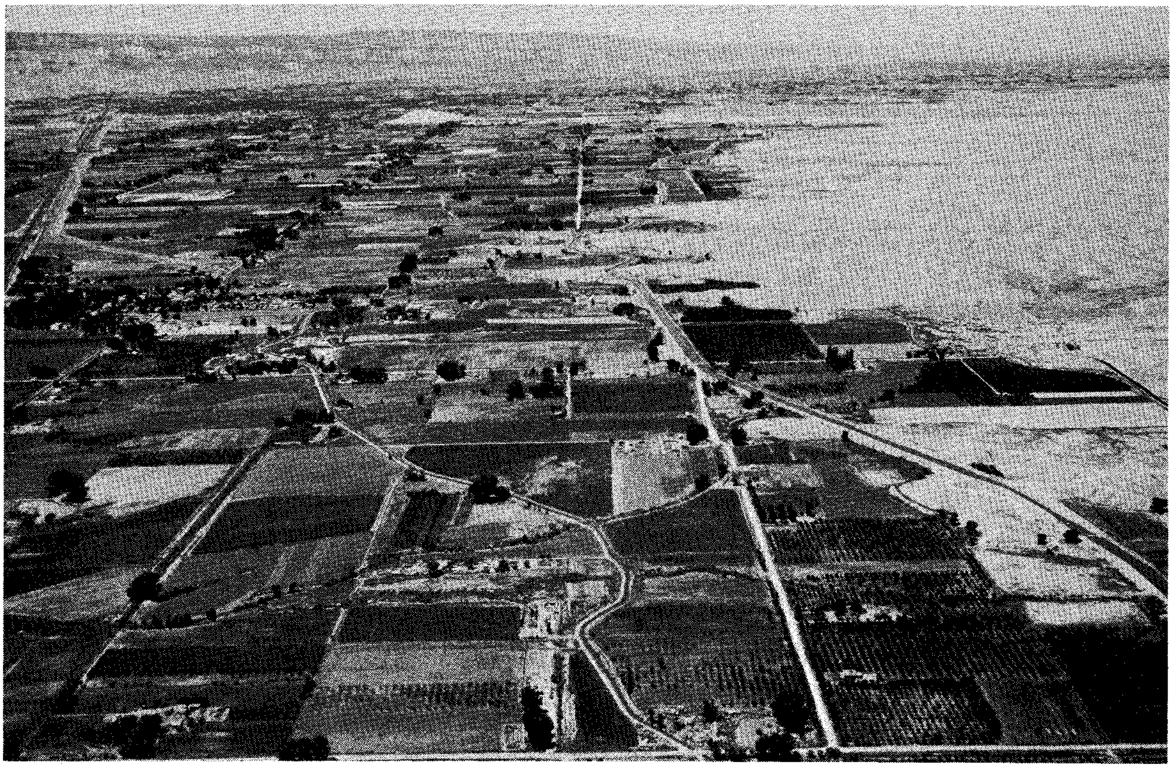
The irrigated lands in Colorado include alluvial soils in high mountain valleys of the widely branched river system. Stream entrenchment and glaciation have created a variety of land forms, including river flood plains, stream terraces, alluvial fans, and steeply undulating mountain slopes. Most of the irrigation occurs as scattered developments on the flood plains, fans, and gravelly terraces. The soils range in texture from sandy loam to clay loam. Because of the climatic restrictions in the higher mountain valleys, production is generally limited to meadow hay and pasture.

At lower elevations the alluvial valley lands are usually grayish brown in color and are highly stratified, varying in texture from loam to clay. They are derived primarily from local shale and sandstone formations. The soils of marine shale origin are inherently high in salt and require considerable drainage and leaching to maintain productivity.

Meadow hay and pasture provide feed for livestock, complementing utilization of surrounding rangeland in the Upper Colorado Region.

Irrigated mesa and terrace lands occur at elevations of 5,500 to 7,500 feet in western and southwestern Colorado. These are primarily reddish-brown, medium- to moderately fine-textured soils of aeolian and alluvial origin formed on an undulating topography. The soils are deep and moderately deep over glacial outwash gravel, sandstone, or shale. They are permeable, retain moisture well, are easy to till, and have no salinity or alkali problems.

By 1965 there were 52,900 acres irrigated in the New Mexico segment of the San Juan-Colorado Subregion, located primarily along the San Juan, Animas, and La Plata Rivers of the San Juan Basin. A few sparsely scattered tracts are located on the Navajo Indian Reservation south of the San Juan River on small ephemeral streams originating in the Lukachukai and Chuska Mountain Ranges. These comprise part of the Region's short supply cropland acreage. Except in a very few extremely dry years, the natural runoff of the San Juan and Animas Rivers has provided essentially a full irrigation supply for lands served by them. The flows of the La Plata River, however, are insufficient in most years to serve lands along its course.



Alluvial soils derived largely from marine shale are irrigated in lower valley lands of Colorado.

Irrigated lands in the New Mexico segment vary in elevation from 4,900 to 6,000 feet. Annual precipitation averages about 8 inches and the average frost-free period is 160 days. The soils of the river valleys are alluvial, largely deposited on fans by the intermittently flowing tributaries entering the river valley. Lands near the outer edges of the valleys are moderately steep and sandy. They become flatter and finer textured near the stream channel. Deep percolation losses of irrigation water on the upper slopes often create seepage and salinity problems in the bottom lands. Predominant crops are hay, irrigated pasture, corn, orchards, beans, and small grains. Truck gardening increased significantly in the San Juan and Animas Valleys immediately prior to 1965. It has been demonstrated that the area is capable of growing excellent quality vegetables with high yields.

Irrigation in the Navajo Reservation, comprising the Arizona segment of the San Juan-Colorado Subregion, has been limited to development of intermittent flows of Chinle Creek and other southern tributaries of the San Juan River. Some 24 small Indian project areas including about 10,900 acres are now irrigated. About 1,200 acres of this land in the Many Farms Project area receive nearly a full water supply. The remaining

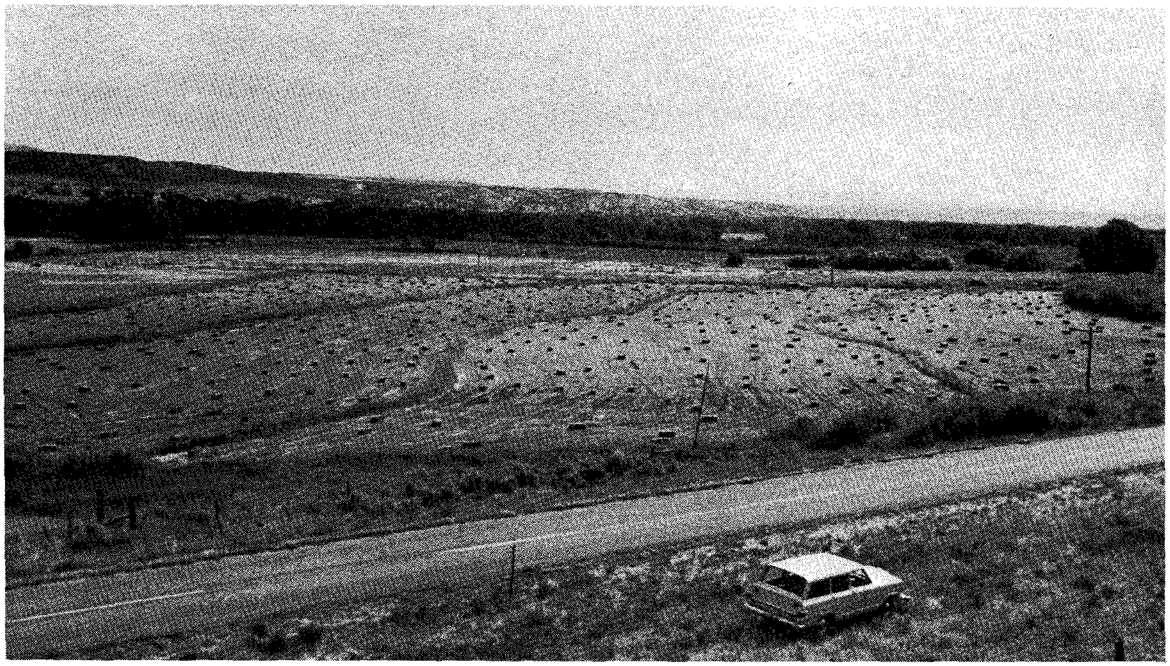
Irrigation water has made possible the opening of many new farms along the San Juan River in New Mexico.

small parcels of land have a very meager supply. Cropped acreage fluctuates widely from year to year with the amount of precipitation received.

The soils of presently irrigated lands in the Arizona segment are primarily alluvial, located along stream valleys where water is available. A smaller percentage is of aeolian origin. Textures vary from loamy sand to clay, depending upon the parent material and mode of deposition by wind or water.

Irrigation Practices

Because of the extreme variation in physical and economic conditions, and institutional arrangements in distributing the water supplies, irrigation practices vary from primitive to highly sophisticated methods of applying water. Unavoidable losses occur in all methods of water application and therefore the desirable efficiency of 100 percent cannot be obtained. Application losses include evaporation, deep percolation, and surface runoff. The extent of losses depend on a number of factors including: water intake characteristics of soils, topography, climate, irrigation methods, depth of water application, adequacy of the irrigation system, and the skill of the irrigator. Because of the wide range of physical factors, namely soils, topography, and climate, there is also a comparable range of application efficiencies. Estimated field efficiencies attainable in the Upper Colorado Region for the various irrigation methods are as follows: level border 50-80 percent, graded border 60-75 percent, furrow 45-70 percent, contour ditch 40-60 percent, corrugation 45-70 percent, and sprinkler 65-75 percent.



Contour ditches in Wyoming demonstrate a common irrigation method used on sloping lands. Note the river bottom meadow lands in background where flood irrigation is practiced.

Sixty-eight percent of the region's irrigated cropland is in grass hay and pasture. About 80 percent of these crops are produced in mountain meadows of Colorado and Wyoming, and most of the remainder (18 percent) is produced in the Uinta Basin and along the east slope of the Wasatch Range of Utah. Permanent pasture and native grass hay are the most common crops grown in high elevation, short-growing season areas. Water is usually diverted by temporary structures and is delivered by gravity canals and ditches to the fields where it is spread by small contour ditches by controlled or uncontrolled flooding. Some of these irrigated areas receive natural overflow water during the period of high streamflow, which corresponds generally with the first part of the irrigation season. In these areas where the growing season is short and the water supply limited, the water application efficiencies are low for the flooding and overflow methods of irrigating. It has not been practical to install elaborate irrigation systems. Costs for applying water are low. The added increment of crop production (above that which would have been obtained from normal precipitation) has made the large ranching operations economically feasible. Ranchers in some areas obtain adequate water for most of the irrigation season by direct diversion of available streamflow. In other areas irrigation shortages occur as the runoff diminishes and storage water is held in reserve for the more intensively cropped lands. Irrigation water is taken off the meadows early enough to allow harvesting to begin about August 1. Continuous and intermittent irrigation are both commonly used. Some seeped areas, phreatophyte growth, and salt accumulations have developed where proper management and development are absent.

Where rotation pasture and improved hay are produced, permanent turnout structures and contour ditches are maintained. Some leveling and smoothing in preparation of the seedbed are accomplished and water, including supplemental storage water, is applied intermittently and in an efficient manner. This method of irrigation, though somewhat laborious, results in increased production of improved species with less water applied.

Border irrigation is an infrequent method used on flatter lands of the region.

Alfalfa is produced on 20 percent of the irrigated cropland in the Upper Colorado Region with the largest share (56 percent) produced in the Colorado portion. The irrigation methods used for alfalfa consist of contour ditches, border, furrow, corrugation, sprinkler, or wild flooding, depending largely upon slope, water supply, soil characteristics, economics and the farmer or rancher. Generally, alfalfa is grown in areas which have an adequate water supply and is under better management than is permanent pasture or native hay. Corrugations or furrows, 1 to 3 feet apart, are developed during initial seeding, with small grain used as a companion crop. These corrugations or furrows may or may not be maintained after growth is established. Alfalfa is irrigated five or more times a season, depending upon availability of water, climate, and other factors.

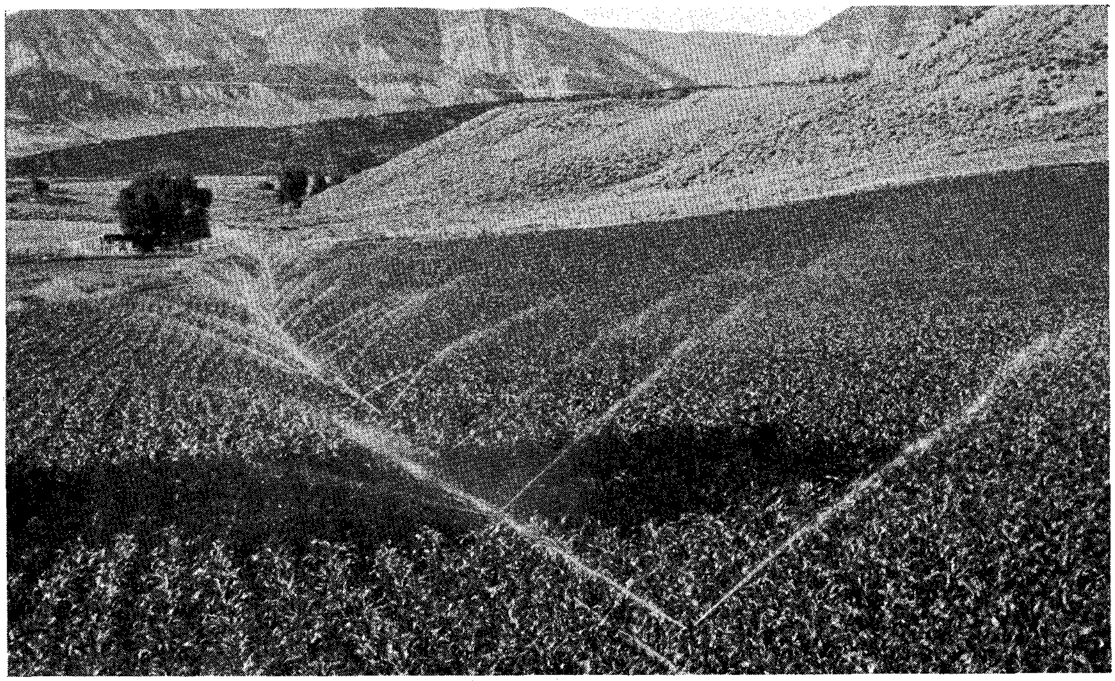
Approximately 200,000 acres of irrigated land in the region are intensively cropped. Small grains and other close growing crops, comprising about 5 percent of the irrigated cropland in the region, are usually irrigated by the corrugation method. These crops, which usually are planted in the fall, receive three or more irrigations a season. Row crops, comprising about 6 percent of the irrigated cropland, are adapted to furrow irrigation. Speciality crops such as sugar beets and orchards are grown in the warmer climates of Mesa, Delta, and Montrose Counties in Colorado and in the Price, Utah, and Farmington, N. Mex., Areas. These crops are produced under conditions of proper air drainage, a stable water supply, permanent irrigation structures, and a higher level of water management than crops used as feed for livestock. Of the 18,300 acres of orchard produced in the region, 75 percent is in Delta and Mesa Counties of western Colorado. Orchards are irrigated five to eight times a year with four to five small furrows between tree rows. The last irrigation during the growing season is applied 10 to 14 days prior to harvest. Since trees need winter moisture, water is applied again following harvest. Good water management is important for orchards as excessive or insufficient irrigation will damage or kill trees.

Heavy fruit harvest in New Mexico reflects good water management.

Approximately 5,000 acres of cropland in the region are irrigated by sprinklers. In the Upper Fremont Valley of Utah in the San Juan-Colorado Subregion some 3,000 acres of former meadow lands served by a gravity system are now producing rotation crops under sprinkler irrigation. An additional 500 acres served by sprinklers are widely distributed throughout other parts of the subregion, primarily on Indian lands. About 500 acres are irrigated by sprinklers in the Upper Main Stem Subregion, primarily in the Dolores River drainage, and approximately 1,000 acres are served by sprinklers in the Green River Subregion.

Sugar beets, a speciality crop grown in the warmer climate of the region, reflect high level of water management.

The traditional irrigation methods practiced by Indian people included interception of flood water where the topography was suitable, diking flat land areas to hold intermittent runoff, and ditch irrigation where there was sufficient water supply. During periods of drought individual plants were watered by hand from vessels carried from nearby sources. All these methods are presently being used to some degree on limited acreages. Corrugation and furrow methods of applying irrigation water are the prevailing methods used on the cultivated lands of major Indian irrigation projects in Arizona, New Mexico, and Utah. About 400 acres formerly irrigated by conventional methods, however, have been converted to sprinkler irrigation in recent years. Regulatory reservoirs are used to provide water for numerous small irrigated tracts and miscellaneous irrigation projects while direct diversion structures are provided on perennial streams for two major Indian irrigation projects located on the Navajo Indian Reservation near Shiprock, N. Mex., and on the Uintah and Ouray Indian Reservation in the Uinta Basin of Utah.



View of sprinkler on close plantings of corn in the Upper Main Stem Subregion of Colorado.

Throughout the Upper Colorado Region crop diversification is most successful in areas served by irrigation projects on the main stream or with storage facilities to supply late-season water. Stable water supplies encourage practices such as land leveling, improved methods of irrigation, drainage, proper crop rotation, improved plant species, and use of commercial fertilizers. These result in improved yields.

Improvements on irrigated lands including assistance in applying on-farm water management and conservation practices has been given impetus by soil conservation districts organized in the 1930's. On-farm water management is essential in preventing excessive waste water runoff, deep percolation, water logging, soil erosion, and loss of plant nutrients. It also has a direct effect on the water quality in the irrigation return flows. Conservation practices are a prerequisite to water management in minimizing water losses in distribution systems and they permit more efficient water use on irrigated farms. Incentive payments provided by the Agricultural Stabilization and Conservation Service have also aided in the application of needed facilities and measures.

Table 4 is a summary of installed irrigation facilities and measures in the Upper Colorado Region.

Table 4 - Installed irrigation facilities and measures--1965

Hydrologic Subregion and State	Irrigation practice			
	Water storage facilities1/ (number)	Ditch and canal excavation and lining (1,000 miles)	Water control structures2/ (thousands)	Land leveling and smoothing (square miles)
Green River				
Colorado	53	1.8	4.4	39
Utah	412	1.6	15.3	30
Wyoming	26	1.3	13.0	62
Subtotal	491	4.7	32.7	131
Upper Main Stem				
Colorado	196	3.9	33.5	97
Utah	22	.2	.4	1
Subtotal	218	4.1	33.9	98
San Juan-Colorado				
Arizona	9	.2	.8	5
Colorado	42	1.8	5.0	50
New Mexico	48	3.7	2.7	14
Utah	121	.3	20.5	7
Subtotal	220	6.0	29.0	76
Total	929	14.8	95.6	305

1/ Water storage facilities are structures that hold water for short (overnight) or long periods of time to be used as water supply for irrigation purposes.

2/ Water control structures convey water, control the direction or rate of flow, or maintain a desired water surface elevation.

Water Utilization for Irrigation

Diversions

Under present conditions (1965), and on the basis of generalized assumptions, it is estimated that 5 to 7 million acre-feet of water are diverted for irrigation in an average year and about 1 percent of this amount is ground water. The quantity of water diverted for irrigation varies from year to year and is dependent upon several factors, including availability of water, precipitation during the growing season, type of crop grown, water rights, ditch losses, and irrigation management practices.

Surface waters account for about 99 percent of the supply for irrigation and consist of flow from streams, lakes, springs, and reservoirs. The snowpack in the mountains is the principal source of water but is augmented by summer precipitation.

The high mountains of the region are extremely valuable for collecting and storing moisture for irrigation.

There is considerable variation in runoff throughout the region, corresponding to the variation in normal annual precipitation from more than 50 inches in the higher elevation areas to less than 6 inches in the lower areas. Irrigation is required in most cropland areas as only 2 to 6 inches of the precipitation is effective in crop production.

Records of water diverted for irrigation within the region are available only for the larger systems. In many locations records are not kept or are not available for publication. In areas where records are kept there is a lack of consistency in reporting from year to year.

Methods used in collecting and reporting data differ among the many canal and reservoir companies. Because the available information lacks consistency and is relatively incompatible, a regional analysis of diversion records is not considered practical.

The most consistent data on irrigation diversions are those of the Census of Irrigation. The Census of Irrigation is conducted by the Bureau of the Census decennially and was last taken in 1959. Census data regarding irrigation operations were obtained from irrigation organizations and with few exceptions included only organizations which supplied water to two or more farms. Table 5 gives Census of Irrigation data for surface water conveyed by irrigation organizations to farm irrigation water users in the Upper Colorado Region. Information as to the substantial quantities of water diverted by individuals is not available. Since the total amount of water diverted for irrigation is unknown, the Census data are only an indication of the relative amounts of water diverted by irrigation organizations within the subregion and States.

Table 5 - Amounts of surface water conveyed by irrigation organizations to farm irrigation water users, 1959[1/]
(Unit--1,000 acre-feet)

Hydrologic Subregions	Arizona	Colorado	New Mexico	Utah	Wyoming	Total
Green River		270.5		739.1	418.1	1,427.7
Upper Main Stem		1,842.9		25.3		1,868.2
San Juan-Colorado	(D)	344.1	135.4	55.9		535.4
Total	(D)	2,457.5	135.4	820.3	418.1	3,831.3

1/ Source: U.S. Census of Agriculture, 1959, Vol. III, Irrigation of Agricultural Lands, State Tables 1. (Includes only that water conveyed to two or more farm irrigation water users.)
(D) Data not available.

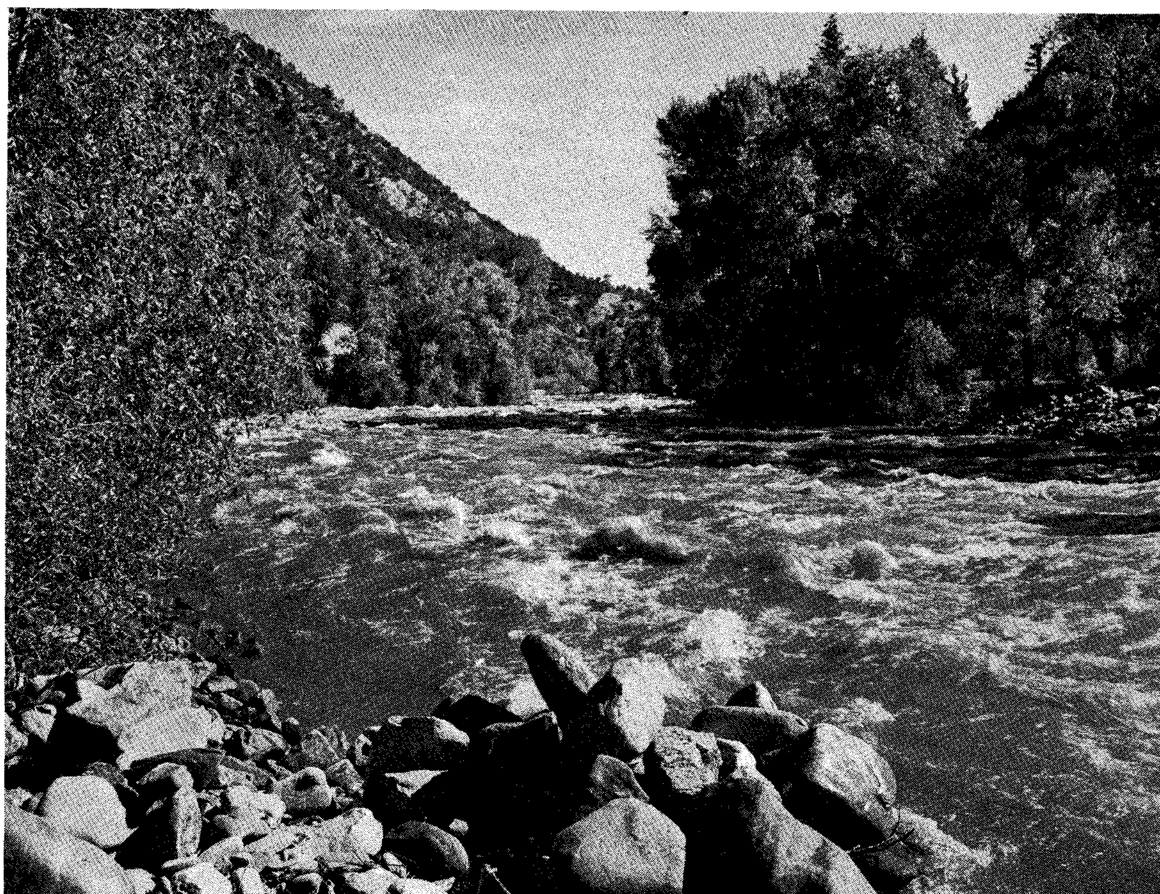
Ground water accounts for about 1 percent of the supply for irrigation in the Region, derived from pumped or flowing wells, and directly from springs. The estimated average acre-feet of withdrawal and consumptive use of ground water used on irrigated lands during the period 1961 to 1965 are shown in Table 6. Further details regarding ground water are found in Part V of Appendix V, Water Resources.

Reservoir storage is essential for effective water control as the streamflow varies both on a seasonal and year-to-year basis. Peak flows occur during the spring and early summer months as a result of melting snow.

Table 6 - Withdrawal and consumptive use of ground water, 1961-65
Upper Colorado Region

Use	Unit (1,000)	Ari-zona	Colo-rado	New Mexico	Utah	Wyo-ming	Regional Total
Lands irrigated							
Full	acres	0	3.0	0	4.0	1.3	8.3
Partial	acres	0	4.7	0	6.9	1.2	12.8
Withdrawal	ac.-ft.	0	18.0	0	22.0	4.6	44.6
Consumptive use	ac.-ft.	0	8.6	0	10.7	2.3	21.6

Source: Appendix V, Water Resources



Rapidly melting snow causes high streamflow during spring runoff in a tributary stream of the Colorado River. Note roily condition of the stream.

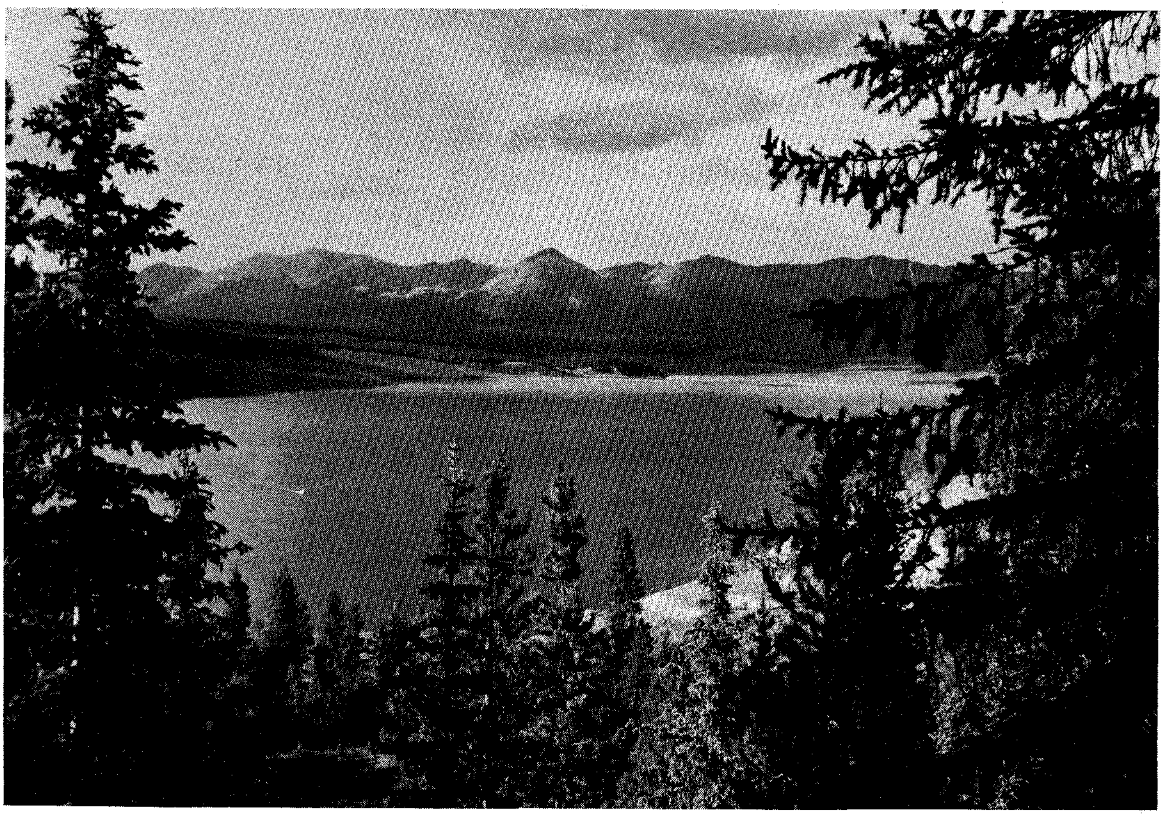
Streamflow diminishes rapidly after midsummer when the crop water requirements are the highest. In many areas reservoir water is available to regulate the fluctuating supply and match the seasonal demand (Table 7).

Table 7 - Usable irrigation reservoir storage--1965 1/
(Unit--1,000 acre-feet)

Hydrologic Subregions	Arizona	Colorado	New Mexico	Utah	Wyoming	Total
Green River		26.8		412.1	503.3	942.2
Upper Main Stem		427.4		1.7		429.1
San Juan-Colorado	21.4	247.3	1,055.0	79.9		1,403.6
Total	21.4	701.5	1,055.0	493.7	503.3	2,774.9

1/ Source: Upper Colorado Region Comprehensive Framework Study, Water Resrouces Work Group Data, Soil Conservation Service, Denver, Colo.

In other areas, but to a lesser degree, regulation storage is also provided to store excess water in high runoff years for use in the drier years. Numerous irrigation reservoirs have been constructed in the region, but more are needed to fully develop the irrigation potential. The lack of information precludes an analysis as to the amount of reservoir water actually used for irrigation during a specific year.



Pine trees frame scenic view of one of several man-made lakes in the Upper Colorado Region to impound water for irrigation of downstream lands.

Return flows

Even with the best controlled irrigation system, some water is lost during an irrigation to surface runoff, deep percolation, and evaporation. Most of the water from surface runoff eventually finds its way back to the stream. Other water which enters the soil percolates through the root zone, contributes to the ground water resource, and eventually gets back to the stream through springs, seeps, or underflow. Diverted flow not stored in the root zone or consumptively used that finds its way back to a source of supply is termed return flow. Because of differences in topography, soils and geology, crops, methods of irrigation (amounts of water and number of irrigations), and other related factors, return flow varies widely.

On many tributary streams the entire flow is often diverted at an upstream location but water is available from return flow for downstream use. Through return and reuse it is not uncommon for the total diversions from a stream to exceed the apparent streamflow.

Return flows that occur as ground water underflows to the stream channel commingle with surface flows and are extremely difficult to monitor. Because of these conditions measurements and records of return flow are meager. Return flows in connection with large projects are commonly estimated as the difference between the irrigation diversion and the computed depletion (water consumptively used), including incidental uses.

Data relating to actual project water efficiencies is meager. As a general estimate the overall project water efficiencies probably average about 30 percent.

Even though the return flows are used several times in different areas within the region, the quality of surface water (with the exception of small isolated areas) has been acceptable for irrigation purposes. Research studies are needed to determine the mineral composition and concentration of water returning to the streams and ground water aquifers.

Crop consumptive use

In lieu of adequate diversion and return flow records and on-site consumptive use measurements, the empirical formula developed by H. F. Blaney and W. D. Criddle was used in estimating the amount of water consumed by irrigated crops (Appendix V--Water Resources). The methodology used is the same as the one developed by H. F. Blaney and adopted by the Upper Colorado River Basin Compact Commission. Slight modifications, based on more recent studies, were made in determining the effective precipitation (net amount of precipitation consumed by crops).

Many factors influence the amount of water consumed by crops. These vary with locality and time. The more important influences are climate, water management, type of crop, and plant growth characteristics.

The magnitude and intensity of rainfall affect the amount of irrigation water required during any season. Under certain conditions the rainfall may be lost through evaporation or surface runoff before it can be utilized by the crop. For other conditions a large percentage of the moisture enters the soil and is available for crop consumptive use.

Consumptive use of water by crops in any particular locality is influenced more by the amount of solar radiation than any other factor. Long-term temperature records are good indicators of solar radiation and the corresponding water use by plants. The growing season, also closely tied to temperature, is an important factor and is frequently considered to be the period between killing frosts. For many annual crops and locations, however, the growing season is much shorter as these crops are usually planted after the frosts are past and mature before they recur. At higher elevations where the growing season is short, many of the annual crops, mostly small grains, do not mature and are cut for hay. For most perennial crops, namely, grass hay and pasture, growth starts as soon as the maximum temperature stays well above the freezing point and continues throughout the season despite later freezes. Many of the hardy crops, especially grasses, mature even though growing season temperatures repeatedly drop below freezing.

The stage of a crop's growth influences its consumptive use rate. From the time of crop emergence and continuing to maturation, the rate of water use increases as the vegetative cover develops. Where adequate moisture is available in the region, the highest use occurs during the time of maximum vegetative cover. After the crop matures, the consumptive use rate decreases.

The term "crop irrigation requirement" as used in this appendix is defined as crop consumptive use less effective precipitation. In general, leaching requirements are nominal for the Upper Colorado Region and are not included in this study. Data in Table 8 include the normal range of crop irrigation requirements for the various crops grown in the Upper Colorado Region.

Adequacy of supply

Shortage of irrigation water is one of the principal problems in the region. It is estimated that about 37 percent of the irrigated land (excluding idle land which receives no irrigation water in an average year) receives inadequate water. Both the quantity and seasonal distribution of water affect the adequacy of supply. For example, in areas where water is ample during the spring and early summer, it is a common practice to overirrigate or apply more water than is actually required by the crops. This is done partly in an attempt to build up the soil moisture for carryover into the late season when the water supply is generally short. Additional storage facilities and better irrigation water management techniques are needed to help alleviate this problem.

Abandoned farm shows effects of a water shortage. Storage facilities planned for this area will alleviate this problem.

Depletion

Of all the man-related uses of water in the region, the consumptive use of water on irrigated lands results in the largest depletion. This on-site depletion of water at the 1965 level of development was about 1,697,300 acre-feet for use on 1,497,100 acres[1/] of land. For the region this averages about 1.13 acre-feet per irrigated acre. When compared with other regions in which agriculture is the major use of the water resource, the consumptive use on irrigated lands in the Upper Colorado Region is relatively small. Considering the relationship of agriculture to the region's economy, irrigation is a vital and important use of the water resource.

1/ A total of 1,621,500 acres of land is irrigated in the region. This includes 124,400 acres of idle land not irrigated in an average year. Consequently, water use estimates are based on the 1,497,100 acres actually receiving water. These estimates of on-site depletions were made specifically for the purpose of this framework study and are not to be construed as depletions charged to the various States under the provisions of the Colorado River and Upper Colorado compacts. In particular, they are site-located and do not necessarily reflect direct relationship to streamflow diminishment at Lee Ferry.

Table 8 - Crop irrigation requirements (crop consumptive use less effective precipitation)--1965

Hydrologic Subregion and State	Full and short water supply	Normal range (inches)									
		Alfalfa	Grass hay and pasture	Small grain	Corn	Potatoes	Sugar beets	Orchard	Truck crops	Sorghum	Dry beans
Green River											
Colorado	F	10.5-22.6	8.6-11.7	7.4-15.8	17.2	8.2			5.7		
	S	7.0-12.8	4.4-9.9								
Utah	F	19.5-29.0	18.1-25.2	15.2-19.6	14.5-23.7		19.8	18.3-21.3	11.2-13.2		
	S	12.5-18.9	9.7-16.6								
Wyoming	F	10.8-18.3	9.5-15.5	8.7-14.6							
	S	6.0-16.4	5.1-13.3								
Upper Main Stem											
Colorado	F	12.9-29.5	7.4-25.4	8.8-16.2	8.8-20.4	7.7-17.8	15.7-22.8	16.4-21.9	13.7-20.1	16.3-23.9	10.4-11.7
	S	7.1-17.5	4.0-13.2								
Utah	F	19.8-32.3	16.6-27.9	13.7-19.2	16.3-24.8						
	S	14.6-16.3	11.7-12.8								
San Juan-Colorado											
Arizona	F				16.3				8.8		
	S	13.1	11.3		10.3			9.9			
New Mexico	F	23.9-28.0	14.3-24.1	14.0-15.0	13.1-20.1	16.8		20.6-24.3	10.6-15.4	20.7	13.1
	S	11.7-12.8	4.3-10.0								
Colorado	F	10.6-19.8	8.7-16.7	8.5-13.0	8.7-15.0	9.9-13.8		13.0-17.0		11.5-15.1	10.0
	S	11.6-14.4	6.3-11.5								
Utah	F	14.1-29.6	12.0-25.5	12.6-19.7	14.4-23.8	9.3		16.2	11.0		
	S	7.0-16.4	5.3-13.3								
Upper Colorado Region	F	10.5-32.3	7.4-27.9	7.4-19.7	8.7-24.8	7.7-17.8	15.7-22.8	13.0-24.3	5.7-20.1	11.5-23.9	10.1-13.1
	S	6.0-18.9	4.0-16.6		10.3			9.9			

Source: Upper Colorado Region Comprehensive Study.

Other depletions related to irrigation include reservoir evaporation and consumptive use of water incidental to the cropped area, phreatophytes, and seeped lands. Water depletion by irrigation and related use was 2,127,800 acre-feet for the 1965 level of development. This amounts to about 62 percent of the 3.45 million-acre-foot total depletion for all uses in the region (including transmountain diversions) for the same period.

Present on-site water depletions by irrigated cropland and related uses are shown in Tables 9 and 10.

Table 9 - Present on-site water depletions by irrigated cropland, incidental use, and irrigation reservoir evaporation--1965[1/]
(Unit--1,000 acre-feet)

	Hydrologic Subregions			
Type of use	Green River Subregion	Upper Main Stem Subregion	San Juan-Colorado Subregion	Total
Irrigated cropland	662.4	747.4	287.5	1,697.3
Incidental use	113.6	167.3	34.7	315.6
Reservoir evaporation	42.4	16.9	55.6	114.9
Total	818.4	931.6	377.8	2,127.8

1/ Source: Upper Colorado Region Comprehensive Framework Study, Water Resources Work Group Data, Soil Conservation Service, Denver, Colo.

Irrigation water being used on beet field in Colorado.

Table 10 - Present on site water depletions by irrigated cropland--1965 1/

Hydrologic Subregion and State	Full and short water supply	Irri-gated cropland 2/ (1,000 acres)	Unit de-pletion 3/ (acre-feet/ acre)	Deple-tion (1,000 acre-feet)
Green River				
Colorado	F	69.2	0.90	62.7
	S	44.9	.53	23.7
Utah	F	162.2	1.55	251.3
	S	101.9	1.02	103.5
Wyoming	F	130.5	.98	128.2
	S	151.5	.61	93.0
Subtotal		660.2	1.00	662.4
Upper Main Stem				
Colorado	F	418.4	1.44	601.9
	S	157.2	.84	132.8
Utah	F	3.5	1.97	6.9
	S	4.8	1.21	5.8
Subtotal		583.9	1.28	747.4
San Juan-Colorado				
Arizona	F	1.2	1.17	1.4
	S	3.5	.86	3.0
New Mexico	F	38.5	1.85	71.1
	S	6.3	.78	4.9
Colorado	F	107.7	1.17	126.2
	S	60.6	.73	44.0
Utah	F	16.6	1.33	22.0
	S	18.6	.80	14.9
Subtotal		253.0	1.14	287.5
Region total		1,497.1	1.13	1,697.3

1/ Source: Upper Colorado Region Comprehensive Framework Study, Water Resources Appendix V.

2/ Does not include 124,400 acres of idle land not irrigated in an average year.

3/ Crop consumptive use less effective precipitation.

Water Quality

General effects on irrigation

Three principal characteristics contribute to the success of irrigated agriculture in the region from the standpoint of water quality.

(1) The region is normally characterized by high flow, good quality runoff in spring and early summer and low flow, poorer quality runoff the remainder of the year. This has been altered in many cases by construction of reservoirs that store the better quality high runoff for use later in the year. Good quality water is beneficial in early spring when the young plants are more susceptible to injury.

(2) There are only a few acres of salt-sensitive crops irrigated in the region, thus the effects of increased salinity of the irrigation water are not great.

(3) Calcium and magnesium in the proper proportions to sodium maintain soil in good conditions of tilth and structure. In most soils of the Upper Colorado Region, calcium and magnesium are the principal cations held by the soil in replaceable or exchangeable form with sodium consisting of a smaller amount. Only in a few localities is the ratio of these constituents reversed, with the excess sodium in the soil causing structure to break down, sealing pores, and decreasing permeability. Waters containing predominantly calcium when applied to such soils decrease the sodium adsorption ratio and potential sodium hazard.

In discussing quality of water for irrigation it is necessary to consider the effects of the water's constituents on both the plant and the soil. The deleterious effects of salts on plant growth can result from: (1) direct physical effects of salts in preventing water uptake by plants (osmotic effects); (2) direct chemical effects upon metabolic reactions of plants (toxic effects); and (3) indirect effects through changes in soil structure, permeability, and aeration.(4)

Absolute limits of the permissible concentration of salts in irrigation water are difficult to assign for several reasons listed below.

(1) It is possible that the soil solution may exceed eight times the concentration of the water that replenishes it because of evaporation from the soil surface, transpiration by plants, and selective adsorption of salts by the plants.

(2) There is apparently no definite relationship between the concentration and composition of the irrigation water and soil solution.

(3) Plants vary widely in their tolerance of salinity, as well as specific salt constituents.

(4) Soil types, climatic conditions, and irrigation practices may all influence the reactions of the crop to the soil constituents.

(5) Interrelationships between and among constituents may be highly significant; the effect of one ion may be modified by the presence of another.

Irrigation water applied to cultivated land is only partly used by crops. The part not consumed is a combination of surface runoff and percolation through the soil beyond the root zone. Water or soil containing soluble salts require sufficient water supply in excess of consumptive use by the crop to prevent salt accumulation in toxic amounts. Generally, in the few areas where salinity is a problem, there is sufficient water applied to provide leaching.

Although absolute limits cannot be set for salinity and sodium content of irrigation water, the U.S. Department of Agriculture's Salinity Laboratory[5] has established some general classifications which are used as a guide where there are no particular soil problems. These are shown in Table 11.

Table 11 - Classification of irrigation waters

	Salinity hazard 1/		Sodium hazard
Classification	Electrical conductivity (EC) (micromhos/cm.)	Total dissolved solids (TDS) (mg./l. or p.p.m.)	Sodium adsorption ratio SAR 2/
Low	100-250	60-160	0-10
Medium	250-750	160-480	10-18
High	750-2,250	480-1,440	18-26
Very high	2,250	1,440	26

1/ For conductivities of less than 5,000 micromhos/cm., the total dissolved solids = conductivity x 0.64. The factor 0.64 is an average.

2/ These SAR limits are for water having low salinity content. When salinity hazard is high the SAR limits are from 0.4 to 0.5 of these values.

Toxic constituent effects on irrigation must also be considered in evaluating water quality. Boron is the most common element considered and is usually found in varying amounts in natural waters. A concentration of 0.5 milligram per liter is considered critical for most sensitive crops, but it can be higher for more tolerant crops generally grown in the Upper Colorado Region. The quality of soil, drainage, and climatic and other environmental factors, such as the amount of rainfall and total amount of irrigation water applied, can modify the safe concentration limits.

A nonmineral criterion[6] to be considered is the sediment content. Colloidal material deposited on soil surfaces can produce crusts which inhibit infiltration, and deposition can reduce capacity of storage and conveyance systems. Waters of high sediment content when used in sprinkler irrigation can cause undue wear of pumps, nozzles, and deposition of films on leaf surfaces affecting plant growth and marketability.

The increased use of insecticides, fungicides, and herbicides is becoming of increasing interest in consideration of water quality. Concentrations are generally very low and have little effect on irrigation in the region.

Suitability of water supply for irrigation

In general, the quality of the water supply in the Upper Colorado Region is suitable for existing irrigated agriculture. The residual sodium carbonates, chlorides, and boron concentration in the irrigation supply are usually well within acceptable limits. Total dissolved solids and the sodium adsorption ratios, though acceptable overall, do present some local problems. Generally, water in streams increases in concentration of total dissolved solids from natural and man-induced sources, including irrigation uses, as it flows downstream. The pattern of increasing mineral concentration downstream is due primarily to the type of geologic formations underlying the drainages. While the headwaters are, for the most part, underlain by igneous or well-leached sedimentary rocks, the lower reaches of the streams in areas of low rainfall frequently dissect sedimentary formations of marine origin containing high concentrations of soluble salt. These salt-laden beds are the principal sources of stream contamination. The quality is further reduced in the lower reaches as a result of stream depletion and the leaching of salts from irrigated lands.

Details concerning the quality of surface and ground water in the region follow. Maps showing the areal distribution of surface and ground water quality, and a more detailed discussion thereof, are presented in Appendix XV, Water Quality, Pollution Control, and Health Factors.

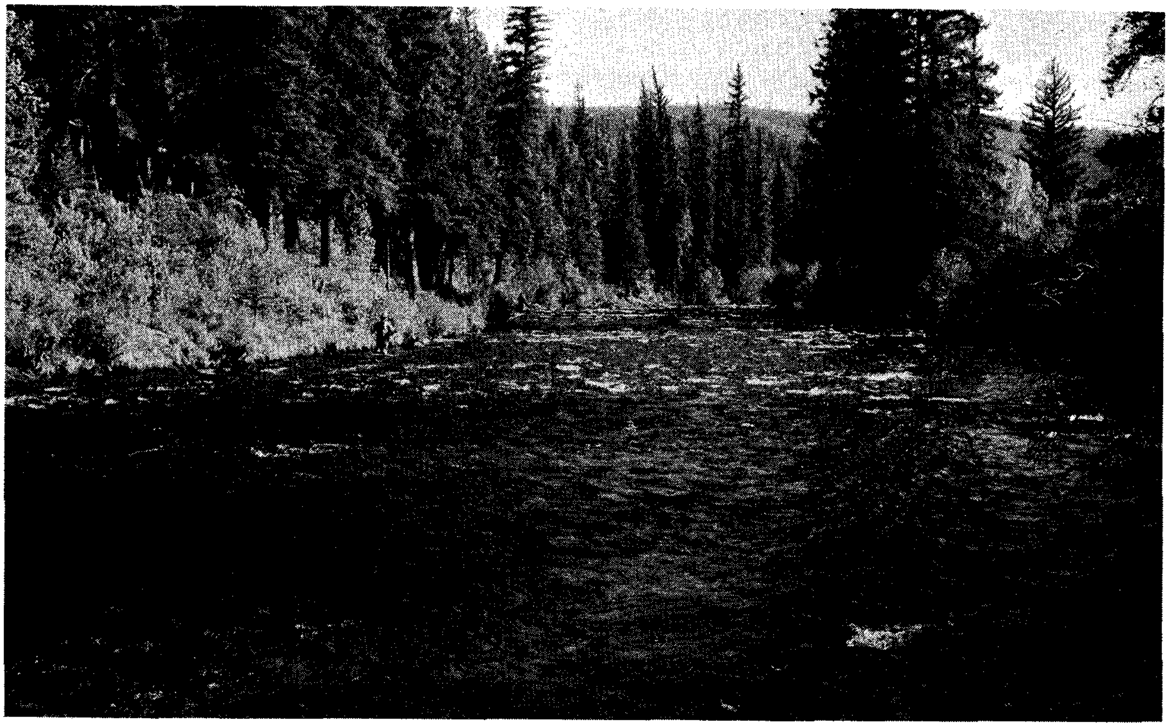
Surface Water

Water quality of streams near their headwaters is considered excellent for irrigation, as the weighted average concentration of total dissolved solids is less than 100 milligrams per liter and the sodium adsorption ratio as well as the sediment content is very low.

During the 1941-66 period, the salt load of the Colorado River at Lee Ferry, Ariz.,1/ the outlet of the region, averaged about 8.2 million tons annually. Of this total, about 33 percent originated in the Green

1/ Lee Ferry is the official compact point dividing the Upper and Lower Colorado Regions. It lies immediately below Lees Ferry, which is the location of the stream gage.

River Subregion, 48 percent in the Upper Main Stem Subregion, and 19 percent in the San Juan-Colorado Subregion.



A reservoir upstream regulates the streamflow and provides clear water of excellent quality for irrigation downstream.

The Green River (except within Flaming Gorge Reservoir), the San Juan River, and the Colorado River above Glenwood Springs, Colo., generally do not have contents of total dissolved solids exceeding 500 mg./l. The Colorado River, extending from Glenwood Springs to Lee Ferry, has total dissolved solids varying between 500 mg./l. and 1,000 mg./l. Salinity hazards for irrigation in the region are considered low to medium for the Green River, the San Juan River, and the Colorado River above Glenwood Springs, and medium to high for the Colorado River below Glenwood Springs. Water of these main rivers is suitable for most irrigated agriculture.

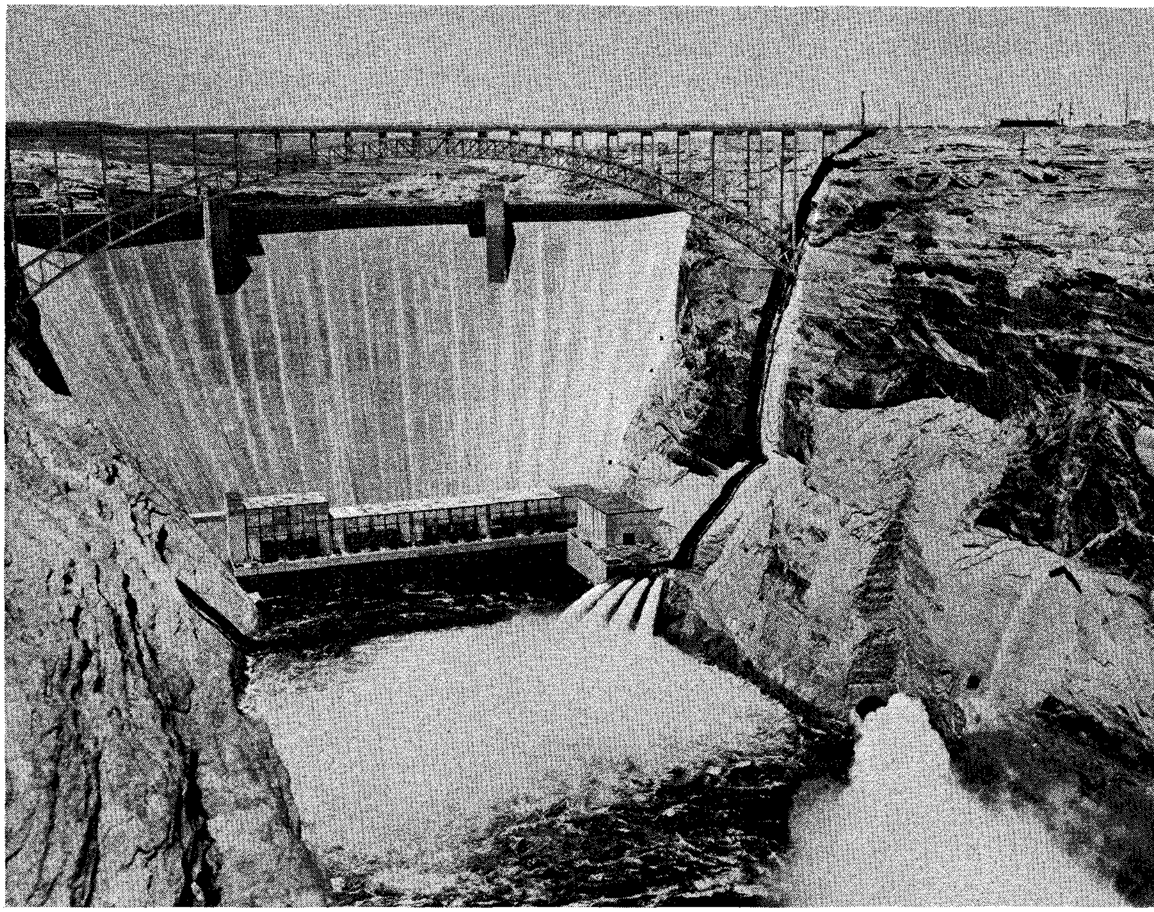
The water of some tributaries of the Green, San Juan, and Colorado Rivers offers possible water quality problems with regard to its use for irrigation. These streams are generally small and are comprised mostly of return flows from irrigation upstream. Little, if any, of this water is reused for irrigation without dilution with better quality water from other streams.

In the Green River Subregion, for example, Big Sandy Creek below Farson, Wyo., reaching to its confluence with the Green River, has total dissolved solids varying from 1,000 to over 4,000 mg./l. and a sodium adsorption ratio as great as 10. The Duchesne River between Myton, Utah, and its confluence with the Green River at Ouray, Utah, often contains in excess of 2,000 mg./l. dissolved solids. The Price River from Wellington, Utah, to its confluence with the Green River has dissolved solids ranging from 1,000 to 5,000 mg./l. Total dissolved solids reach 4,000 mg./l. in the lower reach of the San Rafael River, another tributary of the Green River. Some of the northward-flowing tributaries of the Duchesne River have boron concentrations which reach 10 mg./l. on occasion, well above the critical point. These streams are considered to have a high to very high salinity hazard and low to medium sodium hazard for irrigation.

In the Upper Main Stem Subregion, dissolved solids in the lower reaches of the Uncompahgre River vary between 2,000 and 3,000 mg./l. Cedar Creek upstream from its confluence with the Uncompahgre River and the Uncompahgre River below Montrose, Colo., have sodium adsorption ratios approaching 10. These waters are considered to have a very high salinity hazard and low to medium sodium hazard for irrigation.

In the San Juan-Colorado Subregion below irrigated areas, dissolved solids of the Mancos and La Plata Rivers vary between 500 and 1,200 mg./l. Dissolved solids vary between 2,000 and 4,000 mg./l. in McElmo Creek, a tributary of the San Juan River, since the streamflow is principally return flow from irrigated lands in the vicinity of Cortez, Colo. The former has a medium to high salinity hazard and the latter has a very high salinity hazard for irrigation. Both have a low sodium hazard.

Suspended sediment concentrations vary widely throughout the region. The sediment load is normally light in the upper reaches of major streams but increases in the middle and lower reaches. Prior to construction of Colorado River Storage Project dams, the average annual suspended sediment concentration measured on a long-term basis at Lees Ferry was about 6,000 parts per million. Since 1965, as a result of the closure of Glen Canyon Dam above Lees Ferry and storage in Lake Powell, weighted average concentrations of sediment have been reduced to less than 100 parts per million. Construction of Glen Canyon and similar storage reservoirs has had a beneficial effect on the quality of the water for irrigation.



Clear, cool water being released from Glen Canyon Dam for use in the Lower Colorado Region.

Partial solutions to many of the local problems resulting from use of water of poor quality are achieved by good farm management practices, including the addition of a few chemical amendments and the provision for adequate drainage.

Ground Water

Ground water in the Upper Colorado Region is usually less suitable for irrigation than is surface water, except where it occurs locally in the headwaters of major streams. Ground water, having concentrations of total dissolved solids ranging from 1,000 to 3,000 mg./l. occurs throughout the northeast, central, and southeast parts of the region. The sodium adsorption values for this same area are often greater than 10. High concentrations of boron occur in ground water along the lower reaches of Willow Creek near Ouray, Utah, and in ground water contributions to the Strawberry River and Indian Creek above Duchesne, Utah.

Drainage

Most of the drainage problems in the irrigated lands of the Upper Colorado Region have been caused by one or more of the following factors: (1) improper water management, including continuous irrigation and seepage from unlined canals and laterals; (2) restricted permeability in soil layers or underlying materials, and (3) topographic position. Poor drainage results in inadequate aeration in the plant root zone and some soluble salt accumulations in the upper soil horizons.

As mentioned previously, 68 percent of the region's irrigated crop land is in grass hay and pasture and these are produced primarily in mountain meadows of Colorado and Wyoming at elevations ranging from 6,000 to 9,000 feet. It is common practice for farmers to flood-irrigate the meadow lands during the early season when streamflow is high and discontinue irrigation about the first of August to allow harvesting. High water tables occur throughout the bottom lands of the high mountain valleys as a result of almost continuous application of irrigation water during this period.

Most of the meadow lands are naturally well-drained. Their favorable topography and adequate depths of permeable soils and subsurface materials effectively control water table levels for normal cropping. The extensively grown, shallow-rooted meadow hay species tolerate high water tables for prolonged periods during the irrigation season and the excellent quality of the water supply in the headwaters of the streams permits aeration and little or no accumulation of salts in the soils. When irrigation is discontinued, the ground water usually recedes rapidly to depths well below levels that are injurious to crops. Meadow crop production has been materially improved in a few local areas where drainage, land preparation, reseeding, fertilization, and controlled irrigation are practiced. Where land preparation is inadequate, the high water table permits capillary rise of water in the root zone in high spots in the meadows and results in the development of seeped areas and phreatophyte growth in the low areas. A few shallow drains have been installed in these low spots to provide better surface drainage and some degree of control of the ground water table. As a result the forage is improved and the farmer is able to perform haying operations.

Alfalfa, small grains, and other annuals or speciality crops are produced on about 32 percent of the irrigated acreage in the Upper Colorado Region. These crops are grown on lands along the lower reaches of stream valleys of the region, primarily between elevations of 4,000 and 7,000 feet. The growing season is relatively longer than that in the upper reaches, permitting a wider selection of crops, many of which have a higher irrigation demand. The cropping systems require stringent ground water controls for sustained productivity. Most irrigated lands in lower river valleys occur on large, gently sloping fans, on prominent mesas and terraces, and to a lesser extent on low, flat-lying river flood plains.

Irrigation developments are of greater magnitude than those for meadow lands along upper reaches of tributary streams as they have wider, more complex drainage problems.

Many of the irrigated lands at the lower elevations are naturally well-drained. They occupy favorable topographic positions adjacent to natural drainageways, and the soils have sufficient permeability and depth for adequate removal of surplus water. Existing ground water tables in these lands remain at depths well below critical levels during the irrigation season without artificial measures. Drainage problems, however, have developed in some irrigated areas of lower reaches, particularly where there are no natural drainage channels or escarpment outlets to remove excess waste water or where lands with fine-textured soils lie in unfavorable positions on slopes below coarse-textured higher lands that are being irrigated.

In valley bottoms near Price and Castle Dale, Utah, and Grand Junction, Rifle, Delta, Montrose, and Cortez, Colo., the drainage problems are complex and often difficult to rectify. Fine-textured, massive soils at varying depths over marine shale or mudstone barrier formations restrict drainage and leaching of salt. As a result of ground water buildup and salt accumulations, these lands are unproductive without artificial drainage. Many miles of drains have been installed to remove and dispose of waste water, some of which are improperly located and only partially effective. Solution of the drainage problem in the Grand Junction Area requires a combination of drains and drainage wells. In areas where a permeable gravel aquifer is confined by fine-textured saline soils, the artesian pressure in the deeper aquifers is relieved more effectively by wells than by conventional open or closed drains. Drainage wells in this area have lowered the pressure of the artesian aquifer and allowed conventional drains to operate effectively in lowering the water table and leaching salts.

Some previously waterlogged tracts in the vicinity of Montrose and Cortez, Colo., have been reclaimed into productive units and others remain undrained. The impaired drainage results from abrupt changes in land gradient and the occurrence of a pronounced thinning and concurrent restricted capacity of the gravel aquifers due to undulating shale bedrock approaching or outcropping the surface. The subsurface materials are normally very permeable and respond well to drainage.

Complex drainage problems exist in small, scattered areas on benches and low rolling terrain in Montrose, La Plata, and Montezuma Counties of Colorado. The uneven terrain causes ground water accumulations in topographic lows or at small outcrops on slopes shallow to bedrock. Most of these are localized in nature and generally not susceptible to economic drainage.

The bench areas of the Uinta Basin in eastern Utah are remnants of old glacial outwash plains. The soils are usually underlain by deposits of gravel and cobble. Drainage problems have developed where dikes occur in these deposits or where the tilt of the underlying shale and sandstone strata is such as to cause shallow underground reservoirs to develop. Subsurface drainage has proved successful in some of these areas by dissecting the barrier dikes and submerged ridges in order to lower the water table and provide conditions for salt leaching.

Drainage problems on the several small irrigation projects on the Indian reservations of Arizona and New Mexico are generally caused by improper water management. Problems commonly occur during periods of high runoff when the water table of the cropland rises to within 1 to 2 feet of the surface. In Chinle Valley, Ariz., slowly to very slowly permeable soils contribute to drainage problems. To correct some of these problems in the Many Farms Irrigation Project in Chinle Valley, the main canal is being concrete lined and surface drains are being installed.

Some drainage problem areas that have been in existence for many years have been transformed to permanent wetlands with dependent wildlife populations. In such cases, the benefits of drainage should be weighted against the loss of wildlife values.

Drainage has been provided for about 86,000 acres in the region by the installation of 806.8 miles of tile drains and open ditches.

Open ditch drain newly constructed in irrigated lands in Colorado to relieve waterlogged condition and improve crop production.

Table 12 summarizes the drainage measures that have been taken to alleviate drainage problems and the estimated area drained.

Table 12 - Drainage measures and area drained--1965

Hydrologic Subregion and State	Drainage measures: Tile drains (miles)	Drainage measures: Drain ditches (miles)	Drainage measures: Total drains (miles)	Estimated area drained (acres)
Green River				
Colorado	4.9	27.1	32.0	3,400
Utah	6.1	70.5	76.6	8,200
Wyoming	.6	116.0	116.6	12,400
Subtotal	11.6	213.6	225.2	24,000
Upper Main Stem				
Colorado	53.2	477.6	530.8	56,600
Utah	.3		.3	Negl.
Subtotal	53.5	477.6	531.1	56,600
San Juan-Colorado				
Arizona	.3	.5	.8	100
Colorado	.3	16.3	16.6	1,800
New Mexico	3.5	29.5	33.0	3,500
Utah	.1	-	.1	Negl.
Subtotal	4.2	46.3	50.5	5,400
Total	69.3	737.5	806.8	86,000

Source: Miles of Drains from SCS-99 Report (1965).

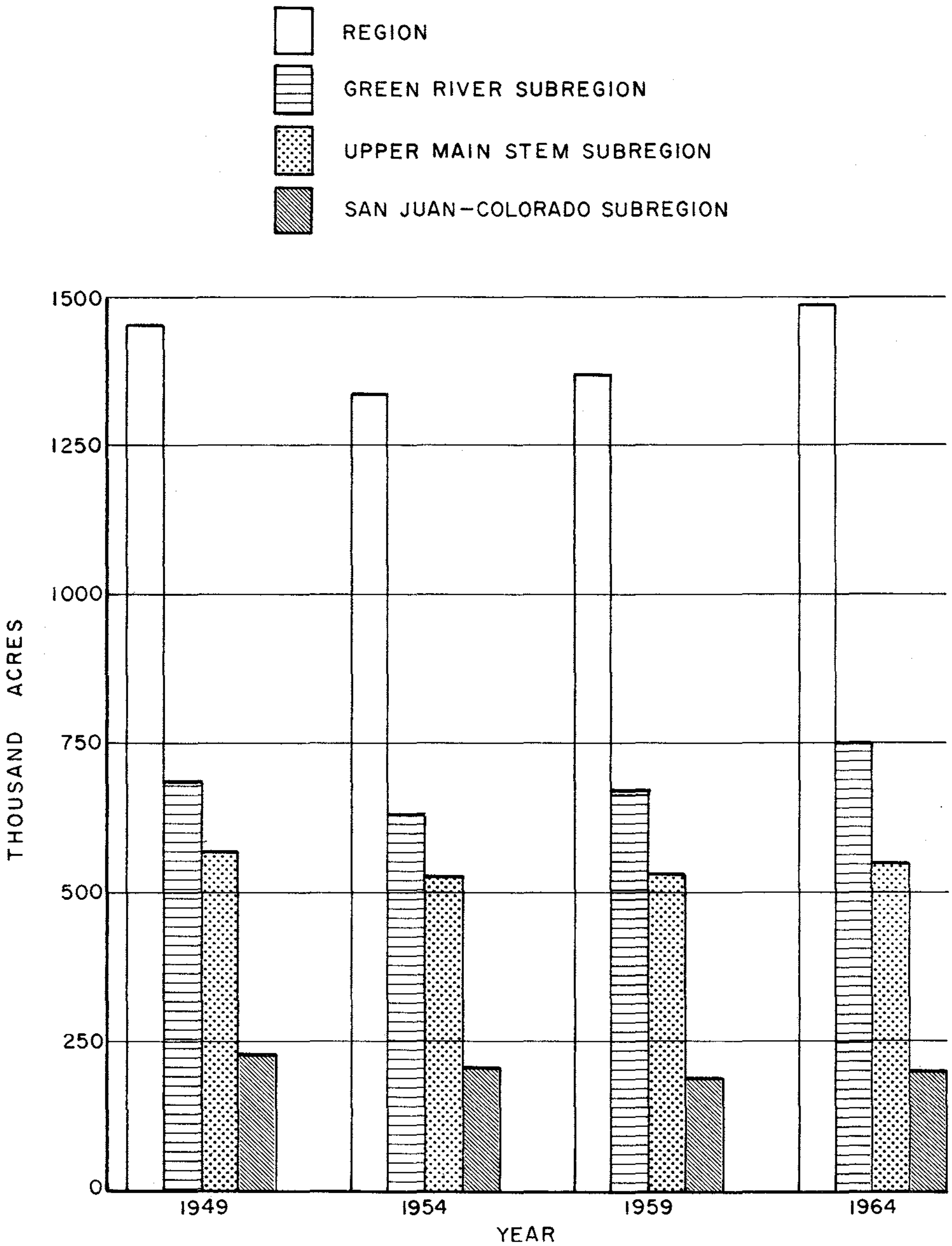
Contribution of Irrigation to Region's Economy[1/]

Characteristics of irrigated farms

Irrigation is the cornerstone of agriculture in the region. The dependence of agriculture upon irrigation is indicated by census figures which show that 65 percent of the cropland harvested in 1964 was from irrigated lands. This production takes place on about 891,000 acres, exclusive of irrigated pasture and meadow land. According to the U.S. Census of Agriculture, total irrigated crop and pasture land in farms within the economic boundaries of the region was nearly 1.5 million acres in 1964. As shown in following figure, there has been a slight increase in irrigated land in farms since 1954 in the Green River and Upper Main Stem Subregions while in the San Juan-Colorado Subregion irrigated land in farms declined between 1954 and 1964. Between 1949 and 1954 there was a general decline of irrigated land in farms throughout the region.

1/ Most of this section refers to the Economic Region and Subregions as shown on the frontispiece map. Boundaries of the Economic Region and Subregions follow State and county lines and exclude Arizona. Source of data: U.S. Census of Agriculture.

IRRIGATED LAND IN FARMS BY ECONOMIC SUBREGIONS



U.S. CENSUS OF AGRICULTURE

Number, Type, and Size of Farms

Livestock farms, other than poultry, are by far the most common type of agricultural enterprise in the Upper Colorado Region. Field crop and general farms are of equal number (Table 13). About 63 percent of the dairy farms in the region are found in the Green River Subregion. Vegetable farms are significant only in the Upper Main Stem Subregion.

Table 13 - Number of farms by type of farm--1964 1/

Economic Subregion and State	Field crop	Cash grain	Vegetable	Fruit and nut	Poultry	Dairy	Livestock other than poultry	General
Green River								
Colorado	141	141	0	0	1	10	491	71
Utah	31	7	3	7	12	209	764	143
Wyoming	18	18	0	0	3	220	545	104
Subtotal	190	166	3	7	16	439	1,800	318
Upper Main Stem								
Colorado	565	333	33	430	28	158	1,624	532
Utah	0	0	1	4	2	0	21	2
Subtotal	565	333	34	434	30	158	1,645	534
San Juan-Colorado								
Colorado	227	201	1	25	18	52	577	106
New Mexico	4	4	0	35	4	17	104	73
Utah	79	51	0	2	3	28	346	34
Subtotal	310	256	1	62	25	97	1,207	213
Total	1,065	755	38	503	71	694	4,472	1,065

1/ A farm was classified as a particular type if the sales value of a particular product or group of products amounted to 50 percent or more of the total value of all farm products sold during the year.
Source: U.S. Census of Agriculture.

Number of farms with irrigated land by acres irrigated is shown in Table 14.

Table 14 - Number of farms by amount of irrigated acreage--1964

Economic Subregion	Acres of irrigated land: 1-9	10-49	50-99	100-199	200-499	500-999	1,000 or more
Green River	193	853	700	751	664	219	101
Upper Main Stem	740	1,627	923	794	498	105	57
San Juan-Colorado	281	822	536	414	183	25	6
Total	1,214	3,302	2,159	1,959	1,345	349	164

Source: U.S. Census of Agriculture.

Table 14 on the foregoing page shows that in 1964 there were 1,858 farms in the Upper Colorado Region which contained 200 or more acres of irrigated land and that 513 of these farms contained 500 acres or more. Only 164 farms, however, had 1,000 or more acres of irrigated land. The modal number of acres of irrigated land per farm is 10 to 49 acres. The Green River Subregion has more farms with 1,000 acres or more of irrigated land than does either the Upper Main Stem or San Juan-Colorado Subregion. The Upper Main Stem Subregion has the greatest occurrence of farms with only 1 to 9 acres of irrigated land per farm.

About 85 percent of the region's farms is classified as commercial although 27 percent of the commercial farms had sales of less than $5,000 in 1964. Gross sales were $40,000 or more for 473 farms (Table 15).

Table 15 - Number of commercial and noncommercial farms by class--1964

Economic Subregion and State	Commercial classes 1/					Total commercial farms	Noncommercial Class VI 2/	Total farms
	Class I	Class II	Class III	Class IV	Class V			
Green River								
Colorado	79	113	180	190	120	682	50	732
Utah	43	68	196	307	345	959	237	1,196
Wyoming	81	97	233	263	176	850	61	911
Subtotal	203	278	609	760	641	2,491	348	2,839
Upper Main Stem								
Colorado	209	395	696	807	759	2,866	545	3,411
Utah	3	3	4	4	10	24	9	33
Subtotal	212	398	700	811	769	2,890	554	3,444
San Juan-Colorado								
Colorado	32	108	214	237	251	842	196	1,038
New Mexico	6	13	33	56	73	181	65	246
Utah	20	36	74	133	149	412	73	485
Subtotal	58	157	321	426	473	1,435	334	1,769
Total	473	833	1,630	1,997	1,883	6,816	1,236	8,052

1/ Based on total value of products sold. Farms with value of sales amounting to $2,500 or more were classified as commercial.

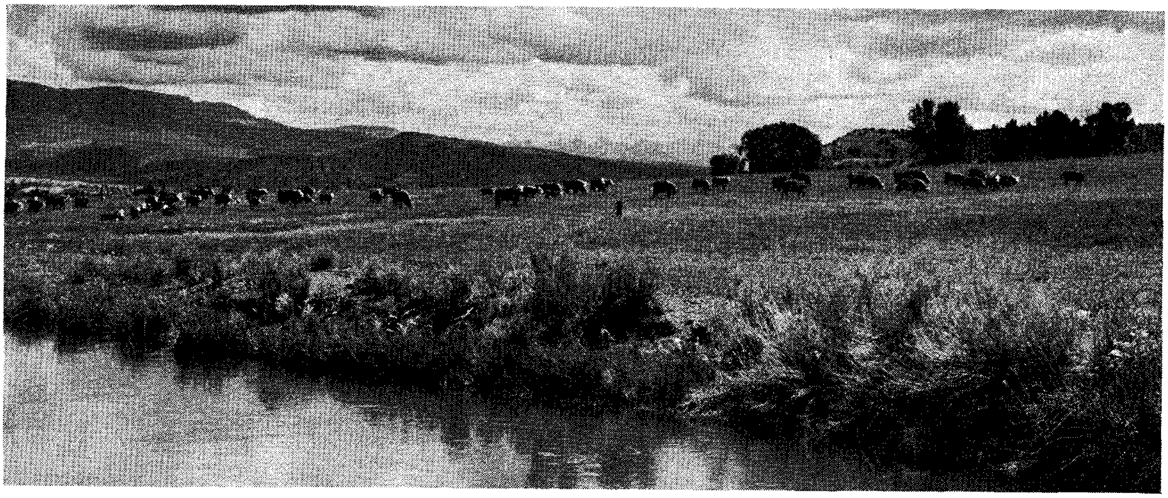
Class I--Sales of $40,000 or more.
Class II--Sales of $20,000 to $39,999.
Class III--Sales of $10,000 to $19,999.
Class IV--Sales of $5,000 to $9,999.
Class V--Sales of $2,500 to $4,999.

2/ Class VI--Sales of $50 to $2,499, provided the farm operator was under 65 years of age and he did not work off the farm 100 days or more.

Source: U.S. Census of Agriculture.

Land Use and Crop Production

Irrigated land in the region is used primarily for the production of feed for livestock. Generally cattle and sheep graze the higher mountains in the summer months, use the foothills and deserts in the spring and fall, and are fed hay and forage at the base ranch during the winter.

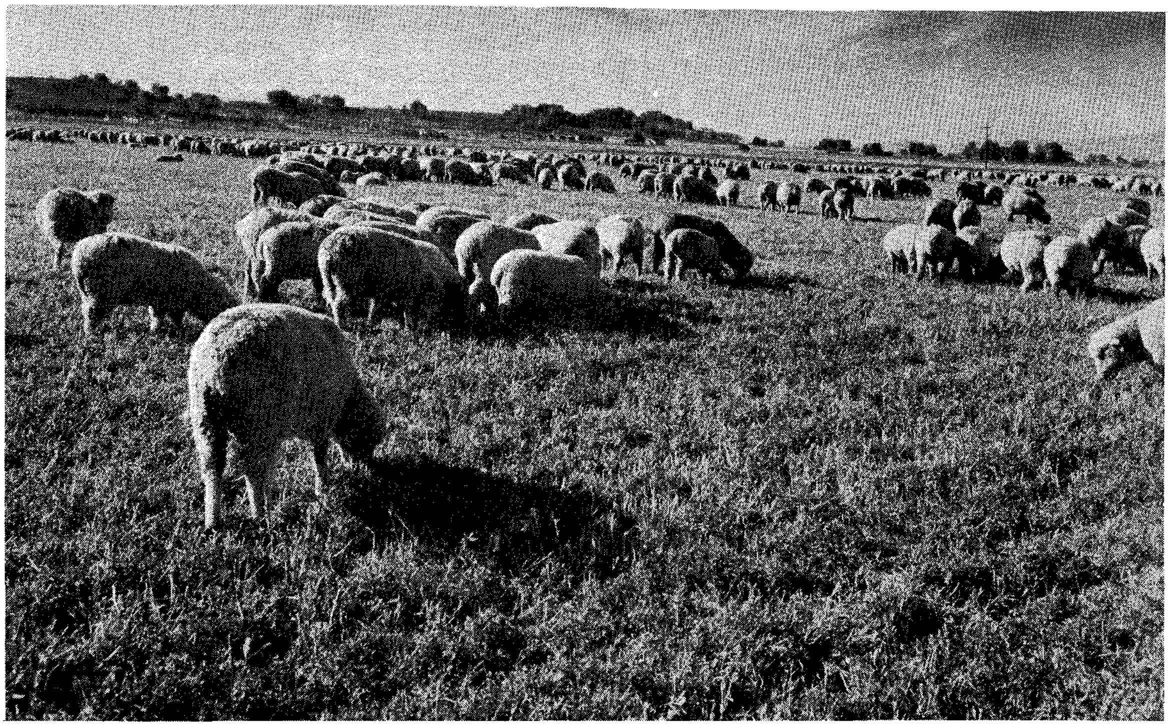


Typical scene of white-faced Hereford cattle grazing contentedly on an irrigated pasture in the Upper Colorado Region.

On some farms the cattle and sheep are sold as feeders. Many are shipped out of the region to be fattened on a diet high in grain concentrates. In some cases the owner produces enough grain and silage on his irrigated land to fatten his cattle or sheep.

Fattening cattle in a feed lot.

The hay and other forage for winter feed which are so vital to the livestock operations are produced on a relatively small acreage of irrigated land. This irrigated land forms a significant base for the livestock industry and complements the utilization of the vast grazing resource.



Sheep grazing on irrigated pasture.

Table 16 shows the irrigated crop distribution by Hydrologic Subregions in the Upper Colorado Region for the base year 1965. Improved and native grasses are the primary types of hay produced, but alfalfa hay is significant also. Approximately the same acreage is devoted to irrigated rotation and permanent pasture as is used for hay production. Nearly 50 percent of the hay and pasture production occurs in the Green River Subregion. The Upper Main Stem Subregion is the next largest producer of these crops. Of the small grains produced, oats and barley comprise the largest acreage in the region. Less than 3 percent of the irrigated acreage is used for other crops such as orchard, sugar beets, dry beans, truck crops, and potatoes. Over 40 percent of this acreage is in orchard, restricted largely to the Upper Main Stem Subregion.

Irrigated crop production and yields in the region for 1965 are shown in Tables 17 and 18. Crop production rates on irrigated land are

Table 16 - Crop distribution on irrigated lands--1965[1/]
(Unit--1,000 acres)

Crop	Hydrologic Subregion: Green River	Hydrologic Subregion: Upper Main Stem	Hydrologic Subregion: San Juan-Colorado	Total
Hay				
Alfalfa	109.2	127.4	61.7	298.3
Other hay				
Improved	50.0	40.0	12.0	102.0
Native	163.3	83.8	11.4	258.5
Subtotal	322.5	251.2	85.1	658.8
Pasture				
Rotation (cropland)	116.3	88.9	42.1	247.3
Permanent (noncropland)	116.2	89.0	42.0	247.2
Other (noncropland)	63.1	55.0	45.7	163.8
Subtotal	295.6	232.9	129.8	658.3
Corn silage	7.7	18.3	11.7	37.7
Feed grains				
Oats	9.2	13.2	4.8	27.2
Barley (excludes Moravian)	14.8	3.7	5.9	24.4
Corn	.6	13.4	2.2	16.2
Subtotal	24.6	30.3	12.9	67.8
Other grains				
Barley (Moravian)		15.0		15.0
Wheat	7.2	.9	7.4	15.5
Subtotal	7.2	15.9	7.4	30.5
Other crops				
Orchard	.5	14.7	3.1	18.3
Sugar beets	1.7	9.8		11.5
Dry beans		8.1	.5	8.6
Truck crops	.3	1.8	1.8	3.9
Potatoes	.1	.9	.7	1.7
Subtotal	2.6	35.3	6.1	44.0
Idle land	52.1	34.5	37.8	124.4
Total	712.3	618.4	290.8	1,621.5

1/ Upper Colorado Region Task Force data.

Table 17 - Irrigated crop yields--1965[1/]

Crop	Unit per acre	Hydrologic Subregion: Green River	Upper Main Stem	San Juan-Colorado	Average
Hay					
Alfalfa	Ton	2.3	3.0	2.5	2.6
Other hay					
Improved	Ton	1.3	1.3	1.3	1.3
Native	Ton	.75	.75	.75	.75
Weighted average	Ton	1.4	2.0	2.0	1.7
Pasture					
Rotation (cropland)	AUM	3.1	3.1	3.1	3.1
Permanent (noncropland)	AUM	1.8	1.8	1.8	1.8
Other (noncropland)	AUM	.6	.6	.6	.6
Weighted average	AUM	2.1	2.0	1.8	2.0
Corn silage	Ton	10.0	13.0	15.0	13.0
Feed grains					
Oats	Bu.	52.0	52.0	42.0	50.0
Barley (excludes Moravian)	Bu.	52.0	52.0	45.0	50.0
Corn	Bu.	41.0	71.0	74.0	70.0
Other grains					
Barley (Moravian)	Bu.	NA	50.0	NA	50.0
Wheat	Bu.	32.0	35.0	30.0	31.0
Other crops					
Orchard	Ton	4.4	4.4	4.4	4.4
Sugar beets	Ton	15.0	15.0	NA	15.0
Dry beans	Cwt.	NA	18.0	19.0	18.0
Truck crops	Cwt.	74.6	74.6	74.6	74.6
Potatoes	Cwt.	234.0	234.0	234.0	234.0

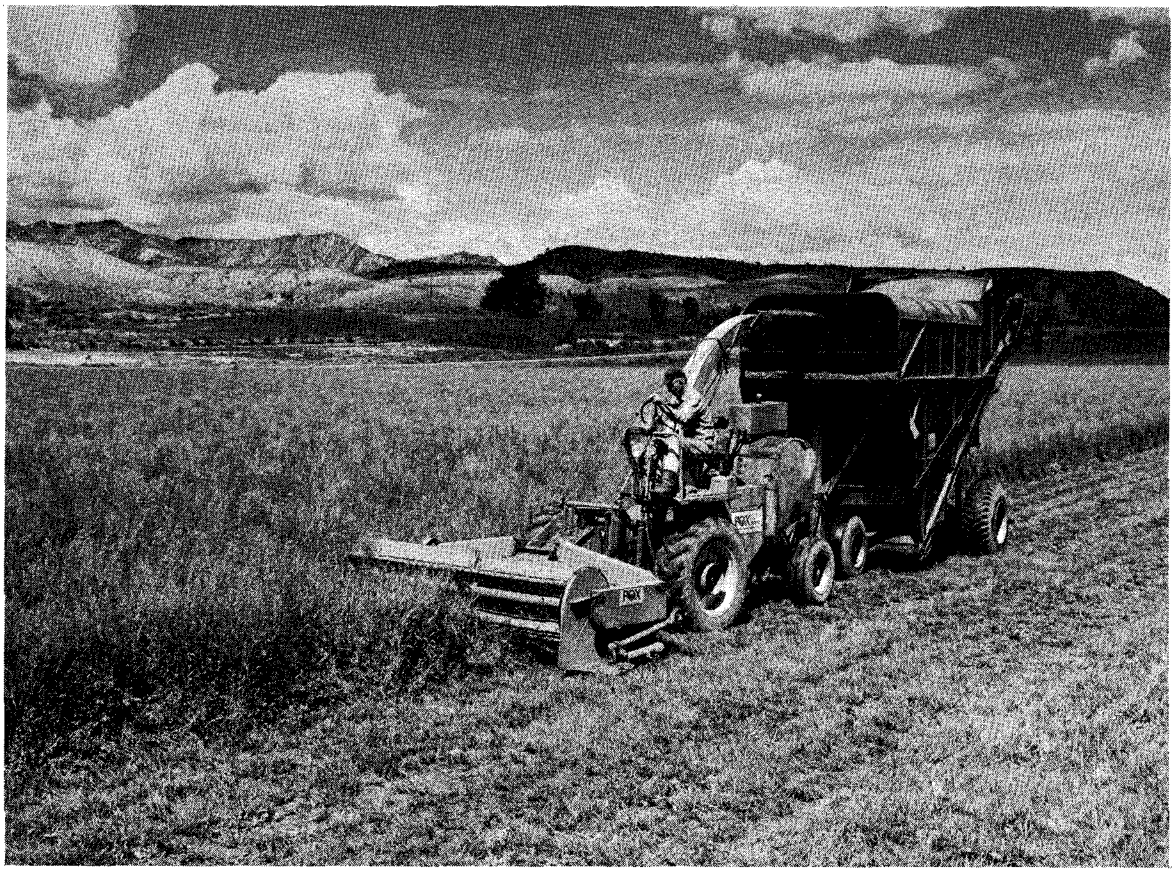
1/ Upper Colorado Region Task Force data.

Table 18 - Total production from irrigated land--1965[1/]

Crop	Units (1,000)	Hydrologic Subregion: Green River	Upper Main Stem	San Juan-Colorado	Total
Hay					
Alfalfa	Ton	251.2	382.2	154.3	787.7
Other hay					
Improved	Ton	65.0	52.0	15.6	132.6
Native	Ton	122.5	62.9	8.6	194.0
Subtotal	Ton	438.7	497.1	178.5	1,114.3
Pasture					
Rotation (cropland)	AUM	360.5	275.6	130.5	766.6
Permanent (noncrop-land)	AUM	209.2	160.2	75.6	445.0
Other (noncropland)	AUM	37.9	33.0	27.4	98.3
Subtotal	AUM	607.6	468.8	233.5	1,309.9
Corn silage	Ton	77.0	237.6	175.5	490.1
Feed grains					
Oats	Bu.	457.6	671.4	231.0	1,360.0
Barley (excludes Moravian)	Bu.	765.0	191.3	263.7	1,220.0
Corn	Bu.	24.5	947.4	162.1	1,134.0
Other grains					
Barley (Moravian)	Bu.	NA	750.0	NA	750.0
Wheat	Bu.	230.4	31.5	222.0	483.9
Other crops					
Orchard	Ton	2.2	64.3	13.6	80.0
Sugar beets	Ton	25.5	147.0	NA	172.5
Dry beans	Cwt.	NA	145.8	9.5	155.3
Truck crops	Cwt.	22.4	134.3	134.3	291.0
Potatoes	Cwt.	23.4	210.6	163.8	397.8

1/ Upper Colorado Region Task Force data.

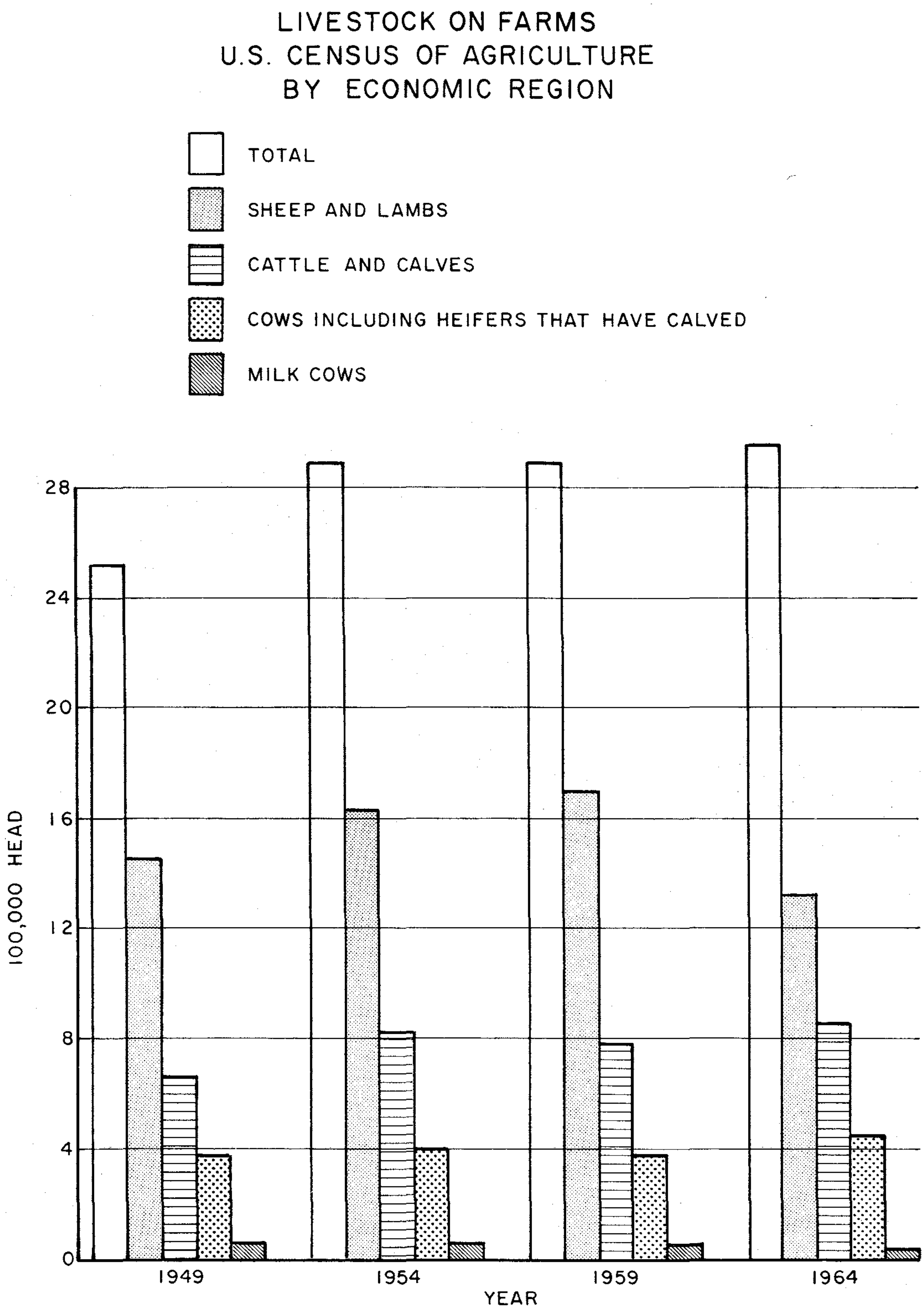
relatively low in most subregions. Alfalfa yields per acre in 1965 averaged 2.6 tons for the region, ranging from 2.3 tons in the Green River Subregion to 3 tons in the Upper Main Stem Subregion. Grass hay yields ranged from 0.75 ton per acre for native hay to 1.3 tons per acre for improved grass mixtures. Yields of oats and barley averaged 50 bushels per acre while yields of corn and wheat average 70 and 31 bushels per acre, respectively.



Alfalfa yield on an irrigated farm in Colorado. Hay will be processed into pellets for feeding livestock.

Livestock Numbers

The U.S. Census of Agriculture reported about 851,000 cattle and calves on ranches and farms in the region in 1964. Sheep and lamb numbers totaled 1,320,000. Sheep and lamb numbers have decreased somewhat in recent years after increasing in the period 1949-59. Numbers of cattle and calves were up in 1964 compared with 1949 and 1954. Milk cow numbers have declined.


LIVESTOCK ON FARMS
U.S. CENSUS OF AGRICULTURE
BY ECONOMIC REGION
TOTAL
SHEEP AND LAMBS
CATTLE AND CALVES
COWS INCLUDING HEIFERS THAT HAVE CALVED
MILK COWS
28
24
20
16
12
8
4
0
100,000 HEAD
1949
1954
1959
1964
YEAR

Value of crops, livestock, and livestock products

Farm sales of agricultural products in the Upper Colorado Region totaled $110.5 million in 1964. Sales of livestock and wool accounted for the largest portion of agricultural sales. Next in order of magnitude of sales were field crops. Dairy products, fruits, and vegetables were of significance. Poultry and poultry products were of less importance in the region.

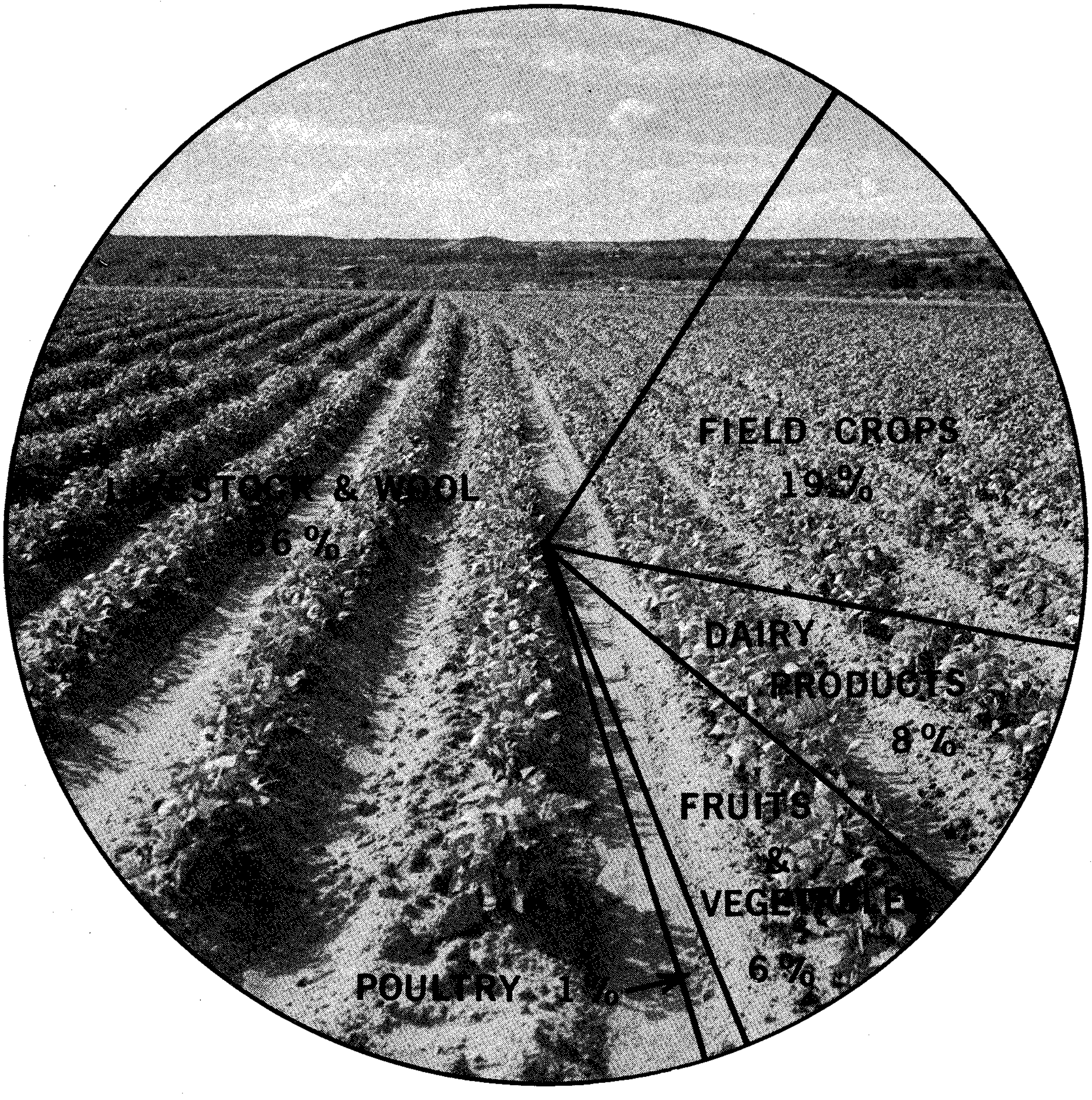
Forty-four percent of the region's total livestock and wool sales originated in the Green River Subregion in 1964. Sales of these products in the Upper Main Stem and San Juan-Colorado Subregions represent 39 and 17 percent, respectively, of the region's total.

Half of the region's production of dairy products was in the Green River Subregion. Dairy production in the San Juan-Colorado Subregion is of less importance than in the Green River and Upper Main Stem Subregions. Fifteen percent of the region's dairy products was produced in the San Juan-Colorado Subregion and 35 percent in the Upper Main Stem Subregion.

About 50 percent of field crops was sold in the Upper Main Stem Subregion and the remaining 50 percent in the Green River and San Juan-Colorado Subregions in roughly equal proportions. Fruit sales were significant in the Upper Main Stem Subregion where 88 percent of the region's sales occurred. The remaining 12 percent of fruit sales was in the San Juan-Colorado Subregion.

Apples being picked for later sale.

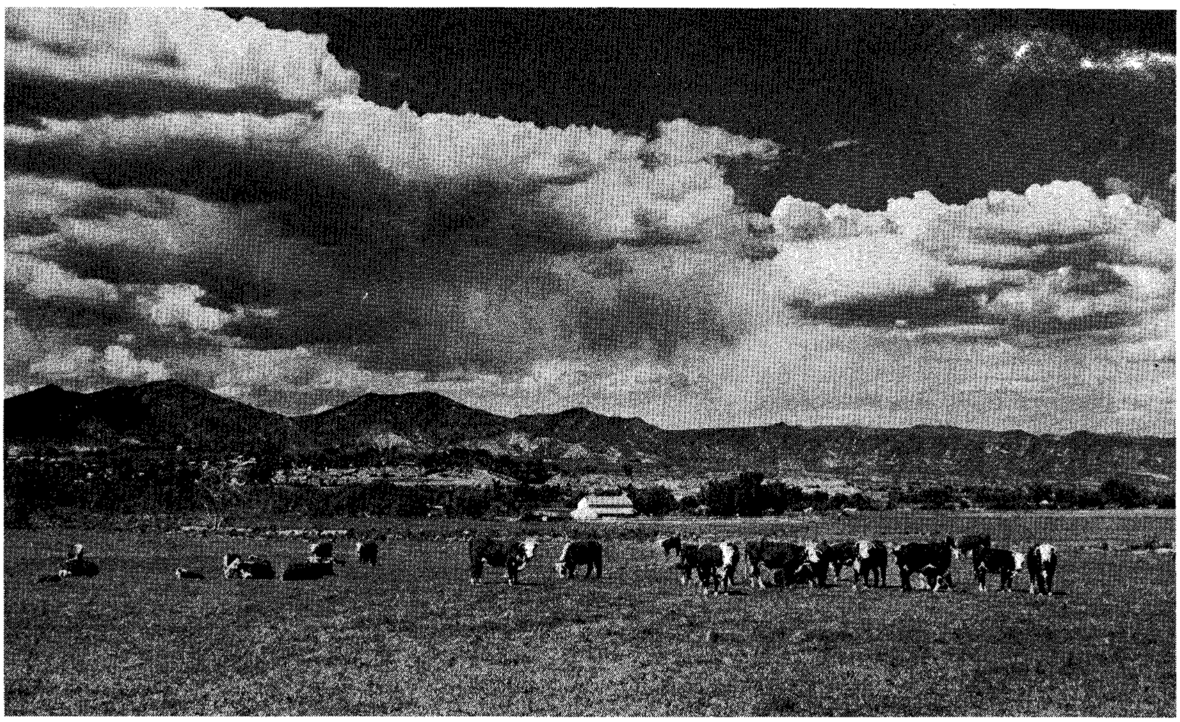
VALUE OF AGRICULTURE SALES BY CATEGORY
1964



U.S. CENSUS OF AGRICULTURE
BY ECONOMIC REGION
TOTAL SALES $110.5 MILLION

The proportion of total sales attributed to irrigated land in the region is as follows: All fruits and vegetables are irrigated crops. About 65 percent of the field crops and field grains is produced on irrigated croplands. With the possible exception of protein supplements, most of the feed inputs to dairy products is produced on irrigated land within the region. In addition to hay, corn silage, feed grains, and wheat fed to livestock, irrigated pasture land and crop aftermath met approximately 18 percent of the total pasture and range requirements measured on an AUM basis[1/] for cattle and sheep in the region. Of the total feed (total digestible nutrients) ingested by livestock in the region in 1965, 43 percent was produced on irrigated lands and 57 percent was from dry land rotation pasture and rangeland.

Total value of irrigated cropland production in the Upper Colorado Region is $61,441,000 based on 1965 prices. The value of production by subregions is $17,734,000 for the Green River, $33,056,000 for the Upper Main Stem and $10,651,000 for the San Juan-Colorado.



Irrigated pasture provides feed for range cattle in the Upper Colorado Region.

1/ Animal unit month. This represents the amount of feed needed to keep a beef cow for 1 month. Thus, a beef cow is 1 animal unit. A sheep is considered to be 1/5 of an animal unit.

Water Rights

The use of water in the Upper Colorado Region is governed by a series of documents known as "The Law of the River" and State water laws. "The Law of the River" includes the 1922 Colorado River Compact, the 1944 Mexican Water Treaty, the 1948 Upper Colorado River Basin Compact, and other compacts along with authorizing project acts and other documents. These documents govern the use of water from the Colorado River system on an international and interstate basis. (See Appendix III for a detailed coverage of these documents and State water laws.)

The right to use water within compact allotments is controlled by the States, and water rights are acquired by appropriation in accordance with State water laws. Water right laws were initiated in the basin as early as 1869 in Wyoming and 1876 in Colorado with other States following around the turn of the century. Early enactment of water laws stemmed from the rapid development of irrigation and mining and the resulting disagreements and conflicts between water users under the same ditch, canal, or river system. These early laws were the basis for establishing water use priorities and limits of use. Refinements and additions to these early laws were the basis for water codes and statutes adopted independently by all the Basin States shortly after 1900. Although the water laws have undergone periodic revision, many of the original principles are still in use. While early laws were enacted to control the use of surface water, ground water laws have since been adopted.

Although State procedures for acquiring water rights vary, many basic laws are similar. In each State water is considered the property of the public, and the right to use the water is granted only by following set procedures. These procedures normally include: (1) filing an application to appropriate water or a statement of claim, (2) constructing works necessary to divert or impound water, and (3) applying the water to beneficial use. The rights are based on the principle of prior appropriation which operates on the rule of "first in time is first in right." In general the limit of the right is based on beneficial use. Differences include variation in the amount of water per acre which may be allowed, the priority or preference applied to various uses, and variation in procedures for acquisition, adjudication, and readjudication of rights. In most States the water is not irrevocably tied to the land, and the point of diversion, nature, and place of use can be changed if other vested rights are not impaired. In Wyoming, however, the water with few exceptions is appurtenant to the land or place of original use.

PART III

IRRIGATION POTENTIAL

Land

Potentially irrigable lands in the Upper Colorado Region in addition to irrigated acreage comprise 7,058,600 acres or less than 10 percent of the total land area. The lands suitable for irrigation development are widely dispersed throughout the region. About 3,776,800 acres or 53 percent is in the San Juan-Colorado Subregion, 2,112,100 acres or 30 percent in the Green River Subregion, and 1,169,700 acres or 17 percent in the Upper Main Stem Subregion. Many of these lands, although having soil, topographic, and drainage conditions favorable for irrigation, are located where water supply is insufficient or inaccessible at the present time but may be conducive to development in the future. The potentially irrigable lands are summarized in Table 19 and are depicted on maps of irrigated and potentially irrigable land presented in Part II.

Table 19 - Summary of potentially irrigable land--1965
(Unit--1,000 acres)

Hydrologic Subregion and State	Potentially irrigable land					Nonirrigable
	Class 1	Class 2	Class 3	Class 4	Total	Class 6
Green River						
Wyoming	70.1	282.8	176.8	175.9	705.6	12,348.1
Utah	50.8	237.7	158.4	82.9	529.8	10,070.2
Colorado	46.3	392.4	260.8	177.2	876.7	5,758.5
Subtotal	167.2	912.9	596.0	436.0	2,112.1	28,176.8
Upper Main Stem						
Colorado	47.0	400.7	320.8	174.2	942.7	12,575.3
Utah	11.4	102.2	56.7	56.7	227.0	2,337.1
Subtotal	58.4	502.9	377.5	230.9	1,169.7	14,912.4
San Juan-Colorado						
Arizona	40.6	221.4	251.0	148.6	661.6	3,749.0
Colorado	12.3	115.7	75.3	42.1	245.4	3,269.1
New Mexico	70.3	773.8	1,034.8	589.7	2,468.6	3,696.2
Utah	26.4	174.2	140.5	60.1	401.2	9,749.7
Subtotal	149.6	1,285.1	1,501.6	840.5	3,776.8	20,464.0
Region by States						
Wyoming	70.1	282.8	176.8	175.9	705.6	12,348.1
Utah	88.6	514.1	355.6	199.7	1,158.0	22,157.0
Colorado	105.6	908.8	656.9	393.5	2,064.8	21,602.9
Arizona	40.6	221.4	251.0	148.6	661.6	3,749.0
New Mexico	70.3	773.8	1,034.8	589.7	2,468.6	3,696.2
Total	375.2	2,700.9	2,475.1	1,507.4	7,058.6	63,553.2

About 375,200 acres or 5 percent of the potentially irrigable land is in Class 1. These lands are suitable for continued high yields of climatically adapted crops under sustained irrigation with minimum costs of development and management.

A total of 2,700,900 acres of land or 38 percent of the potentially irrigable land is in Class 2. These lands are moderately productive or require intermediate costs for development and management because of slight to moderate limitations in land characteristics.

Approximately 2,475,100 acres or 35 percent of the potentially irrigable land is in Class 3. These are lands of restricted productivity for most crops or they require relatively high costs for development and management because of moderate to severe limitations in land characteristics.

About 1,507,400 acres or approximately 21 percent of the potentially irrigable land is in Class 4. These lands have restricted crop adaptability because of severe limitations in one or more land characteristics. These limitations include steep or irregular topography with adequate soil for high income crops such as fruit or less favorable soils adapted to low income crops such as pasture. This class also includes marginal lands with adverse soil conditions such as slowly permeable, saline, sodic, or shallow soils which adapt them only to pasture and meadow use.

Approximately 63,553,200 acres, comprising more than 90 percent of the total land area of the region, are in Class 6. These are lands with extreme limitations in land characteristics which make them unsuitable for sustained irrigation.

The specifications[1] for the above irrigation land classes are presented in Table 20.

Irrigation land classes are similar to irrigation soil classes as presented in Appendix VI with respect to permissible ranges of soil properties. The soil classes do not include consideration of on-farm land development such as clearing of brush, trees, and stones, leveling, and drainage. Also, they do not consider such economic factors affecting feasibility of irrigation development as size and shape of tracts or distribution pattern of the lands.

The complex physiography and geology of the region are principal factors governing the pattern of occurrence of the potentially irrigable lands shown on subregional maps presented previously. The lands are located in highly dissected mountainous plateaus, typified by deep canyons, river valleys, rolling ridges, and flat-topped mesas. These are bordered by mountain ranges studded with high, rugged peaks. This highly dissected landscape has been largely scoured and eroded by rivers, streams, and to

Table 20 - Land classification specifications for irrigation land classes1/

Land characteristics	Irrigation land classes				
	Class 1	Class 2	Class 3	Class 4	Class 6
Soils					All other lands not meeting criteria for irrigability
Texture (surface 12 inches)2/	Loamy very fine sand to clay loam	Loamy sand to clay	Medium sand to clay	Medium sand to clay	
Available water-holding capacity to 48 inches3/	6.0"	4.5"	3.0"	2.5"	
Effective depth (inches)4/	40	30	20	10	
Salinity ($EC_e \times 10^3$ at equilibrium with irrigation water)	4	8	12	16	
Sodic conditions5/					
Percent area affected	5	15	25	35	
Severity of problem6/	Slight	Moderate	Moderate	Moderate	
Permeability (in place--inches/hour)	0.2-5.0	0.05-5.0	0.05-10.0	No limit	
Permissible coarse fragments (percent by volume)					
Gravel	15	35	55	70	
Cobbles	5	10	7/15	7/35	
Rock outcrops (distance apart in feet)	200	100	50	30	
Soil erosion8/					
Topography (or land development items)9/					
Stone for removal (cubic yards per acre)	10	25	50	70	
Slope (percent)					
Moderately to severely erodible	2	5	10	20	
Slightly erodible	4	10	20	25	
Surface leveling or tree removal (amount of cover)	Light	Medium	Medium heavy	Medium heavy	
Irrigation method10/					
Drainage					
Soil wetness					
Depth to water table during growing season with or without drainage					
Loam or finer	60"	40"	20"	10"	
Sandy	50"	30"	20"	10"	
Surface drainage	Good	Good	Restricted	Good	
Depth to drainage barrier in feet	7	6	5	1.5	
Air drainage11/	No problem	Minor	Restricted	Restricted	

1/ Specifications are representative of conditions after land is developed for irrigation. Each individual factor represents a minimum requirement, and unless all other factors are near optimum two or more interacting deficiencies may result in land being placed in lower class or designated class 6--nonarable.

2/ Finer textures may be required than those indicated for each class in areas subject to critical hot spells or wind; coarser textures permissible for specific crop and climatic conditions.

3/ In areas of very warm growing season 3 inches may be required for class 4 and in cold areas as little as 5 inches may be permitted for class 1.

4/ Depth of 60 inches or more required for class 1 where deep-rooted crops are important in crop pattern.

5/ More extensive and severe sodic problems may be tolerated in areas of wide crop adaptability.

6/ Severity of problem: Slight--ESP less than 15 percent or less than 25 percent if dominated by nonswelling clays, moderate--ESP less than 20 percent or less than 30 percent if clay minerals favorable, severe--ESP less than 30 percent; with certain soil minerals may range above 50 percent as measured by usual techniques.

7/ May range above 50 percent in subsoil for certain crops if surface soil favorable.

8/ Soil erosion--for all classes: severely eroded soils will be downgraded one class. Less severely eroded soils may be downgraded one class, depending on other conditions.

9/ Special crop and management practices may justify exceeding the limits for stone removal or slope in class 4; irregularity of slope may necessitate downgrading of class unless deficiency is compensated for by possibility of sprinkler irrigation.

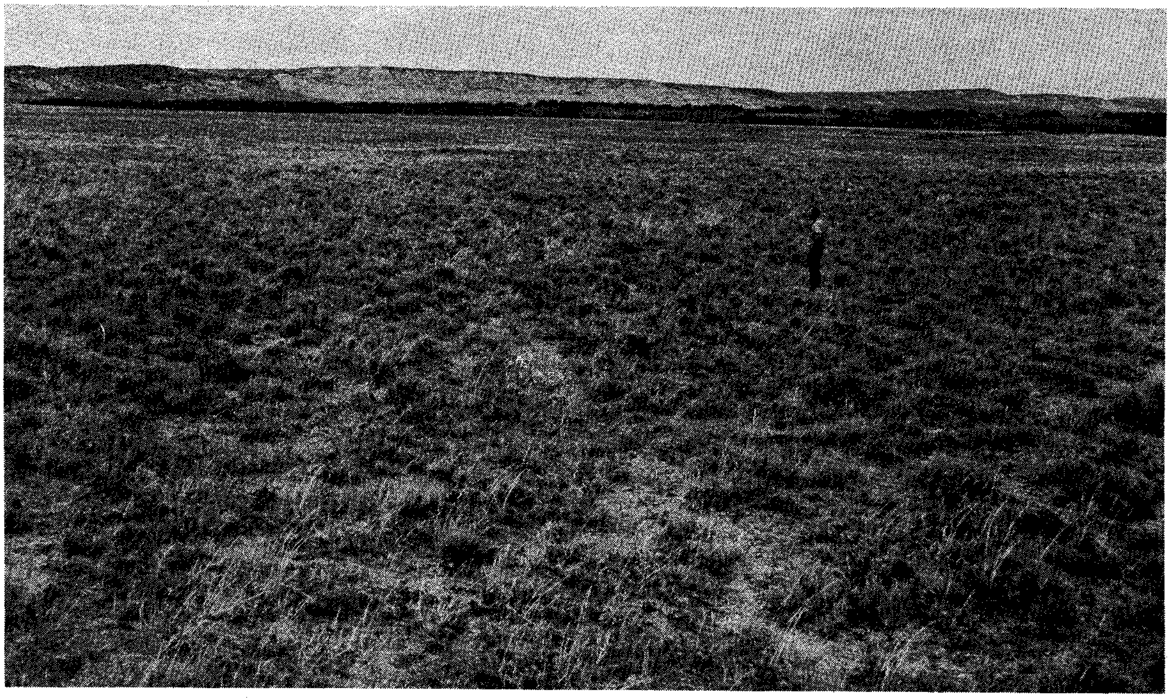
10/ Irrigation method--lands unsuited to gravity irrigation where land grading would permanently reduce soil fertility below irrigable limits or exceed permissible costs, or field pattern too complex, may be considered for sprinkler irrigation. Land must meet other requirements for irrigability. Designated by "S," as for example, class 3S.

11/ Air drainage a consideration mainly in areas adapted to fruit or to early or late vegetables.

some extent by glaciation. Such action has given rise to an assemblage of land forms of variable sizes, shapes, and topographic positions.

Except for the mountain ranges of igneous rocks, the basin is generally underlain by sandstone, mudstone, and shale composing the parent rock from which the soil-forming material has been derived. Four general types of soil are found: (1) alluvial soils of stream-deposited materials, (2) glacial soils in the form of terraces or outwash plains derived partly from granites and other igneous materials of the higher mountains, (3) residual soils formed in place by the weathering of surface rocks but altered in places through deposition from higher residual lands, and (4) aeolian or wind-deposited soils.1/

Most lands suitable for irrigation in the upper valleys of the region are composed of alluvial soils confined to the bottom lands, terraces, and valley fills. Those that are not presently irrigated have the highest potential for development as they are generally located in a position where water supply is or can be made available at costs presently conducive to development. A portion of these lands occurs within irrigation projects that either have been authorized or have been found feasible for construction of project works for delivery of water.



Potentially irrigable land within an authorized Federal project in the Green River Subregion. This rangeland is to be developed for irrigation.

1/ Refer to Appendix VI for detail on soils.

The alluvial soils in the river or stream valleys are high in organic matter and are inherently fertile. There is a notable variation in their source, textural composition, profile development, permeability, and drainability. With the exception of small localized areas, they are free from harmful accumulations of salt and alkali. Most have good natural drainage provided by coarse-textured soil over gravelly subsoil and a moderate slope. The depth and texture of the soil, water table levels, size and shape of tracts, and the amount of rock on the surface usually determine the suitability of alluvial lands for irrigated agriculture.

Broader expanses of potentially irrigable land occur in more remote positions on intervening ridges and benchlands separating the upper stream valleys. Many of these lands lie above limiting elevations for delivery of water from adjacent streams by gravity and therefore require higher costs for irrigation development. Moderately shallow residual or aeolian soils on sedimentary rock and moderately to steeply rolling terrain are characteristic of these lands. Shallow lands overlying a barrier substratum will have a high drainage requirement when developed for irrigation.

Typical reddish-brown aeolian soils on undulating topography being dry farmed in the San Juan-Colorado Subregion. Planned Federal irrigation project will provide dependable water supply for these lands for increased production of diversified crops.

Mesas, plateaus, and upland plains dissected by occasional deeply entrenched canyons of the river system characterize the lower (desert) portion of the region. Alluvial soils of canyon and valley bottoms and aeolian or residual soils on more remote mesas and plateaus are the most suitable for irrigation where the soil is of sufficient depth and slopes are gentle to moderate. Vast areas of residual soils that are too shallow or too saline for consideration for agricultural use occur in these desert areas. Topographically, many of the canyon lands bordering the Colorado River and its tributaries are too deeply dissected and eroded for agricultural consideration. Aeolian soils, which are most extensive in the San Juan-Colorado Subregion, are typically coarse to medium textured and occur on a rolling ridge- and swale-type terrain. The narrow swales and other topographic lows are not suitable for irrigation because of an unrectifiable drainage deficiency under irrigation.

Potentially irrigable lands range in elevation from 3,100 to 9,500 feet. The northern portion and other mountainous areas are characterized by short, warm summers and long, cold winters. The southern portion and desert areas have long, moderately hot summers and mild winters. The length of the growing season varies from about 70 days in the higher elevations and northern portion of the region to more than 200 days in the lower elevations and southern part of the region. The latter will permit a wide crop adaption and increased yields of adapted crops whereas the former will restrict cropping mainly to meadow hay and pasture, similar to the present cropping pattern on irrigated lands.

Irrigation practices on newly developed irrigable lands will be comparable to those now existing on closely associated irrigated lands in the region, as discussed in Part II. It is anticipated that gravity irrigation methods will improve and the use of sprinklers will increase as additional lands are developed for irrigation in the future. In this report sprinklers are not included in the development and cost tables. It will be essential not only to provide drainage for newly developed areas but also to maintain production on presently irrigated lands by providing additional drainage works, as discussed in Part IV.

Water

Requirements

Water requirements per acre for potentially irrigable land are expected to be essentially the same as those for presently irrigated lands. Current water requirements reflect the wide variation in climatic conditions, soil and topographic conditions, irrigation practices, and the mix of crops grown. Since many of the potentially irrigable lands are interspersed and adjacent to irrigated lands, climatic and physical conditions will be similar. It is also expected that irrigated land will continue to be used principally for production of crops which support the livestock industry. Although improved technology in use of water for irrigated agriculture is taking place, the effect on the water actually consumed by the crops is expected to be small.

Irrigation requirements for crops adapted to the region are tabulated and discussed in Part II of this appendix in the section "Water Utilization for Irrigation." Estimates of irrigation requirements based on the current cropping pattern and a full water supply are shown in Table 21. The range of values in each subregion reflects the variation in climate and physical conditions. In general, irrigation requirements are lowest in the higher areas where the growing season is shorter and the precipitation greater as compared with lands at lower elevations.

Table 21 - Summary of irrigation water requirements for potentially irrigable lands (consumptive use minus effective precipitation)
(Unit--acre-feet per acre)

Hydrologic Subregion	Irrigation requirement
Green River	0.90-1.61
Upper Main Stem	1.05-1.97
San Juan-Colorado	1.04-1.97

In applying the above requirements it should be recognized that the figures represent water that is consumed by crops. Diversion requirements from the streams are two to three times the amounts shown to allow for seepage losses in canals and laterals and farm losses, including water percolating through the root zone to ground water reservoirs and surface runoff. With the exception of water consumed by areas incidental to irrigation or evaporated from irrigation reservoirs, water applied in excess of crop use will return to the river system and be available for use at other downstream locations. (Projection of quality of water being returned for use downstream is covered in Part IV of this appendix.)

Availability

The average annual undepleted flow at Lee Ferry, the outlet of the region, is estimated at 14.872 million acre-feet over the 1914-65 period. Table 22 shows the average annual outflow by subregions for the 1914-65 period based on the undepleted water supply and shows the residual flow reflecting the 1965 level of development. Further details concerning water resource availability are presented in Appendix V, Water Resources.

Table 22 - Water supply available, Upper Colorado Region, in 1965
(Unit--1,000 acre-feet)

	Green River Subregion	Upper Main Stem Subregion	San Juan-Colorado Subregion	Upper Colorado Region
Undepleted water supply (1914-65)	5,460	6,806	2,606	14,872
Level of depletions (1965)	993	1,397	418	2,808
Modified flow (1914-65) (excluding Main Stem evaporation)	4,467	5,409	2,188	12,064
Main Stem Reservoir evaporation normalized (1965)	67		576	643
Residual flow	4,400	5,409	1,612	11,421

Large variations in annual discharge occur from year to year due to yearly variations in precipitation, and over periods of years due to long-term climatic trends. The average annual measured discharge of the Colorado River at Lee Ferry was 12,426,000 acre-feet for the 52-year period 1914-65, with extremes of 21,894,000 acre-feet in 1917 and 4,396,000 acre-feet in 1934. For the 17-year period 1914-30, the average discharge was 15,919,000 acre-feet per year, while for the 26-year dry cycle 1931-56, the average discharge was 11,183,000 acre-feet per year. These are residual flows reflecting upstream depletions approximating 1,800,000 acre-feet in 1914 increasing to about 2,800,000 acre-feet in 1962. By 1965 the depletion was at the 3,451,000-acre-foot level, primarily due to the increased evaporation potential at the main stem reservoirs.

As mentioned under "Water Rights" in Part II, the development of water in the Upper Colorado Region is governed by compacts, documents, and water laws, collectively referred to as "The Law of the River." These documents and the restraints imposed are discussed in detail in Appendix III, Legal and Institutional Environments. The availability of water for development in the Upper Colorado Region is restricted by the Colorado River Compact which specifies that an aggregate of 75 million acre-feet over a 10-year period will be released for use in the Lower Colorado River Basin.

Within the limits of institutional restraints, development of irrigation water supplies is dependent, to a large extent, on development of regulatory storage. Current developments on tributary streams fully utilize available supplies during the late summer months, particularly during years of subnormal runoff. Availability of new irrigation water supplies is thus dependent on provision of seasonal storage regulation and regulation to smooth out the variation in annual flows.

PART IV

FUTURE DEMAND

General

Production of more forage crops by irrigation is needed to meet the regionally interpreted OBERS projections of population growth in the region. Opportunities exist for increasing irrigation development in the region to meet the production needs. Some 7 million acres of potentially irrigable lands requiring a full water supply could be developed for irrigation and over one-half million acres of the 1,621,500 acres of presently irrigated land are in need of supplemental water.

Several important forces that affect the future agricultural economy of the region were explicitly considered in developing the projections of demand for agricultural products. Among these were the following: population growth; rising per capita disposable income, changes in consumer tastes, and their influence on per capita uses of agricultural products; industrial and other uses of agricultural commodities; livestock feeding efficiencies and composition of the feed ration; and the foreign market for agricultural products.

The following assumptions specify the conditions under which projected crop yields and livestock feeding efficiencies were estimated.

1. General economic stability will prevail during the projection period. No major war or economic recession will occur. A high level of economic activity and nearly full employment will be maintained. This does not rule out periodic cyclical adjustments in economic activities.

2. Government programs are expected to exist during the projection period; however, market forces are assumed to be the dominant factor in allocation of resources. This implies a gradual decrease in production restraints and greater market influence during the projection period.

3. Government programs in extension and research will continue at present levels and the average level of management of all farmers and ranchers will continue to improve.

4. Marketing and transportation facilities will be adequate to handle the projected agricultural production.

5. Current normal price relationships among inputs, and between inputs and outputs, will continue throughout the projection period.

6. Credit availability, tenure arrangements, zoning, and taxation policies will not interfere with agricultural adjustments, including farm consolidation or purchases of new technologies.

7. Water, fertilizer, insecticides, etc., required for crop production and feeds of various types, etc., needed for production of livestock and livestock products will be available at current normal price relationships.

8. The quality of water for irrigation in the three target years (1980, 2000, and 2020) will be suitable for irrigation.

Domestic consumption of food commodities for each target date was projected by applying projected per capita consumption rates to the expected increase in population. This was the principal determinant of future production. Quantities were projected which represent industrial and other uses of agricultural products. These were added to domestic consumption to derive projections of total domestic production requirements. Net demand from the foreign market was added to these requirements. Per capita consumption was assumed in the study to remain unchanged after 1980 although rates of change in production factors are different from those for population.

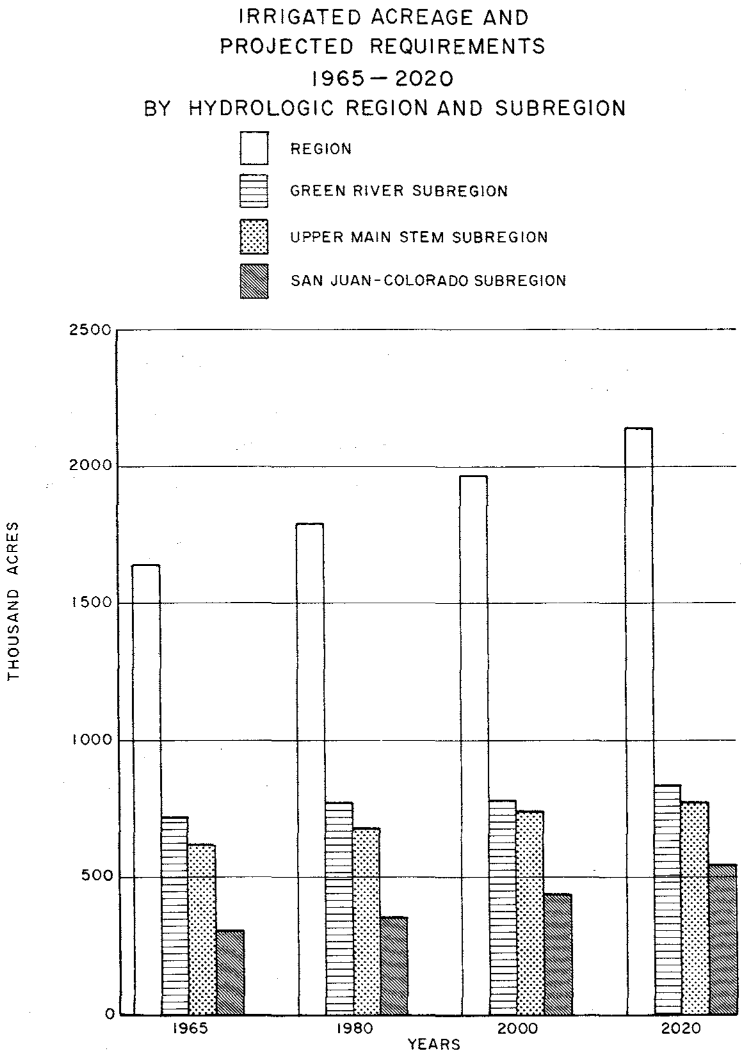
The "Regional Interpretation" of OBERS determined crop production needs consistent with livestock output projections. The task force assigned to this study concluded that livestock output based upon projections of population and per capita consumption were more reliable and important than the crop output projections. It then determined the projected feed crop production sufficient to produce the projected livestock output. Allowance was made for imported protein supplement and some feed grains. In summary, an attempt was made to get consistent projections of feed and forage production (hay, pasture, range, corn silage) and livestock output. These were then used to determine projected irrigated acreage requirements.

The projections represent an economy where agricultural production is in balance with estimated future demand. Future demand draws on numerous analyses and appraisals, some based on formal statistical models, others on trends and a knowledge of factors affecting them. Accordingly, the projections consider important factors which will shape the growth and development in agriculture in years ahead.

The comprehensive framework plan is based upon identified needs and requirements, using available resources to meet regionally interpreted OBERS objectives through the year 2020. This plan is described in detail and then is followed by alternative plans that reflect emphasis on different uses for the available water supplies and resources.

Projections of Demand for Irrigated Land

The irrigated acreages by crops for 1965 are presented in Part II under the heading "Contribution of Irrigation to Region's Economy." The acreages of various crops required to meet OBERS projections for 1980, 2000, and 2020 for the three subregions in the Upper Colorado Region are shown in Tables 23, 24, and 25 and illustrated below.



Total acreages of irrigated cropland needed to meet the economic demands of the region were projected to increase from 1,621,500 to 2,122,100 acres, or by 500,600 acres, during the period 1965 to 2020. An additional 86,800 acres of potentially irrigable land will be needed to replace presently irrigated land expected to be abandoned or converted to urbanization, reservoir inundation, recreation, and interstate highway right-of-way. Anticipated losses are shown in Table 26.

Table 23 - Crop distribution requirements--1980[1]
(Unit--1,000 projected irrigated acres)

Crop	Hydrologic Subregion Green River	Upper Main Stem	San Juan-Colorado	Total
Hay				
Alfalfa	109.7	129.1	79.5	318.3
Other hay				
Improved	52.8	37.8	11.4	102.0
Native	163.3	83.8	11.4	258.5
Subtotal	325.8	250.7	102.3	678.8
Pasture				
Rotation (cropland)	143.0	110.4	76.0	329.4
Permanent (noncropland)	115.8	88.3	41.8	245.9
Other (noncropland)	62.8	54.6	45.4	126.8
Subtotal	321.6	253.3	163.2	738.1
Corn silage	8.6	20.3	12.5	41.4
Feed grains				
Oats	15.9	21.5	8.8	46.2
Barley (excludes Moravian)	11.8	5.3	7.7	24.8
Corn	.7	16.1	4.2	21.0
Subtotal	28.4	42.9	20.7	92.0
Other grains				
Barley (Moravian)		23.2	2.7	25.9
Wheat	18.5	3.5	18.7	40.7
Subtotal	18.5	26.7	21.4	66.6
Other crops				
Orchard	.5	14.7	3.1	18.3
Sugar beets	1.8	16.2		18.0
Dry beans		8.6	1.5	10.1
Truck crops	.3	1.8	1.8	3.9
Potatoes	.1	.9	.8	1.8
Subtotal	2.7	42.2	7.2	52.1
Idle land	51.8	34.9	37.9	124.6
Total	757.4	671.0	365.2	1,793.6

1/ Upper Colorado Region Task Force data.

Table 24 - Crop distribution requirements--2000[1]
(Unit--1,000 projected irrigated acres)

Crop	Hydrologic Subregion: Green River	Hydrologic Subregion: Upper Main Stem	Hydrologic Subregion: San Juan-Colorado	Total
Hay				
Alfalfa	110.5	131.3	103.2	345.0
Other hay				
Improved	56.5	35.0	10.5	102.0
Native	163.3	83.8	11.4	258.5
Subtotal	330.3	250.1	125.1	705.5
Pasture				
Rotation (cropland)	178.6	139.0	121.2	438.8
Permanent (noncropland)	115.2	87.4	41.4	244.0
Other (noncropland)	62.4	54.0	45.1	161.5
Subtotal	356.2	280.4	207.7	844.3
Corn silage	11.6	22.5	14.8	48.9
Feed grains				
Oats	13.1	15.6	6.3	35.0
Barley (excludes Moravian)	11.5	8.7	12.0	32.2
Corn	.7	16.8	5.6	23.1
Subtotal	25.3	41.1	23.9	90.3
Other grains				
Barley (Moravian)		34.1	6.4	40.5
Wheat	17.4	4.0	17.5	38.9
Subtotal	17.4	38.1	23.9	79.4
Other crops				
Orchard	.5	14.7	3.1	18.3
Sugar beets	1.8	22.8		24.6
Dry beans		9.6	2.8	12.4
Truck crops	.3	1.8	1.8	3.9
Potatoes	.1	1.0	.8	1.9
Subtotal	2.7	49.9	8.5	61.1
Idle land	50.9	34.9	38.9	124.7
Total	794.4	717.0	442.8	1,954.2

1/ Upper Colorado Region Task Force data.

Table 25 - Crop distribution requirements--2020[1/]
(Unit--1,000 projected irrigated acres)

Crop	Hydrologic Subregion Green River	Upper Main Stem	San Juan-Colorado	Total
Hay				
Alfalfa	111.2	133.6	127.0	371.8
Other hay				
Improved	60.2	32.1	9.7	102.0
Native	163.3	83.8	11.4	258.5
Subtotal	334.7	249.5	148.1	732.3
Pasture				
Rotation (cropland)	214.1	167.6	166.5	548.2
Permanent (noncropland)	114.6	86.5	41.1	242.2
Other (noncropland)	62.0	53.4	44.7	160.1
Subtotal	390.7	307.5	252.3	950.5
Corn silage	14.6	25.0	16.7	56.3
Feed grains				
Oats	7.9	8.5	3.3	19.7
Barley (excludes Moravian)	11.6	12.1	16.3	40.0
Corn	.7	18.7	7.2	26.6
Subtotal	20.2	39.3	26.8	86.3
Other grains				
Barley (Moravian)		45.0	10.0	55.0
Wheat	20.0	5.0	20.0	45.0
Subtotal	20.0	50.0	30.0	100.0
Other crops				
Orchard	.5	14.7	3.1	18.3
Sugar beets	2.0	31.0		33.0
Dry beans		10.4	4.1	14.5
Truck crops	.3	1.8	1.8	3.9
Potatoes	.1	1.0	.9	2.0
Subtotal	2.9	58.9	9.9	71.7
Idle land	50.0	35.0	40.0	125.0
Total	833.1	765.2	523.8	2,122.1

1/ Upper Colorado Region Task Force data.

Table 26 - Loss of irrigated cropland acreage (1965-2020)
(Unit--1,000 acres)

Hydrologic Subregion	Urbanization	Interstate highway rights-of-way	Reservoir inundation	Abandonment	Recreation	Total
Green River	11.5		3.4	13.2	1.8	29.9
Upper Main Stem	15.5	2.5	6.0	8.5		32.5
San Juan-Colorado	15.2			9.2		24.4
Total	42.2	2.5	9.4	30.9	1.8	86.8

Thus to satisfy OBERS requirements for irrigation in the region, a total of 587,400 acres of potentially irrigable land, including approximately 492,000 acres of existing range and forest land and 95,000 acres presently dry farmed, will need to be developed by 2020. In addition, 421,100 acres of short-supply irrigated lands will need to be provided supplemental water. These acreages are shown by time frames, subregions, and States in Table 27.

Table 27 - Projected new irrigation development and presently irrigated land to receive supplemental water
(Unit--1,000 acres)

Hydrologic Subregions and States	Potentially irrigable land[1/]				Presently irrigated land			
	1980	2000	2020	Total	1980	2000	2020	Total
Green River								
Colorado	15.7	5.3	6.2	27.2	5.9	7.2	6.0	19.1
Utah	8.2	1.0	23.2	32.4	102.6			102.6
Wyoming	34.9	42.3	14.0	91.2	59.0	26.0	10.0	95.0
Subtotal	58.8	48.6	43.4	150.8	167.5	33.2	16.0	216.7
Upper Main Stem								
Colorado	60.4	64.1	53.8	178.3	59.2	40.1	27.2	126.5
Utah			1.0	1.0			2.0	2.0
Subtotal	60.4	64.1	54.8	179.3	59.2	40.1	29.2	128.5
San Juan-Colorado								
Arizona								
Colorado	30.0	40.6	15.0	85.6	48.8	5.0	2.0	55.8
New Mexico	53.3	37.9	37.0	128.2	5.5			5.5
Utah		18.7	24.8	43.5		7.0	7.6	14.0
Subtotal	83.3	97.2	76.8	257.3	54.3	12.0	9.6	75.9
Total	202.5	209.9	175.0	587.4	281.0	85.3	54.8	421.1

1/ Includes 500,600-acre total increase required by OBERS plus an additional 86,800 acres of new land needed to replace presently irrigated land abandoned or converted to other uses.

OBERS projections of total irrigated acreage requirements by 2020 in the region approximate the 1965 level of development plus acreage included in authorized Federal and estimated non-Federal future developments. In comparing OBERS projections with scheduled Federal and estimated non-Federal developments, differences occur primarily with regard to irrigated acreage requirements for the intervening target years, 1980 and 2000, and within the three subregions.

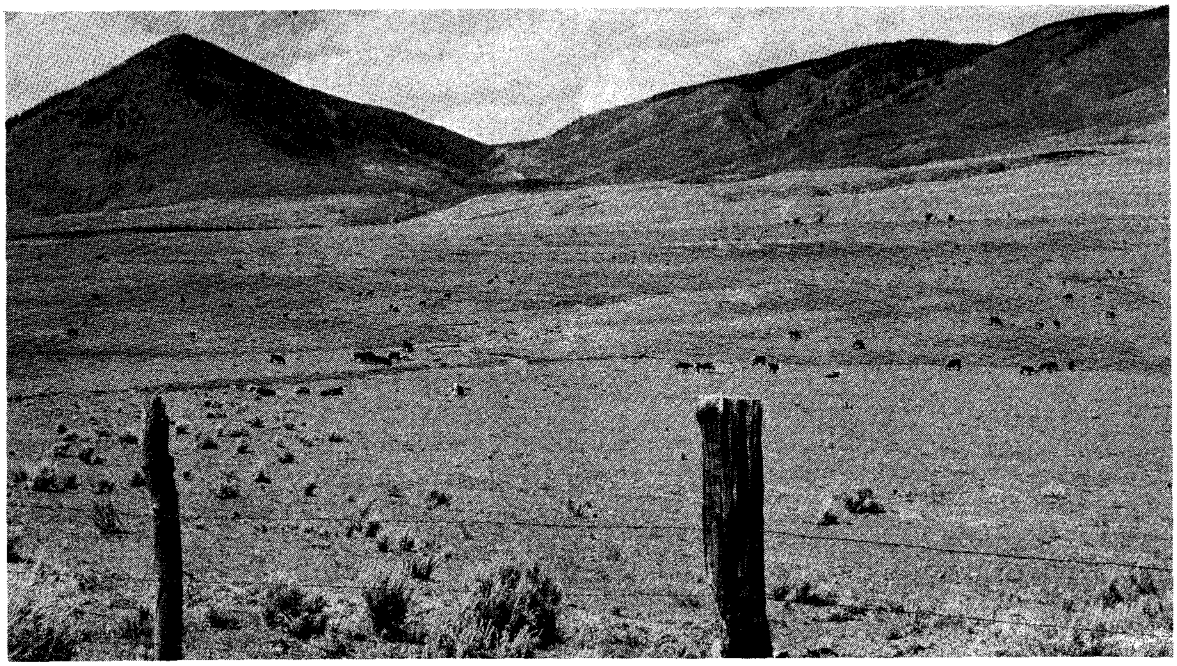
This fallow land will receive a full water supply under an authorized Federal irrigation project in the San Juan-Colorado Subregion of southwestern Colorado.

Projections of Water Requirements

Diversions

Additional water will be required for development of the 587,400 acres of new land. A total of 421,100 acres of the 549,300 acres of existing irrigated lands which are now short of a full water supply will receive a supplemental supply.

In the past, adequate records have not been kept of the number of diversions or the amount of water diverted. This situation will need to be rectified and is a prerequisite to efficient water management.



Cattle grazing on potential meadow land in high mountain valley. These lands could be provided with a full water supply.

Storage provided by a reservoir upstream will alleviate a shortage of late-season water for these irrigated lands.

As the demand for water increases, the value of water will also increase and changes will be necessary in handling the available water. Many of the smaller irrigation companies, especially those which have duplicating and overlapping facilities, will need to be consolidated. This will lessen the total number of diversions in relation to the amount of land irrigated. Consolidation will also help to increase the overall irrigation system efficiencies. The development of new land and water supplies will require additional diversions; however, the number of diversions will be proportionally less than compared with the amount of irrigated land under existing systems and facilities.

Return flows

Potentially irrigable lands are scattered throughout the subregions, much the same as presently irrigated areas. Since most water originates at higher elevations, return flows from irrigation systems in the upper areas will be reused by lower outlying areas. This process of using return flows will generally be repeated many times before the water is eventually consumed or returns to the stream below any possible use in the region.

Crop consumptive use

Many factors influence the amount of water consumed by irrigated crops. Included are climate, type of crop, plant growth characteristics, and water management. More detailed information on these factors is presented in Part II of this appendix. For estimation purposes, the projected rates of consumptive use by crops will remain essentially the same as those tabulated under present status (refer to Table 8, Part II). The most significant change will result from improved water management in those areas where an adequate water supply will be provided for the short supply lands.

Adequacy of supply

The supply of water in the region is adequate to meet the projected irrigation water requirements. This includes a full water supply for 587.4 million acres of new land and supplemental water for 421,100 acres of presently irrigated land with varying degrees of short water supply. Even though the region's water supply is physically adequate to meet the irrigation needs, many other constraints such as land ownership, political boundaries, water rights and compacts, water exports from the region, and the rapidly growing requirements for municipal and industrial supply and for outdoor recreation, including fish and wildlife, will need to be resolved before projected development becomes a reality.

Depletions

Present on-site water depletions by irrigated land, related incidental use, and irrigation reservoir evaporation amount to about 2.128

million acre-feet annually. Projected demands for irrigation will increase the annual depletions to about 3.294 million acre-feet by the year 2020. This is 50.5 percent of the total projected on-site depletion for all uses in the Upper Colorado Region. Table 28 includes projected irrigated land acreage and related water depletions for the target years 1980, 2000, and 2020. The 3.294 million-acre-foot water depletion for irrigation includes 2,707,000 acre-feet in irrigation consumptive use, 187,000 acre-feet in irrigation reservoir evaporation, and 400,000 acre-feet in incidental use on water-consuming noncropped areas.

Table 28 - Projected on-site water depletions by irrigated land (new and supplemental), incidental use, and irrigation reservoir evaporation--Framework Plan

Hydrologic subregion and state	1980			2000			2020		
	Irrigated land (1,000 acres)		Water depletions (1,000 ac.-ft.)	Irrigated land (1,000 acres)		Water depletions (1,000 ac.-ft.)	Irrigated land (1,000 acres)		Water depletions (1,000 ac.-ft.)
	Total 1/	Supplemental		Total 1/	Supplemental		Total 1/	Supplemental	
Green River									
Colorado	128.7	5.9	132.0	130.3	13.1	139.0	134.9	19.1	147.0
Utah	287.3	102.6	518.0	284.6	102.6	516.0	305.8	102.6	572.0
Wyoming	341.5	59.0	334.0	379.5	85.0	407.0	392.5	95.0	428.0
Subtotal	757.5	167.5	984.0	794.4	200.7	1,062.0	833.2	216.7	1,147.0
Upper Main Stem									
Colorado	662.8	59.2	1,064.0	709.4	99.3	1,153.0	757.2	126.5	1,216.0
Utah	8.2		14.0	7.6		13.0	8.0	2.0	17.0
Subtotal	671.0	59.2	1,078.0	717.0	99.3	1,166.0	765.2	128.5	1,233.0
San Juan-Colorado									
Arizona	10.0		7.0	9.4		8.0	9.4		9.0
Colorado	211.7	48.8	283.0	247.8	53.8	341.0	259.8	55.8	360.0
New Mexico	104.2	5.5	245.0	139.2	5.5	329.0	174.2	5.5	411.0
Utah	39.2		56.0	46.4	7.0	76.0	80.3	14.6	134.0
Subtotal	365.1	54.3	591.0	442.8	66.3	754.0	523.7	75.9	914.0
Region									
Arizona	10.0		7.0	9.4		8.0	9.4		9.0
Colorado	1,003.2	113.9	1,479.0	1,087.5	166.2	1,633.0	1,151.9	201.4	1,723.0
New Mexico	104.2	5.5	245.0	139.2	5.5	329.0	174.2	5.5	411.0
Utah	334.7	102.6	588.0	338.6	109.6	605.0	394.1	119.2	723.0
Wyoming	341.5	59.0	334.0	379.5	85.0	407.0	392.5	95.0	428.0
Total	1,793.6	281.0	2,653.0	1,954.2	366.3	2,982.0	2,122.1	421.1	3,294.0

1/ Total includes new and supplemental irrigated land and idle land not irrigated in an average year.

Projections of Water Quality

The dilution effect of intervening streamflows immediately below irrigation projects plus the stabilization of base flows through reservoir operation will help maintain the overall quality for reuse of water for irrigation developments with the Upper Colorado Region. Development of the 587.4 million acres of potentially irrigable land and the effects of new stream depletions, however, will result in significantly larger increases in salinity concentrations of the Colorado River for reuse by irrigated agriculture in downstream areas of the Lower Colorado Region. Based on the OBERS level of development projected to 2020 and without an improvement program, the Water Quality, Pollution Control, and Health Factors Work Group projected total dissolved solid concentrations of 750 mg./l. in the Green River at Green River, Utah (a 61-percent increase over 1965); 1,300 mg./l. in the San Juan River near Bluff, Utah (a 184-percent increase); and 920 mg./l. in the Colorado River at Lees Ferry (a 57-percent increase). Data for these and other monitoring stations are shown in Table 29.

Table 29 - Projected concentrations of total dissolved solids in streams with and without a salinity improvement program--Framework Plan (mg/l)

Location	1965	1980		2000		2020		Percent change 1965-2020	
		Without program	With program	Without program	With program	Without program	With program	Without program	With program
Colorado River near Cisco, Utah	647	730	520	800	490	840	520	+30	-20
Green River at Green River, Utah	465	540	520	690	520	750	560	+61	+20
Colorado River below confluence with Green River	576	660	400	770	510	820	550	+42	-5
Colorado River above confluence with San Juan River	610	700	430	830	560	880	600	+44	-2
San Juan River near Bluff, Utah1/	457	680	680	960	960	1,300	1,300	+184	+184
Colorado River at Lees Ferry, Arizona	586	700	460	840	600	920	660	+57	+13

Based on 1941-66 period of record, considered to be a low average of water supply available in outflow records used in Appendix V.

1/ No effective program on San Juan River, as increased salinity occurs below points of use. The program is more economically feasible and effective in Upper Main Stem and Green Rivers, principal sources of salinity.

Major causes of salinity increases are the additional stream depletions for irrigation, thermal-power production, exports, and the additional salts leached from newly irrigated lands. Considering the combined effects of both salt loading and salt concentrating, approximately one-half of the increased water quality degradation will result from increased irrigation, as projected by OBERS. A comprehensive discussion of the salinity problem and its relationship to irrigated agriculture in downstream areas is presented in Appendix XV.

The water quality effects on downstream areas given above are based on extension of historical trends assuming development with and without a salinity improvement program. The Bureau of Reclamation in cooperation with the Environmental Protection Agency is conducting a research project entitled "Prediction of Mineral Quality of Return Flow Water from Irrigated Land" which is expected to provide a firmer basis for estimating the water quality effects on downstream areas. The initial study is being conducted in the Vernal Area of Utah. The research project is expected to provide a computer model to predict the salt pickup from various soil profiles. When the salt pickup from an irrigated area can be predicted and the processes by which salts are dissolved from the soil by return flows are better understood, drains and irrigation systems can be designed to reduce the volume of the salt pickup from newly developed irrigated lands.

The Bureau of Reclamation and the Environmental Protection Agency have completed a cooperative reconnaissance salinity improvement program study of the Upper Colorado River Basin. A report of this study suggesting salinity improvement projects for further study is expected to be published soon. Initial information obtained from this study led to the recent plugging of two abandoned oil test wells in western Colorado which were discharging about 62,500 tons of dissolved solids per year into the Colorado River system. (For more detail regarding salinity improvement and costs, see Appendix XV.)

Projected Ownership, Land Use, and Crop Production

Land ownership

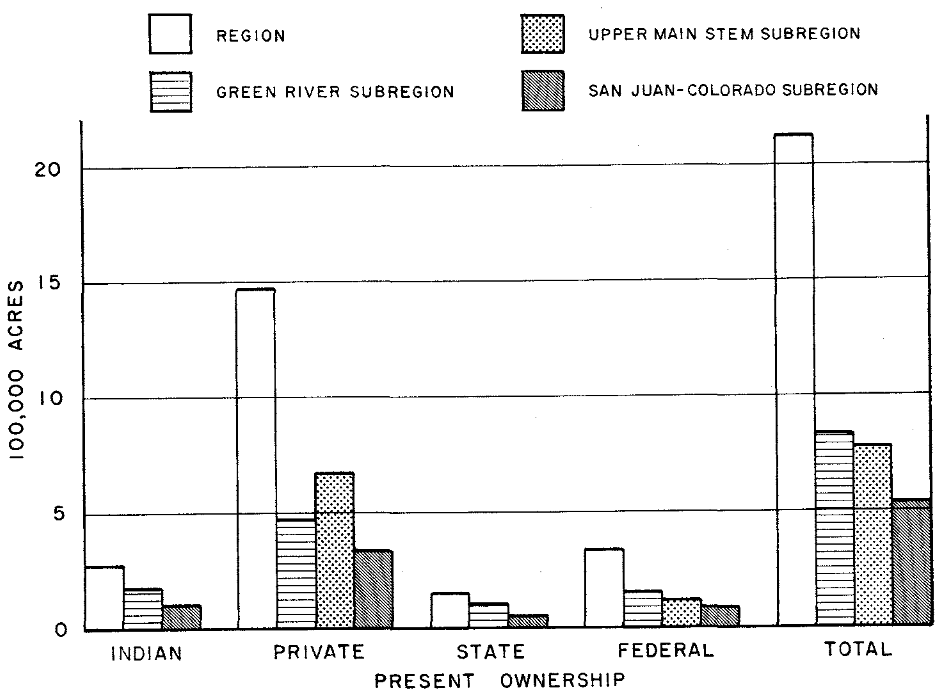
The 1,621,500 acres of irrigated land in the region (1965) are essentially all privately owned (including Indian lands). Total acreage of land required for irrigation in the region to meet future demands is 1,793,600 acres in 1980, 1,954,200 acres in 2000, and 2,122,100 acres in 2020. The present land ownership status of the latter acreage is shown by Hydrologic Subregions in Table 30 and is illustrated below.

Table 30 - Ownership of lands required for irrigation in 2020
(Unit--1,000 acres)

Hydrologic Subregion	Indian	Private	State	Federal	Total
Green River	166.7	466.6	58.3	141.6	833.2
Upper Main Stem		655.7		99.5	765.2
San Juan-Colorado	99.5	335.2	5.2	83.8	523.7
Total	266.2	1,467.5	63.5	324.9	2,122.1

Source: Project Reports, Bureau of Reclamation.

OWNERSHIP OF LAND REQUIRED
FOR IRRIGATION IN 2020
BY HYDROLOGIC SUBREGION



The most significant characteristic of the acreages shown in Table 30 is that approximately four-fifths of the land required for irrigation by 2020 is now privately owned, including individual or corporate ownerships and Indian tribal or individual ownerships held in trust by the Bureau of Indian Affairs. The remaining one-fifth of the land is in Federal and State ownership, with most of it in public domain administered by the Bureau of Land Management for multiple uses. Ownership of these lands contrasts with that of the total land area of the region, in which nearly two-thirds is in public ownership under Federal, State, or local administration.

In developing the 587.4 million acres of potentially irrigable land for irrigation, consideration will be given to the pattern of ownerships and their relationship to developed lands. Where undeveloped public lands are interspersed with privately owned irrigated lands in relatively small tracts, they may be incorporated into existing farm units through a land sale program to private individuals. This can be done under present Bureau of Land Management policy and public land laws governing disposition of public domain lands. Where large noncontiguous areas of public or privately owned lands occur, these will be included in new farm units. The transfer of land from public to private ownership will require considerable planning and coordination. Under Reclamation law, for instance, an individual cannot receive water from a reclamation project for more than 160 acres of Class 1 land or its equivalent of Class 2, 3, and 4 land. The types of farm development on Indian-owned irrigable lands may include tribal corporate, development lease, individual or combinations of these.

Land use

The projected crop distribution by hydrologic subregions in the Upper Colorado Region is shown in Tables 23, 24, and 25. In 1965 the primary uses of irrigated cropland for hay, pasture, corn silage, and feed grains accounted for 87 percent of all irrigated lands. In 2020 these same crops are expected to account for 86 percent of all irrigated lands while other crops and idle lands are expected to account for 14 percent.

The projected acreages of orchard and truck crops remain the same throughout the study period. Projected yields increased at about the same rate as projected output requirements. Both orchard and truck crops, however, account for only a minor part of the expected use of the total irrigated acreage.

Crop yields and production

Projections of crop yields and total production from irrigated land for 1980, 2000, and 2020 are shown by Hydrologic Subregions in the Upper Colorado Region in Tables 31 to 36, inclusive.

Table 31 - Projected irrigated crop yields--1980[1/] for Framework Plan

Crop	Unit per acre	Hydrologic Subregion: Green River	Upper Main Stem	San Juan-Colorado	Region
Hay					
Alfalfa	Ton	2.8	3.3	3.2	3.1
Other hay					
Improved	Ton	1.6	1.6	1.6	1.6
Native	Ton	.8	.8	.8	.8
Average	Ton	1.6	2.2	2.7	2.0
Pasture					
Rotation (cropland)	AUM	4.2	4.3	4.7	4.3
Permanent (noncrop-land)	AUM	2.0	2.0	1.8	1.9
Other (noncropland)	AUM	.7	.7	.7	.7
Average	AUM	2.7	2.7	2.8	2.7
Corn silage	Ton	13	14	17	15
Feed grains					
Oats	Bu.	60	58	47	57
Barley (excludes Moravian)	Bu.	68	74	64	68
Corn	Bu.	64	89	100	90
Other grains					
Barley (Moravian)	Bu.	NA	61	53	60
Wheat	Bu.	49	55	42	46
Other crops					
Orchard	Ton	5.9	5.9	5.9	5.9
Sugar beets	Ton	18	20		20
Dry beans	Cwt.		19	20	19
Truck crops	Cwt.	97.7	97.7	97.7	97.7
Potatoes	Cwt.	257	259	262	260

1/ Upper Colorado Region Task Force data.

Table 32 - Projected irrigated crop yields--2000[1/] for Framework Plan

Crop	Unit per acre	Hydrologic Subregion: Green River	Upper Main Stem	San Juan-Colorado	Region
Hay					
Alfalfa	Ton	3.4	3.8	3.7	3.6
Other hay					
Improved	Ton	2.0	2.0	1.9	2.0
Native	Ton	.9	.9	.9	.9
Average	Ton	1.9	2.6	3.3	2.4
Pasture					
Rotation (cropland)	AUM	5.1	5.3	5.4	5.2
Permanent (noncropland)	AUM	2.2	2.2	1.8	2.1
Other (noncropland)	AUM	.7	.7	.7	.7
Average	AUM	3.4	3.5	3.7	3.5
Corn silage	Ton	16	18	20	18
Feed grains					
Oats	Bu.	68	67	53	65
Barley (excludes Moravian)	Bu.	74	76	66	72
Corn	Bu.	85	102	111	104
Other grains					
Barley (Moravian)	Bu.		67	58	65
Wheat	Bu.	59	62	49	55
Other crops					
Orchard	Ton	7.9	7.9	7.9	7.9
Sugar beets	Ton	22	23		23
Dry beans	Cwt.		19	21	19
Truck crops	Cwt.	128.2	128.2	128.2	128.2
Potatoes	Cwt.	289	291	294	292

1/ Upper Colorado Region Task Force data.

Table 33 - Projected irrigated crop yields--2020[1] for Framework Plan

Crop	Unit per acre	Hydrologic Subregion: Green River	Upper Main Stem	San Juan-Colorado	Region
Hay					
Alfalfa	Ton	4.0	4.2	4.0	4.1
Other hay					
Improved	Ton	2.4	2.5	2.4	2.4
Native	Ton	1.0	1.0	1.0	1.0
Average	Ton	2.2	2.9	3.7	2.8
Pasture					
Rotation (cropland)	AUM	5.7	6.0	5.7	5.8
Permanent (noncropland)	AUM	2.4	2.4	1.8	2.3
Other (noncropland)	AUM	.8	.8	.8	.8
Average	AUM	4.0	4.1	4.2	4.1
Corn silage	Ton	20	22	24	22
Feed grains					
Oats	Bu.	75	75	60	73
Barley (excludes Moravian)	Bu.	77	77	67	73
Corn	Bu.	100	111	116	112
Other grains					
Barley (Moravian)	Bu.	NA	70	61	68
Wheat	Bu.	65	65	53	60
Other crops					
Orchard	Ton	9.9	9.9	9.9	9.9
Sugar beets	Ton	25	25	NA	25
Dry Beans	Cwt.	NA	20	21	20
Truck crops	Cwt.	159	159	159	159
Potatoes	Cwt.	320	320	320	320

1/ Upper Colorado Region Task Force data.

Table 34 - Total projected production from irrigated land--1980[1/] for Framework Plan

Crop	Units (1,000)	Hydrologic Subregion: Green River	Upper Main Stem	San Juan-Colorado	Total
Hay					
Alfalfa	Ton	304.0	431.0	250.7	985.7
Other hay					
Improved	Ton	86.7	59.7	17.7	164.1
Native	Ton	133.6	68.6	9.3	211.5
Subtotal	Ton	524.3	559.3	277.7	1,361.3
Pasture					
Rotation (cropland)	AUM	595.2	474.7	353.7	1,423.6
Permanent (noncropland)	AUM	227.1	173.1	75.2	475.4
Other (noncropland)	AUM	41.1	35.6	29.7	106.4
Subtotal	AUM	863.4	683.4	458.6	2,005.4
Corn silage	Ton	111.7	284.9	213.4	610.0
Feed grains					
Oats	Bu.	956.6	1,247.6	413.0	2,617.2
Barley (excludes Moravian)	Bu.	800.8	393.3	489.5	1,683.6
Corn	Bu.	43.6	1,430.7	420.7	1,895.0
Other grains					
Barley (Moravian)	Bu.		1,404.5	144.5	1,549.0
Wheat	Bu.	901.1	192.3	777.6	1,871.0
Other crops					
Orchard	Ton	2.9	86.8	18.3	108.0
Sugar beets	Ton	33.1	327.9		361.0
Dry beans	Cwt.		161.9	30.1	192.0
Truck crops	Cwt.	29.3	175.8	175.9	381.0
Potatoes	Cwt.	25.7	240.4	197.7	463.8

1/ Upper Colorado Region Task Force data.

Table 35 - Total projected production from irrigated land--2000[1/] for Framework Plan

Crop	Units (1,000)	Hydrologic Subregion: Green River	Upper Main Stem	San Juan-Colorado	Total
Hay					
Alfalfa	Ton	374.4	496.0	379.4	1,249.8
Other hay					
Improved	Ton	115.6	70.0	20.4	206.0
Native	Ton	148.5	76.2	10.3	235.0
Subtotal	Ton	638.5	642.2	410.1	1,690.8
Pasture					
Rotation (cropland)	AUM	908.0	740.1	651.4	2,299.5
Permanent (noncropland)	AUM	251.1	190.4	74.6	516.1
Other (noncropland)	AUM	45.3	39.2	32.7	117.2
Subtotal	AUM	1,204.4	969.7	758.7	2,932.8
Corn silage	Ton	185.2	402.5	294.3	882.0
Feed grains					
Oats	Bu.	894.2	1,046.3	332.5	2,273.0
Barley (excludes Moravian)	Bu.	848.5	662.7	790.6	2,301.8
Corn	Bu.	56.9	1,718.4	622.7	2,398.0
Other grains					
Barley (Moravian)	Bu.		2,277.3	369.1	2,646.4
Wheat	Bu.	1,029.4	247.1	859.5	2,136.0
Other crops					
Orchard	Ton	3.9	115.7	24.4	144.0
Sugar beets	Ton	39.5	525.5		565.0
Dry beans	Cwt.		183.2	57.8	241.0
Truck crops	Cwt.	38.5	230.8	230.7	500.0
Potatoes	Cwt.	28.9	280.2	242.8	551.9

1/ Upper Colorado Region Task Force data.

Table 36 - Total projected production from irrigated land--2020[1/] for Framework Plan

Crop	Units (1,000)	Hydrologic Subregion: Green River	Upper Main Stem	San Juan-Colorado	Total
Hay					
Alfalfa	Ton	444.8	561.1	508.0	1,513.9
Other hay					
Improved	Ton	144.6	80.3	23.1	248.0
Native	Ton	163.3	83.8	11.4	258.5
Subtotal	Ton	752.7	725.2	542.5	2,020.4
Pasture					
Rotation (cropland)	AUM	1,220.7	1,005.4	948.9	3,175.0
Permanent (noncrop-land)	AUM	275.0	207.6	74.0	556.6
Other (noncropland)	AUM	49.6	42.7	35.8	128.1
Subtotal	AUM	1,545.3	1,255.7	1,058.7	3,859.7
Corn silage	Ton	291.9	550.5	400.4	1,242.8
Feed grains					
Oats	Bu.	591.0	640.3	197.0	1,428.3
Barley (excludes Moravian)	Bu.	895.4	931.2	1,090.6	2,917.2
Corn	Bu.	71.9	2,074.8	833.9	2,980.6
Other grains					
Barley (Moravian)	Bu.		3,150.0	610.0	3,760.0
Wheat	Bu.	1,300.0	325.0	1,060.0	2,685.0
Other crops					
Orchard	Ton	4.9	145.4	30.7	181.0
Sugar beets	Ton	50.0	775.0		825.0
Dry beans	Cwt.		207.1	87.0	294.1
Truck crops	Cwt.	47.7	286.1	286.1	619.9
Potatoes	Cwt.	32.0	320.0	288.0	640.0

1/ Upper Colorado Region Task Force data.

Crop yield projections for 1980, 2000, and 2020 include consideration of new knowledge and new technology not currently available but reasonably anticipated. In the projections an attempt was made to reflect the average level of performance reasonably expected of all farm operators with the average level of management expected to prevail in each of the target years.

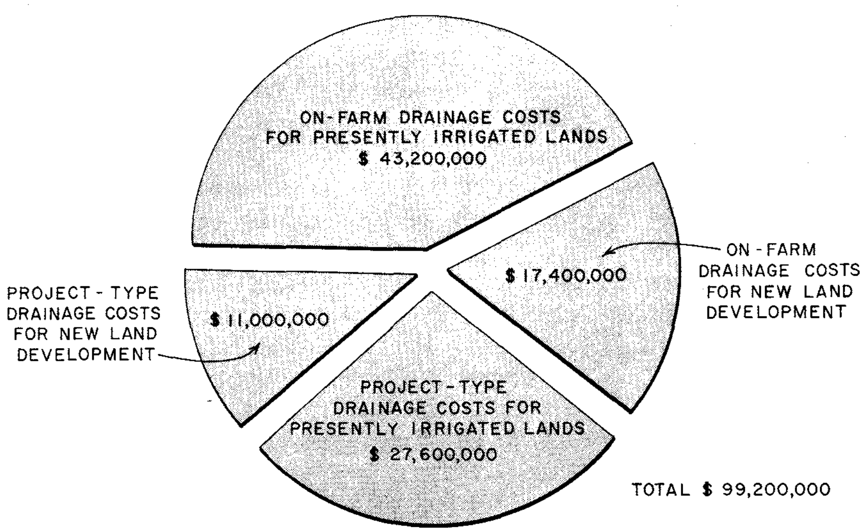
Over the entire 1965 to 2020 period the yield per acre for all hay in the region was projected to increase 64 percent from 1.7 to 2.8 tons per acre. Pasture yields in 2020 were projected to be about double 1965 yields, and corn silage yields were projected to be 1.69 times as great as 1965 base year yields. Feed grain yields were projected to be about 1.5 times as high in 2020 as in 1965. Wheat yields are expected to about double during the study period. It was recognized that increments in new technology occur irregularly and it is not possible to project in which year they may occur. It is assumed for this study, however, that increments in technology would be evenly distributed throughout the study period.

Projections of Drainage Requirements and Costs

Drainage summary

A total installation cost of nearly $100 million will be required for drainage in the Upper Colorado Region during the period of 1966 to 2020. This cost amounts to $160 for each acre of drainage-deficient land or $47 for each acre of the total acreage irrigated by 2020. The costs are depicted below.

PROJECTED COSTS FOR DRAINAGE --- 1966 – 2020



These drainage costs are summarized in Table 37 and discussed in greater detail in the following sections.

On-farm drainage

In addition to drainage already provided for presently irrigated lands in the region, as discussed in Part II, on-farm drainage will be needed on 436,900 acres of presently irrigated land in the region, requiring 4,093 miles of open ditches and tile drains for a total installation cost of $43,223,000 by 2020. One mile of on-farm drain is expected to provide relief for approximately 106 acres of drainage deficient land. The cost will be an average of $100 per acre of drainage-deficient irrigated land or $21 per acre of total land presently irrigated. This cost could be reduced significantly by more efficient use of irrigation water than has been used historically.

Projected on-farm drainage required for presently irrigated lands is shown by Hydrologic Subregions and States for each projected time period in Table 38.

An estimated 176,300 acres, comprising about 30 percent of the new land projected to be developed by 2020 in the region, will need on-farm drainage. Approximately 1,651 miles of drains will be needed to provide drainage for this additional acreage at an estimated total cost of $17,434,400 and at an average cost of $100 per acre. On-farm drains required for new lands are listed by Hydrologic Subregions and States for each projected time period in Table 39.

Project-type drainage

It is not only essential to provide on-farm drainage for presently irrigated and potentially irrigable lands to be developed for irrigation but also to provide project-type subsurface drains and outlet channels to serve a group of several farms. These drains are installed as part of Federal and occasionally non-Federal project developments which are usually not a direct cost to individual landowners.

Costs for installing approximately 1,060 miles of project-type open ditch and tile drains on 436,900 acres of presently irrigated land needing additional drainage relief will total about $27,588,500 by 2020, as shown in Table 40. This averages approximately $60 for each acre of drainage-deficient irrigated land and each mile of drain will provide an outlet or relief for about 400 acres. Project drainage requirements on presently irrigated lands in the Upper Main Stem Subregion are well below those of other subregions. This is attributed to the unusually rough topography and high elevation of much of this subregion which limit many irrigated lands to meadow hay and pasture production and to small localized seepage areas not requiring or susceptible to project-type drainage. In other areas where the terrain is more even and occurs in broader tracts, subsurface drainage costs are higher, particularly so in the San Juan-Colorado Subregion where diverse cropping requires more stringent ground water control.

Requirements for providing project drainage on 176,300 acres of drainage-deficient potentially irrigable land to be developed for irrigation in the region by 1980, 2000, and 2020 are shown in Table 41. Approximately 420 miles of these subsurface drains will be required at a total installation cost of about $11 million. This averages about $60 per acre of drainage-deficient new land to be developed by 2020. It is anticipated that about one-half of the deep drains required will be tile drains and the remainder will be open drains to serve several farms and provide outlet channels for closer spaced and generally shallower on-farm drains.

Projections of Irrigation Costs

Summary

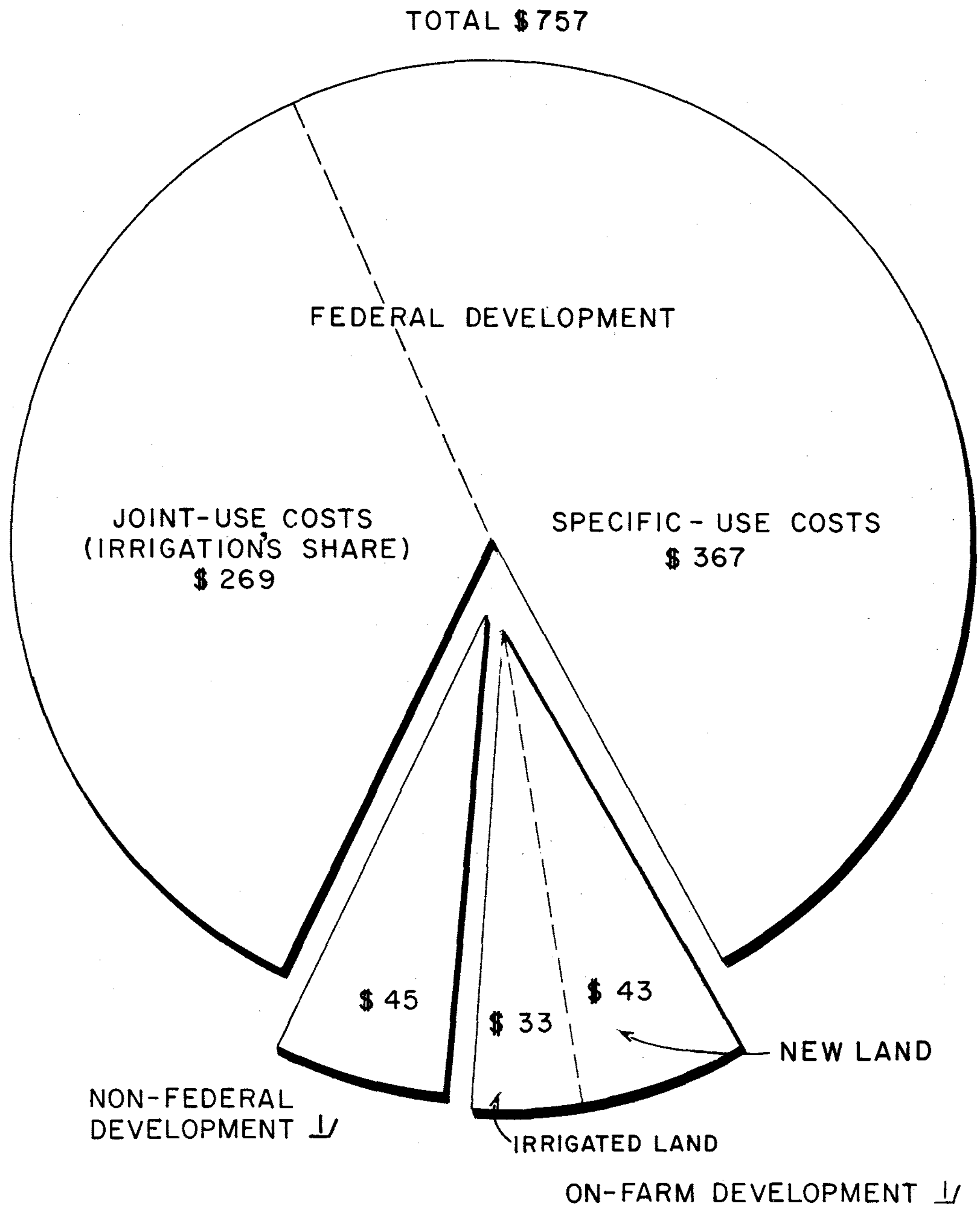
Irrigation installation costs in the region, exclusive of drainage costs, will total approximately $757 million by 2020.1/ These include non-Federal and Federal costs. Non-Federal developments and on-farm costs include Federal participation on a cost-sharing basis. Federal developments consist of two parts: (1) specific-use costs definitely tied to irrigation and (2) irrigation's prorated share of joint-use costs of major multipurpose facilities which include some non-Federal costs of privately developed multipurpose facilities. These various categories are illustrated in the figure on page 86 and discussed in the sections that follow.

On-farm costs

On-farm development costs for new land projected for irrigation development by the year 2020 are approximately $43,304,400 for the region. These installation and annual operation, maintenance, and replacement costs are listed in Table 42 and are based on projected acreage of land requiring brush and rock clearing followed by leveling and smoothing, miles of canal and ditch construction, and a number of water control structures (exclusive of on-farm drainage). About half of these on-farm irrigation developments will generally be funded by the Federal Government and half by the landowners.

1/ Total installation costs for the Upper Colorado Region for irrigation system improvement, drainage, and irrigation's prorated share of storage and major distribution systems is $857 million for an irrigated acreage of 2.1 million acres of land in 2020.

PROJECTED IRRIGATION INSTALLATION COSTS 1966-2020
(UNIT: 1 MILLION DOLLARS)



1/ Includes Federal participation

Table 41 - Costs for project-type drainage of potentially irrigable lands developed for irrigation

Hydrologic Subregion and State	1966-1980 Land 1/ (1,000 acres)	1966-1980 Drainage costs ($1,000) Instal-lation 2/	1966-1980 Drainage costs ($1,000) Annual operation, maintenance, and re-placement 3/	1981-2000 Land 1/ (1,000 acres)	1981-2000 Drainage costs ($1,000) Instal-lation 2/	1981-2000 Drainage costs ($1,000) Annual operation, maintenance, and re-placement 3/	2001-2020 Land 1/ (1,000 acres)	2001-2020 Drainage costs ($1,000) Instal-lation 2/	2001-2020 Drainage costs ($1,000) Annual operation, maintenance, and re-placement 3/	Total Land 1/ (1,000 acres)	Total Instal-lation costs ($1,000)
Green River											
Colorado	4.7	305.5	2.4	1.6	104.0	0.8	1.9	487.5	3.8	8.2	897.0
Utah	2.5	162.5	1.3	.3	19.5	.2	4.2	156.0	1.2	7.0	338.0
Wyoming	10.5	682.5	5.2	12.7	825.5	6.3	7.0	208.0	1.6	30.2	1,716.0
Subtotal	17.7	1,150.5	8.9	14.6	949.0	7.3	13.1	851.5	6.6	45.4	2,951.0
Upper Main Stem											
Colorado	18.1	633.5	9.1	19.2	672.0	9.6	16.1	563.5	8.0	53.4	1,869.0
Utah							.3	10.5	.2	.3	10.5
Subtotal	18.1	633.5	9.1	19.2	672.0	9.6	16.4	574.0	8.2	53.7	1,879.5
San Juan-Colorado											
Arizona											
Colorado	9.0	720.0	4.5	12.2	976.0	6.1	3.9	312.0	2.0	25.1	2,008.0
New Mexico	16.0	1,280.0	8.0	11.4	912.0	5.7	11.7	936.0	5.8	39.1	3,128.0
Utah				5.6	448.0	2.8	7.4	592.0	3.7	13.0	1,040.0
Subtotal	25.0	2,000.0	12.5	29.2	2,336.0	14.6	23.0	1,840.0	11.5	77.2	6,176.0
Total	60.8	3,784.0	30.5	63.0	3,957.0	31.5	52.5	3,265.5	26.3	176.3	4/11,006.5

1/ Acreage needing drainage, comprising 30 percent of projected new land development.

2/ Based on per acre drainage costs of $65, $35, and $80, respectively, for Green River, Upper Main Stem, and San Juan-Colorado Subregions. From Bureau of Reclamation and Bureau of Indian Affairs project data.

3/ Based on average operation, maintenance, and replacement costs of $0.50 per acre of land requiring drainage. From Bureau of Reclamation project data. Non-Federal costs paid by water users.

4/ Cost to construct approximately 420 miles of drains at an average field cost of $26,000 per mile.

Table 42 - On-farm land development costs for new irrigated land[1]
(Unit--$1,000)

Hydrologic Subregion and State	Total installation costs[2]				Annual operation, maintenance, and replacement costs[2]		
	1980	2000	2020	Total	1980	2000	2020
Green River							
Colorado	1,293.9	435.2	504.4	2,233.5	77.6	26.1	30.3
Utah	665.0	80.4	1,898.4	2,643.8	39.9	4.8	113.9
Wyoming	2,874.0	3,481.0	1,148.0	7,503.0	172.4	208.9	68.9
Subtotal	4,832.9	3,996.6	3,550.8	12,380.3	289.9	239.8	213.1
Upper Main Stem							
Colorado	3,882.4	4,124.6	3,462.6	11,469.6	232.9	247.5	207.7
Utah			94.0	94.0			5.6
Subtotal	3,882.4	4,124.6	3,556.6	11,563.6	232.9	247.5	213.3
San Juan-Colorado							
Arizona							
Colorado	2,263.0	3,048.6	974.2	6,285.8	135.8	182.9	58.4
New Mexico	4,012.5	2,849.5	2,933.4	9,795.4	240.7	171.0	176.0
Utah		1,403.9	1,875.4	3,279.3		84.2	112.5
Subtotal	6,275.5	7,302.0	5,783.0	19,360.5	376.5	438.1	346.9
Total	14,990.8	15,423.2	12,890.4	43,304.4	899.3	925.4	773.3

1/ Does not include drainage costs.
2/ 50-50 cost-sharing by Federal and non-Federal funds.

The continuing on-farm irrigation improvement program on 910,880 acres of presently irrigated lands, including 421,100 acres to receive supplemental water and 489,780 acres with an adequate water supply, is shown in Table 43. These 50-50 cost-sharing installation costs for improving the present irrigation system for increased yields will total approximately $32,846,000 by 2020.

Project costs

Non-Federal Developments

Project costs for non-Federal irrigation developments in the region involving some 87,000 acres of potentially irrigable land and 94,900 acres of supplemental service land not included in Federal irrigation projects are estimated to total $44,894,000 by 2020. These costs, with other supporting land and water data, are listed in Table 44. Although designated as non-Federal, costs for these private irrigation developments are shared by the Government and by the land owners involved, usually on the basis of 65-35 percent, respectively.

Federal Developments

Specific-use costs.--Federal irrigation developments in the region, involving some 587.4 million acres of potentially irrigable land and approximately 421,100 acres of supplemental service land, are estimated to cost $366,590,000 by 2020, as shown in Table 45. This total includes specific costs identified with single-purpose Federal irrigation developments, such as main and secondary laterals, pumping plants, some main canals, and other items not listed in previous tables.

Joint-use costs.--Costs of major multipurpose facilities, such as reservoir storage, collection systems for reservoirs, and most main water conveyance systems, are distributed among the "major functions" (irrigation, flood control, recreation, etc.) in accordance with proportionate use. The prorated share of these joint-use costs attributable to irrigation totals $269,200,000, as listed also in Table 45. This includes joint-use costs of major multipurpose non-Federal irrigation facilities, some of which are included in Table 44.

Other costs

There may be other direct and indirect costs which cannot be accurately identified until actual project feasibility studies are made. These miscellaneous costs may include the cost of acquiring land, cost of discontinuing current uses of lands to be developed for irrigation, increased costs for environmental protection, etc.

Table 43 - On-farm system improvement program on presently irrigated land

Hydrologic Subregion and State	1966-1980					1981-2000					2001-2020					Total		
		Cost ($1,000) 1/					Cost ($1,000) 1/					Cost ($1,000) 1/					Installation cost ($1,000) 1/	
		Installation		Annual operation, maintenance, and replacement			Installation		Annual operation, maintenance, and replacement			Installation		Annual operation, maintenance, and replacement				
	Land (acres)	Federal	Non-Federal	Federal	Non-Federal	Land (acres)	Federal	Non-Federal	Federal	Non-Federal	Land (acres)	Federal	Non-Federal	Federal	Non-Federal	Land (acres)	Federal	Non-Federal
Green River																		
Colorado	14,070	252.2	252.2	14.7	14.7	24,460	433.5	433.5	25.2	25.2	14,150	253.7	253.7	4.8	4.8	52,680	939.4	939.4
Utah	121,630	2,262.3	2,262.3	131.3	131.3	79,100	1,364.4	1,364.4	79.4	79.4	39,550	682.2	682.2	39.7	39.7	240,280	4,308.9	4,308.9
Wyoming	82,250	1,513.2	1,513.2	87.8	87.8	90,900	1,609.6	1,609.6	93.6	93.6	43,050	758.6	758.6	44.1	44.1	216,200	3,881.4	3,881.4
Subtotal	217,950	4,027.7	4,027.7	233.8	233.8	194,460	3,407.5	3,407.5	198.2	198.2	96,750	1,694.5	1,694.5	88.6	88.6	509,160	9,129.7	9,129.7
Upper Main Stem																		
Colorado	84,385	1,550.4	1,550.4	90.0	90.0	106,130	1,894.9	1,894.9	110.2	110.2	58,785	1,057.6	1,057.6	61.4	61.4	249,300	4,502.9	4,502.9
Utah	575	19.1	19.1	1.1	1.1	1,150	38.2	38.2	2.2	2.2	2,175	49.9	49.9	2.9	2.9	3,900	107.2	107.2
Subtotal	84,960	1,569.5	1,569.5	91.1	91.1	107,280	1,933.1	1,933.1	112.4	112.4	60,960	1,107.5	1,107.5	64.3	64.3	253,200	4,610.1	4,610.1
San Juan																		
Arizona																		
Colorado	53,840	1,006.8	1,006.8	58.3	58.3	33,600	587.6	587.6	34.1	34.1	16,400	286.1	286.1	16.6	16.6	103,840	1,880.5	1,880.5
New Mexico	8,875	161.9	161.9	9.5	9.5	8,950	154.4	154.4	9.0	9.0	4,475	77.2	77.2	4.5	4.5	22,300	393.5	393.5
Utah	2,675	46.1	46.1	2.7	2.7	10,950	200.0	200.0	11.6	11.6	8,755	163.1	163.1	9.5	9.5	22,380	409.2	409.2
Subtotal	65,390	1,214.8	1,214.8	70.5	70.5	53,500	942.0	942.0	54.7	54.7	29,630	526.4	526.4	30.6	30.6	148,520	2,683.2	2,683.2
Total	368,300	6,812.0	6,812.0	395.4	395.4	355,240	6,282.6	6,282.6	365.3	365.3	187,340	3,328.4	3,328.4	183.5	183.5	910,880	16,423.0	16,423.0

1/ Includes costs for land leveling, smoothing, and water control structures, exclusive of on-farm drainage.

Table 44 - Projected cost for non-Federal irrigation developments1/

Hydrologic Subregion and State	1966-1980						1981-2000						2001-2020						Total				
	Land2/ (1,000 acres)		Water development (1,000 ac.-ft.)	Cost ($1,000)			Land2/ (1,000 acres)		Water development (1,000 ac.-ft.)	Cost ($1,000)			Land2/ (1,000 acres)		Water development (1,000 ac.-ft.)	Cost ($1,000)			Land2/ (1,000 acres)		Water development (1,000 ac.-ft.)	Installation cost ($1,000)	
				Installation		Annual operation, maintenance, and replacement3/				Installation		Annual operation, maintenance, and replacement3/				Installation		Annual operation, maintenance, and replacement3/					
	New	Supplemental		Federal	Non-Federal		New	Supplemental		Federal	Non-Federal		New	Supplemental		Federal	Non-Federal		New	Supplemental		Federal	Non-Federal
Green River																							
Colorado		2.5	1.3	126.7	68.3	1.0	1.0	3.5	3.3	321.8	173.2	2.5	0.5	6.0	4.0	390.0	210.0	3.0	1.5	12.0	8.6	838.5	451.5
Utah		11.3	10.2	1,555.4	837.6	12.0	1.0		1.8	175.5	94.5	1.4	2.0		3.5	341.3	183.7	2.6	3.0	11.3	15.5	2,072.2	1,115.8
Wyoming	2.0	13.0	12.6	614.3	330.7	4.7	2.0	20.0	12.4	347.1	186.9	2.7	6.0	10.0	11.0	729.3	392.7	5.6	10.0	43.0	36.0	1,690.7	910.3
Subtotal	2.0	26.8	24.1	2,296.4	1,236.6	17.7	4.0	23.5	17.5	844.4	454.6	6.6	8.5	16.0	18.5	1,460.6	786.4	11.2	14.5	66.3	60.1	4,601.4	2,477.6
Upper Main Stem																							
Colorado	2.0	1.0	4.8	468.0	252.0	3.6	4.0	1.0	8.7	848.3	456.7	6.5	4.0	3.0	10.2	994.5	535.5	7.7	10.0	5.0	23.7	2,310.8	1,244.2
Utah													1.0	2.0	12.0	1,807.0	973.0	13.9	1.0	2.0	12.0	1,807.0	973.0
Subtotal	2.0	1.0	4.8	468.0	252.0	3.6	4.0	1.0	8.7	848.3	456.7	6.5	5.0	5.0	22.2	2,801.5	1,508.5	21.6	11.0	7.0	35.7	4,117.8	2,217.2
San Juan-Colorado																							
Arizona																							
Colorado							3.0	5.0	11.0	900.0	225.0	5.6	15.0	2.0	37.7	3,108.0	777.0	19.4	18.0	7.0	48.7	4,008.0	1,092.0
New Mexico																							
Utah							8.7	7.0	34.1	5,672.0	1,418.0	35.4	34.8	7.6	110.0	15,504.0	3,876.0	96.9	43.5	14.6	144.1	21,176.0	5,294.0
Subtotal							11.7	12.0	45.1	6,572.0	1,643.0	41.0	49.8	9.6	147.7	18,612.0	4,653.0	116.3	61.5	21.6	192.8	25,184.0	6,296.0
Total	4.0	27.8	28.9	2,764.4	1,488.6	21.3	19.7	36.5	71.3	8,264.7	2,554.3	54.1	63.3	30.6	188.4	22,874.1	6,947.9	149.1	87.0	94.9	288.6	33,903.2	10,990.8

1/ Source: Soil Conservation Service. Cost sharing by Federal (65%) and non-Federal (35%). Includes some prorated share of reservoir storage and conveyance costs. (See joint-use costs.)
2/ Upper Colorado Region Task Force Study.
3/ Non-Federal costs.

Table 45 - Projected costs for Federal irrigation developments
(Unit--$1,000)

	1966-1980		1981-2000		2001-2020		
	Instal-lation	Annual operation, maintenance, and re-placement	Instal-lation	Annual operation, maintenance, and re-placement	Instal-lation	Annual operation, maintenance, and re-placement	Instal-lation costs
			Specific-use Costs 1/				
Green River	31,110	350	34,480	430	15,150	210	80,740
Upper Main Stem	45,930	520	37,560	470	19,820	270	103,310
San Juan-Colorado	91,970	1,030	78,520	980	12,050	170	182,540
Total	169,010	1,900	150,560	1,880	47,020	650	366,590
			Joint-use Costs 2/				
Green River	32,800		10,000		33,200		76,000
Upper Main Stem	92,300		30,900		7,700		130,900
San Juan-Colorado	49,800		12,500		0		62,300
Total	174,900		53,400		40,900		269,200

1/ Includes specific items definitely identified with irrigation such as main and secondary laterals, pumping plants, some main canals, and other items not listed in other tables. (OM&R costs predominantly non-Federal.)

2/ Includes irrigation's prorated share of costs of multipurpose facilities such as reservoir storage, collection systems for reservoirs, and most main water conveyance systems. Also includes some non-Federal joint-use costs included in Table 44. Joint operation, maintenance, and replacement costs for all major functions total $2,476,000, of which irrigation's share would be approximately $817,000 annually (predominantly non-Federal).

PART V

ALTERNATE LEVELS OF DEVELOPMENT

Summary

Agriculture in this region is tied to irrigated cropland production; therefore, the increase in production on existing irrigated lands by improved management practices and supplying supplemental water and the development of newly irrigated land relate to a large portion of the agricultural activity. Projected irrigated acreage for the alternative levels of development by time frame is shown in Table 46.

Table 46 - Projected irrigated acres for alternative levels of development by time frames

Level of development	Irrigated acreage (1,000 acres) 1965	1980	2000	2020
Framework plan	1,622	1,794	1,954	2,122
OBERS "as Published"	1,622	1,499	1,529	1,551
States' alternative (6.5 MAF)	1,622	1,792	2,102	2,118
States' alternative (8.16 MAF)	1,622	1,872	2,224	2,354
States' alternative (water available)	1,622	1,872	2,259	2,579

OBERS "as Published"

The OBERS "as Published" alternative represents an estimate of projected crop and livestock production required to meet regional and national needs. The "Regionally Interpreted" OBERS described in this appendix appraised crop production needs consistent with livestock output projections by utilizing the region's resources and determined an irrigated acreage requirement. The two approaches lead to different estimates of irrigated acreage requirements, as indicated in Table 47.

Table 47 - Comparison of projected irrigated acreage requirements between OBERS "as Published" and the "Regional Interpretation," 1965 to 2020
(Unit--1,000 acres)

Year	OBERS "as Published"	OBERS "Regional Interpretation"	Difference
1965	1,621.5	1,621.5	0
1980	1,498.7	1,793.6	294.9
2000	1,529.2	1,954.2	425.0
2020	1,550.8	2,122.1	571.3
Difference-- 1965-2020	-70.7	+500.6	

The OBERS "as Published" analysis results in a reduction of 70,700 acres of irrigated land from 1965 to 2020, as compared with an increase of 500,600 acres resulting from the "Regional Interpretation." However, it has been shown in the framework plan that an additional 86,800 acres of potentially irrigable land will be needed to replace presently irrigated land abandoned or converted to other uses by 2020 (Table 26 in Part IV). Some of the presently irrigated land not needed for production in the OBERS "as Published" alternative (70,700 acres) could be converted to partially satisfy other land use requirements. The remainder of the 86,800 acres of irrigated land required for other uses would be replaced by potentially irrigable land acreage in order to have a net of 1,550,800 acres in production by 2020, as required by the OBERS "as Published" plan.

A portion of the short-supply irrigated lands would be provided a supplemental water supply under this analysis to partially offset the reduction in total irrigated acreage, resulting in an increase in on-site depletions of approximately 72,000 acre-feet by 2020, for a total of 2.2 million acre-feet attributed to irrigation, incidental use, and irrigation reservoir evaporation.

The crop production projected in the OBERS "as Published" alternative would not provide the feed requirements to produce the livestock outputs developed at the regional level. Livestock feed and feeder calves would need to be imported for a feedlot-type production system under this analysis. The "Regional Interpretation" analysis indicates that the region could produce the OBERS "as Published" projected livestock output in the target years, and studies show that land resources and water are available to meet the production goals established. For this reason the "Regional Interpretation" of OBERS projection has been adopted as the framework plan for the Upper Colorado Region.

State Alternative at 6.5 Million Acre-feet

For comparative purposes the States have proposed an alternate development of 6.5 million acre-feet of water per annum, the quantity required to satisfy the regionally interpreted OBERS level of development.

Projected on-site water depletions by irrigated land (new and supplemental), incidental use, and irrigation reservoir evaporation are shown by States (Table 48) and by Hydrologic Subregions (Table 49) for the 6.5 million-acre-foot State Alternative Plan.

Table 48 - Projected on-site water depletions by irrigated land (new and supplemental), incidental use, and irrigation reservoir evaporation by States--1980, 2000, and 2020
(Unit--1,000 acre-feet per year)

Year	Arizona	Colorado	New Mexico	Utah	Wyoming	Region
1980	7.0	1,391.1	245.0	576.6	334.0	2,553.7
2000	7.6	1,778.2	411.0	660.6	407.0	3,264.4
2020	9.0	1,754.4	411.0	695.2	427.1	3,296.8

Table 49 - Projected on-site water depletions by irrigated land (new and supplemental), incidental use, and irrigation reservoir evaporation by Hydrologic Subregions--1980, 2000, and 2020
(Unit--1,000 acre-feet per year)

Year	Green River	Upper Main Stem	San Juan-Colorado	Region
1980	935.4	1,007.8	610.5	2,553.7
2000	1,197.5	1,184.5	882.4	3,264.4
2020	1,253.3	1,166.5	877.0	3,296.8

Table 50 shows both the projected irrigated land acreage and on-site water depletions by time periods, Hydrologic Subregions, and States for the 6.5 million-acre-foot State alternative level of development.

Table 50 - Projected on-site water depletions by irrigated land (new and supplemental), incidental use, and irrigation reservoir evaporation for the State alternative at the 6.5 million-acre-foot level of development - Upper Colorado Region

Hydrologic Subregion and State	1980			2000			2020		
	Irrigated land (1,000 acres)		Water depletions 1,000 acre-feet	Irrigated land (1,000 acres)		Water depletions 1,000 acre-feet	Irrigated land (1,000 acres)		Water depletions 1,000 acre-feet
	Total	Supplemental 1/		Total	Supplemental 1/		Total	Supplemental 1/	
Green River									
Colorado	129.3	6.1	124.8	192.2	17.1	257.9	193.2	17.1	258.6
Utah	286.8	31.0	476.6	295.7	102.6	532.6	314.8	102.6	567.6
Wyoming	341.5	59.0	334.0	379.5	85.0	407.0	392.5	95.0	427.1
Subtotal	757.6	96.1	935.4	867.4	204.7	1,197.5	900.5	214.7	1,253.3
Upper Main Stem									
Colorado	646.4	25.7	991.1	727.2	99.3	1,167.3	718.2	99.3	1,149.3
Utah	9.6	2.0	16.7	9.7	2.0	17.2	9.7	2.0	17.2
Subtotal	656.0	27.7	1,007.8	736.9	101.3	1,184.5	727.9	101.3	1,166.5
San Juan-Colorado									
Arizona	10.0		7.0	9.4	1.0	7.6	9.4	2.0	9.0
Colorado	209.7	28.7	275.2	248.0	53.8	353.0	247.0	53.8	346.6
New Mexico	104.2	5.5	245.0	174.2	5.5	411.0	174.2	5.5	411.0
Utah	54.4		83.3	65.7	7.0	110.8	59.1	14.6	110.4
Subtotal	378.3	34.2	610.5	497.3	67.3	882.4	489.7	75.9	877.0
Region									
Arizona	10.0		7.0	9.4	1.0	7.6	9.4	2.0	9.0
Colorado	985.4	60.5	1,391.1	1,167.4	170.2	1,778.2	1,158.4	170.2	1,754.5
New Mexico	104.2	5.5	245.0	174.2	5.5	411.0	174.2	5.5	411.0
Utah	350.8	33.0	576.6	371.1	111.6	660.6	383.6	119.2	695.2
Wyoming	341.5	59.0	334.0	379.5	85.0	407.0	392.5	95.0	427.1
Total	1,791.9	158.0	2,553.7	2,101.6	373.3	3,264.4	2,118.1	391.9	3,296.8

1/ Supplemental acreage included in total.

Departures from the basic data contained in the regionally interpreted OBERS plan with regard to irrigation are shown in Table 51 and described below.

Table 51 - Departure from regionally interpreted OBERS plan due to States' adjustment in irrigation use (6.5 million-acre-foot level of development in year 2020) (Unit--1,000 acres and acre-feet)

	Hydrologic Subregions							
	Green River		Upper Main Stem		San Juan-Colorado		Total	
States	Acres	Acre-feet	Acres	Acre-feet	Acres	Acre-feet	Acres	Acre-feet
Arizona								
Colorado	+58.3	+111.6	-39.0	-66.7	-12.8	-13.4	+6.5	+31.5
New Mexico								
Utah	+9.0	-4.4	+1.7	+.2	-21.2	-23.6	-10.5	-27.8
Wyoming		1/ -.9						1/ -.9
Total	+67.3	+106.3	-37.3	-66.5	-34.0	-37.0	-4.0	+2.8

1/ Supplemental water supply reduced.

Arizona retained its exact allotment of 50,000 acre-feet per annum; hence, there was no change in use for irrigation.

Wyoming revised its irrigation depletions downward 900 acre-feet per annum to stay exactly within its 14-percent allotment. This involves no change in irrigated acreage but reduces supplemental water development.

Utah revised downward its irrigation acreage (-10,500 acres) to stay within its 23-percent allotment under the compact.

Colorado varies from regionally interpreted OBERS as follows for irrigated land acreage and water depletions for the years 1980, 2000, and 2020, respectively: 18,000 less acres, depleting 88,000 acre-feet less water; 80,000 more acres, depleting 145,000 acre-feet more water; and 6,500 more acres of land, depleting 31,500 acre-feet more water. As a result, it appears that Colorado will deplete its 51.75-percent allotment by the year 2000. In addition, 22,100 acre-feet of irrigation water will be transferred between the years 2001 and 2020 to meet municipal and industrial requirements.

In order to stay within its 11.25 percent of the 6.5-million-acre-foot level of development in 2020, it was necessary to reduce New Mexico's depletion by a net of 9,500 acre-feet annually. There will be no change, however, in irrigated acreage or acre-feet of water.

State Alternative at 8.16 Million Acre-feet

This is an alternate level of development which reflects 8.16 million acre-feet of manmade depletions in the Upper Basin plus the delivery of an average of 7.5 million acre-feet of water per annum at Lee Ferry. It includes the amounts of water evaporated from reservoirs related to deliveries at Lee Ferry. The depletion distribution among the States in 2020 is on the basis of percentage of consumptive use contained in the Upper Colorado River Basin Compact.

Development of some resources will not be limited by water availability. State projections indicate the increased production associated with this level of development will be readily absorbed within national and increasing western markets. This is especially true since the added increment is a small part of the national market and will accordingly have a small impact.

Arizona retained its allotment of 50,000 acre-feet for irrigation of 9,400 acres of land in 2020 with no changes in types of uses for regionally interpreted OBERS.

Colorado plans to irrigate 1,256,300 acres in 2020, which is 104,000 acres more than the regionally interpreted OBERS showed, with a depletion of 1,941,500 acre-feet.

New Mexico plans no changes in agriculture, fish and wildlife, or recreation from regionally interpreted OBERS and will irrigate about 174,200 acres by the year 2000 and 2020.

Utah will increase its use by irrigated crops to 10,700 acre-feet over regionally interpreted OBERS and will irrigate about 401,200 acres by 2020.

Wyoming's agricultural base of irrigated land will be higher than OBERS allowed and increases to 513,300 acres by year 2020.

Table 52 summarizes projected irrigated acreage by State for the 8.16 million-acre-foot State alternative level.

Table 52 - Projected irrigated acres by States--1980, 2000, and 2020 at 8.16 million-acre-foot State alternative level of development

Hydrologic Subregion and State	Irrigated land (1,000 acres)		
	1980	2000	2020
Green River			
Colorado	129.3	192.2	217.4
Utah	286.8	295.7	312.9
Wyoming	421.3	494.8	513.3
Subtotal	837.4	982.7	1,043.6
Upper Main Stem			
Colorado	646.4	727.2	771.8
Utah	9.6	9.7	8.0
Subtotal	656.0	736.9	779.8
San Juan-Colorado			
Arizona	10.0	9.4	9.4
Colorado	209.7	255.0	267.1
New Mexico	104.2	174.2	174.2
Utah	54.4	65.7	80.3
Subtotal	378.3	504.3	531.0
Region			
Arizona	10.0	9.4	9.4
Colorado	985.4	1,174.4	1,256.3
New Mexico	104.2	174.2	174.2
Utah	350.8	371.1	401.2
Wyoming	421.3	494.8	513.3
Total	1,871.7	2,223.9	2,354.4

Table 53 and 54 enumerate the water depletions by States, Hydrologic Subregions, and by time frames 1980, 2000, and 2020 for the 8.16 million-acre-foot level of development.

Table 53 - Projected on-site water depletions by irrigated land (new and supplemental), incidental use, and irrigation reservoir evaporation by States--1980, 2000, and 2020
(Unit--1,000 acre-feet per year)

Year	Arizona	Colorado	New Mexico	Utah	Wyoming	Region
1980	7.0	1,391.1	245.0	576.6	431.5	2,651.2
2000	7.6	1,792.5	411.0	660.6	534.5	3,406.2
2020	9.0	1,941.5	411.0	733.7	562.5	3,657.7

Table 54 - Projected on-site water depletions by irrigated land (new and supplemental), incidental use, and irrigation reservoir evaporation by Hydrologic Subregions--1980, 2000, and 2020
(Unit--1,000 acre-feet per year)

Year	Green River	Upper Main Stem	San Juan-Colorado	Region
1980	1,032.9	1,007.8	610.5	2,651.2
2000	1,325.0	1,198.8	882.4	3,406.2
2020	1,470.1	1,262.6	925.0	3,657.7

State Alternative for Water Supply Available at Site

This is a plan of development which would be possible if the States of the Upper Colorado Region utilize water which would be physically available at the site of project development. There has been no agreement between the States or within the States that the plan can be accomplished in the way indicated, but rather the plan shows the possible utilization of water that will be physically available for development. It is contemplated that there would be shifts between types of use as the needs develop. The plan would not meet Colorado River Compact requirements for delivery at Lee Ferry.

This level is a measure of possible development in the region if exchanges could be arranged and if the Colorado River is augmented at or below Lake Powell. Proper consideration of possible detriment to power revenues and of augmentation costs will be required.

States have expressed interest in a regional plan at a level of development described above and have submitted data in Tables 55 and 56 as their choice under a plan which would utilize water supply available at site.

Table 55 - Projected irrigated acres by States--
1980, 2000, and 2020 (water available at site)

Hydrologic Subregion and State	Irrigated land (1,000 acres) 1980	2000	2020
Green River			
Colorado	129.3	192.2	217.4
Utah	286.8	295.7	366.8
Wyoming	421.3	494.8	513.3
Subtotal	837.4	982.7	1,097.5
Upper Main Stem			
Colorado	646.4	727.2	810.9
Utah	9.6	9.7	35.4
Subtotal	656.0	736.9	846.3
San Juan-Colorado			
Arizona	10.0	9.4	9.4
Colorado	209.7	255.0	267.1
New Mexico	104.2	209.2	244.2
Utah	54.4	65.7	114.3
Subtotal	378.3	539.2	635.0
Region			
Arizona	10.0	9.4	9.4
Colorado	985.4	1,174.4	1,295.4
New Mexico	104.2	209.2	244.2
Utah	350.8	371.1	516.5
Wyoming	421.3	494.8	513.3
Total	1,871.7	2,258.9	2,578.8

Table 56 - Projected on-site water depletions by irrigated land--
1980, 2000, and 2020 (water supply available at site)
(Unit--1,000 acre-feet per year)

Year	Arizona	Colorado	New Mexico	Utah	Wyoming	Region
1980	7.0	1,391.1	245.0	576.6	431.5	2,651.2
2000	7.6	1,792.5	491.0	660.6	534.5	3,486.2
2020	9.0	2,010.5	571.0	935.5	562.5	4,088.5

Water depletions for irrigation in the region increased 430,800 acre-feet above the 8.16 million-acre-foot level of development.

Arizona's water depletions for irrigation remain unchanged from those projected for the 8.16 million-acre-foot level of development.

Colorado has planned additional projects at this level of development, which would increase irrigation above the 8.16 million-acre-foot level in 2020 by 69,000 acre-feet, primarily in the Upper Main Stem Subregion.

New Mexico's water depletions would increase by 160,000 acre-feet for irrigation of 70,000 more acres of new land by 2020 above those projected for development at the 8.16 million-acre-foot level.

Utah increased its projected depletions for irrigation from the 8.16 million-acre-foot level of development by 201,800 acre-feet for use on 115,300 acres of additional land by 2020.

Wyoming has not increased its projected depletions for irrigation over those projected for the 8.16 million acre-foot level of development.

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