UNITED STATES DEPARTMENT OF THE INTERIOR
Walter J. Hickel, Secretary

BUREAU OF RECLAMATION
Floyd E. Dominy, Commissioner
REGION 4, SALT LAKE CITY, UTAH
David L. Crandall, Regional Director

S A N J U A N I N V E S T I G A T I O N

UTAH AND COLORADO

SEPTEMBER 1969

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FOREWORD

At its inception in 1965, when its name was adopted, the San Juan Investigation was planned only for San Juan County, Utah. It was later extended to include adjacent areas in Grand County, Utah, and Dolores, San Miguel, Montrose, and Mesa Counties, Colo., that are southwest of the Dolores River.

The investigation grew from a desire of the local people to have a comprehensive study made of possibilities for water resource developments within their area. Understandably, they desired these possibilities to be considered with those of other areas in the Upper Colorado River Basin in determining the best utilization of the basin's undeveloped water resources. Active support for the investigation was given by the San Juan County Water Conservancy District, formed in 1964, and initially by the Utah Water and Power Board, and later by the Board's successors, the Utah Board of Water Resources and the Division of Water Resources in the Department of Natural Resources. Congress cooperated by amending the 1966 Public Works Appropriation Bill to provide funds to start the study. The Conservancy District and the Water and Power Board also contributed funds for the work.

The interrelationship of water with other resources in this uniquely endowed study area led to their comprehensive investigation.

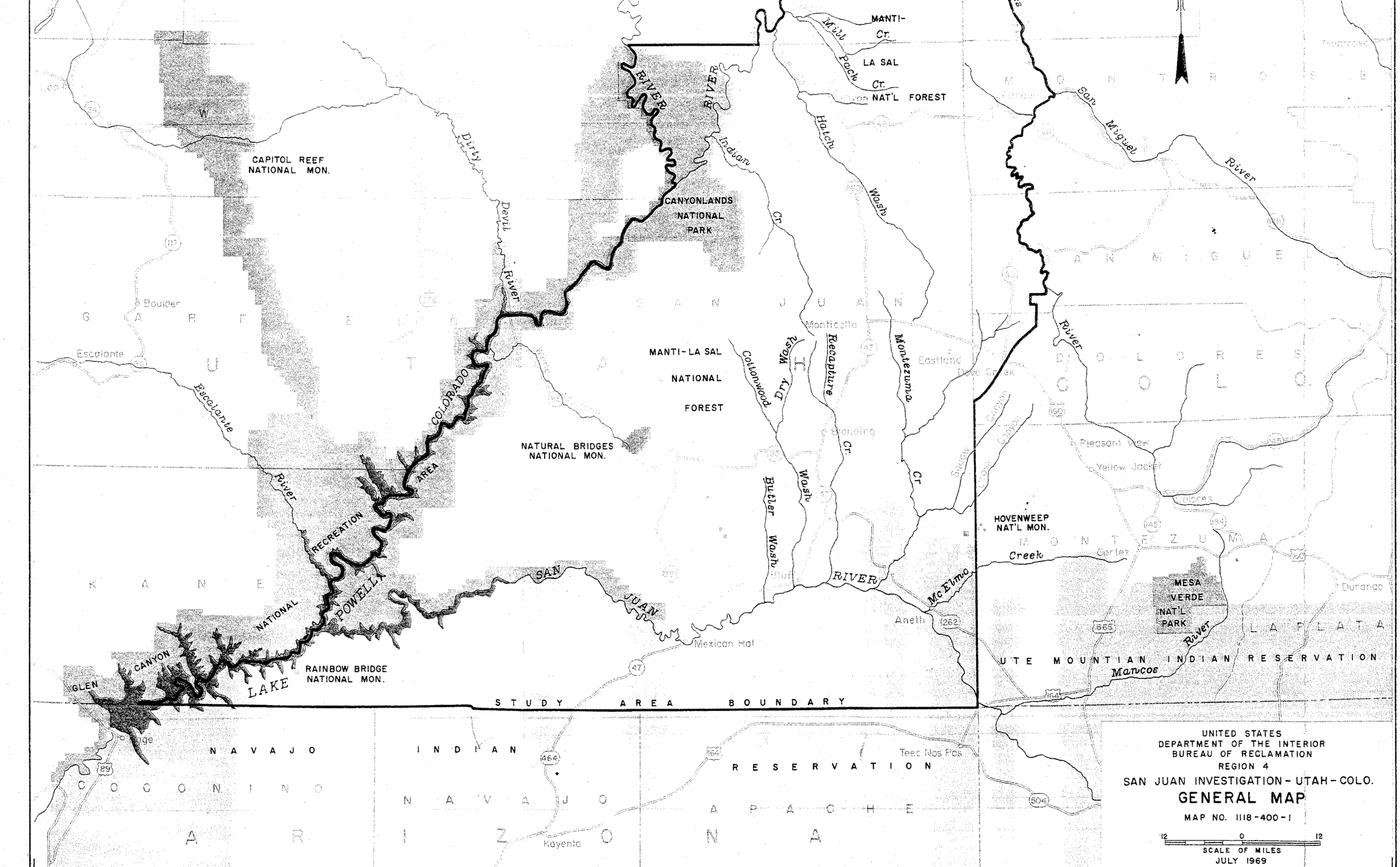
In the preparation of this report various Federal and State agencies and local groups cooperated with the Bureau of Reclamation in providing data and advice to assure that the planning would be keyed to the welfare of the people of the area and to others having an interest in the development of its resources. The San Juan County Water Conservancy District and the Utah Division of Water Resources provided counsel and other assistance in the investigation.

The Utah Geological and Mineralogical Survey prepared a comprehensive report in 1969 on the mineral resources of the area. This has been published in two volumes--Part I (Special Studies 24) on Petroleum, Potash, Ground Water, and Miscellaneous Minerals and Part II (Special Studies 24II) on Uranium and other Metals in Sedimentary Host Rocks. Information on preliminary plans for a road development program was provided by the Utah State Department of Highways.

The National Park Service reported on existing and potential recreation as one of the important economic values of the study area. Appraisals of recreational aspects of a number of potential water resource projects were made by the Bureau of Outdoor Recreation. The Bureau of Sport Fisheries and Wildlife appraised the fish and wildlife potentialities of these projects and reported generally on fish and wildlife resources of the area.

FOREWORD

The Bureau of Land Management which administers about 41 percent of the lands of the study area reported on its program of multiple use of this vast land resource to best meet present and future needs of the American people. The Bureau of Indian Affairs provided information on Indian resources and programs on the more than a million acres of the Navajo Indian Reservation that are within the study area. The Forest Service reported on the La Sal Division of the Manti-La Sal National Forest that is wholly within the area, and the Soil Conservation Service reported on its soil and water conservation activities.


CAPITOL REEF NATIONAL MON.
CANYONLANDS NATIONAL PARK
MANTI-LA SAL NATIONAL FOREST
NATURAL BRIDGES NATIONAL MON.
GLEN CANYON NATIONAL RECREATION AREA
LAKE POWELL
RAINBOW BRIDGE NATIONAL MON.
HOVENWEEP NAT'L MON.
MESA VERDE NAT'L PARK
UTE MOUNTIAN INDIAN RESERVATION
NAVAJO INDIAN RESERVATION
STUDY AREA BOUNDARY
Green River
Dirty Devil River
Indian Cr.
Hatch Wash
San Miguel River
Dolores River
Escalante River
Colorado River
San Juan River
Butler Wash
Dry Wash
Recapture Cr.
Montezuma Cr.
Cottonwood
Mill Cr.
Peak Cr.
McElmo Creek
Mancos River
Boulder
Escalante
Monticello
Blanding
Eastland
Pleasant View
Yellow Jacket
Cortez
Durango
Mexican Hat
Aneth
Kayenta
Tees Nos Pos
LA SAL NAT'L FOREST
GARFIELD
SAN JUAN
MONTROSE
SAN MIGUEL
DOLORES
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DEPARTMENT OF THE INTERIOR
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SAN JUAN INVESTIGATION - UTAH - COLO.
GENERAL MAP
MAP NO. 1118-400-1
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SCALE OF MILES
JULY 1969

CHAPTER I

SUMMARY AND CONCLUSIONS

General Description

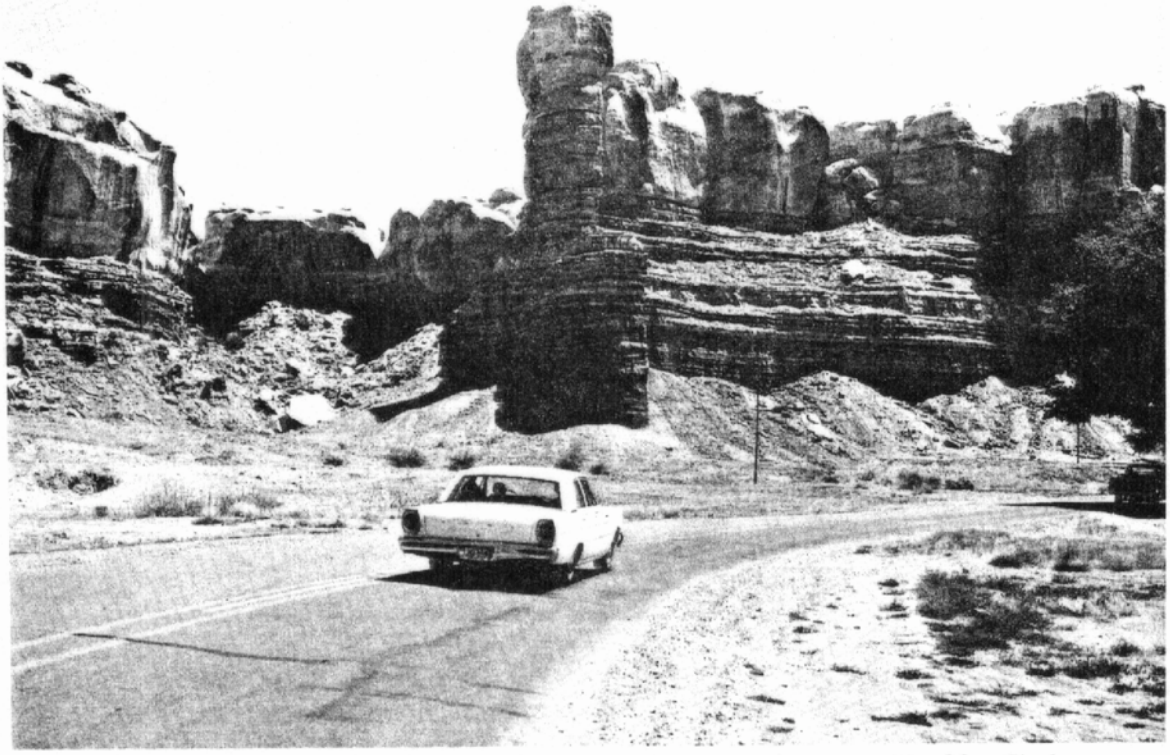
The triangularly shaped San Juan Area is roughly perched between the deep canyons of the Colorado River and its tributaries, the Dolores and San Juan Rivers. Because of their deep-seated positions, mostly in rugged terrain, these rivers provide only a small amount of water for present uses within the area and limited potentialities for future water conservation developments. Creeks flowing from the Abajo and La Sal Mountains which rise within the area provide most of the water for local use. Water supplies are far short of the needs. Only about 13,000 acres are irrigated out of a total of 400,000 acres of arable land. Approximately 160,000 acres are dry-farmed.

The principal ground water aquifers in the San Juan Area are in bedrock or consolidated formations which underlie much of the area. Alluvium or other unconsolidated materials are not known to constitute an important ground water source except in Spanish Valley and possibly in Castle Valley, both of which extend northwest from the La Sal Mountains toward the Colorado River. The potential of bedrock aquifers as a source of ground water should be further evaluated.

The colorful area with its spectacular rock formations is a wonderland of scenic and recreational attractions. Many places of interest are not easily accessible, however, and only in the last decade or so have significant numbers of tourists been attracted to the area. The growing current interest can be attributed in large measure to the construction of Glen Canyon Dam on the Colorado River with its 186-mile-long Lake Powell, the creation of the Glen Canyon National Recreation Area and Canyonlands National Park, and the good start being made in extending hard-surfaced roads to the more prominent scenic and recreation attractions. A continuation of the program for road improvement and extensions is regarded by many as the greatest need of the San Juan Area.

Minerals are among the more important resources of the area. Mineral exploration and production have been erratic, with activities stimulated from time to time by new discoveries, promotions, or technological developments. Minerals that are currently most important economically are petroleum and natural gas, uranium and other metals in sedimentary host rocks, and potash. Coal is found in the Dakota sandstone in parts of the San Juan Area, but deposits as yet have not been determined to be comparable in quality and mineability to nearby deposits on the Navajo Indian Reservation in New Mexico and Arizona. The Black Mesa coal field in

northern Arizona could well be the source of fuel for future large-scale powerplants in the vicinity of Mexican Hat, Utah.



Colorful sandstone and shale formations north of Bluff, Utah, as seen by travelers on Utah State Highway 47.

With more than 80 percent of the land in San Juan Area either in Federal ownership or in the Navajo Indian Reservation, a number of Federal agencies are actively engaged in land administration and land use improvement programs. These include the Bureau of Land Management, Forest Service, National Park Service, and Bureau of Indian Affairs. Other Federal, State, and local agencies also are active in land development. Most of the public land areas are managed to the greatest practical extent for multiple uses, including sustained yields of water, forage and timber, continuing recreation, and mineral production.

Potential Water Developments

More than 20 potential water resource developments, including five possibilities of extending the authorized Dolores Project, are discussed in Chapter IX. A number of these projects have physical and engineering practicability, adequate water, and would fill present or estimated local future needs. The more favorable prospects under present conditions are

the Pack Creek, West Paradox, Dolores Municipal Water Extension, Bluff, West Bluff, and Blanding Projects, and the Halgaitoh Reservoir segment of the Mexican Hat Project. As circumstances warrant these and any other projects that show promise of economic justification should be appraised in more detail. Since most of the projects are relatively small, it may be desirable following detailed studies to group several of them into a consolidated development to be considered by Congress for authorization.

Various plans for the Pack Creek Project have been considered by different agencies over a period of many years. A development there is made urgent by the minor flood damage that occurs frequently in the vicinity of Moab and by the disastrous floods that would occur if the Pack and Mill Creek drainage areas were hit by a cloudburst of an intensity approaching the 1968 storm in the Cottonwood Creek area.

The West Paradox Project has already been investigated in feasibility scope by the Soil Conservation Service. Local sponsorship will be required for further progress toward project development.

The service that would be provided by the Dolores Project Municipal Water Extension is needed now in most of the service area that is east of Monticello, Utah. The Monticello need is anticipated with future community growth. In this instance also local sponsorship will be necessary to promote a detailed study of the extension and its authorization as an extension of the yet to be constructed Dolores Project.

The Bluff and West Bluff Projects both appear to have favorable benefit-cost comparisons but the operation and maintenance costs would be high because of the necessity of pumping all project water from the San Juan River. Under the present practice of growing alfalfa and other livestock feeds the operation and maintenance costs may exceed the payment capacity of the irrigators. The climate and soils are suitable for more intensive and profitable farming such as the growing of orchard fruits and vegetables, although marketing conditions are not presently favorable for these crops.

Justification of the Blanding Project is partly dependent upon the extent of the transportation (highway) benefit that would accrue from construction of the reservoir dam on Recapture Creek. A further appraisal of this benefit in cooperation with the Utah State Highway Department would be one of the initial steps in determining whether or not a project feasibility study should be undertaken.

Studies of the Mexican Hat Project indicate that the off-stream Halgaitoh Reservoir would offer the most economical means of providing water for a large steam-electric powerplant in the vicinity of Mexican Hat. The reservoir plan would be similar to that of the recently constructed Four Corners Plant in New Mexico. The site may receive further study from private power interests.

While the Paradox Salinity Control Project is within the San Juan study area, its principal benefit would accrue to downstream users of Colorado River water. With salinity control becoming increasingly important, further attention to this project may be expected. An economically justified plan that would reduce the salt inflow from Paradox Valley into the Dolores River is highly desirable and will be pursued in cooperative studies with the Federal Water Pollution Control Administration.

The availability of water for potential water-consuming projects is a matter of special concern in the Upper Colorado River Basin. Not only must water be available at the development site but the resulting depletions must be within the allowances made to the affected State by the Upper Colorado River Compact. Utah presently has unused water in the Upper Colorado River Basin that could be used to develop the more attractive projects outlined in this report if the State of Utah elects to dedicate water to these projects.

Economic Projections

The resources and development potentials of the San Juan Area indicate that the greatest future economic developments will be in the fields of recreation and mining, including oil and gas production. An estimate of future recreational progress can be based on visible resources. The future of mineral extraction is dependent largely on indicated, but as yet undiscovered, underground deposits.

Agriculture, limited mainly by a lack of irrigation water, should show some increase in production, although probably accompanied by a continuing decrease in farm employment. The trend toward increasing government employment is expected to continue. It will be sustained by planned improvements on the extensive land areas in Federal ownership or within the Navajo Indian Reservation and by improvements and extensions of the road network. Advancement in the trades, service industries, and miscellaneous economic pursuits will no doubt keep pace with progress in the basic industries and recreation and will benefit from the national trend toward greater needs and uses per person.

Agriculture

Construction of the more favorable potential irrigation projects would provide supplemental water to some lands now irrigated and a full water supply for other lands. These projects and other farm improvement and farm management programs, if carried out, will increase agricultural production. More livestock feeds will be grown to supplement range grazing. This will permit stabilization and some expansion of livestock farming, the principal agricultural pursuit. The trend for farms to increase in size and decrease in number will likely continue. Agricultural employment, which dropped from 2,200 in 1940 to 500 in 1965, will likely

decline further in the years ahead unless more intensive types of farming develop.

Mining

Petroleum

Crude petroleum production in San Juan County started in 1955 and reached a peak of 35 million barrels in 1959. It has since declined fairly evenly to 17 million barrels in 1965. The decline is a result of depletion of reserves and lessened exploration activity. The drilling fervor that followed important discoveries about a decade ago has subsided but conservative drilling programs are still underway. An orderly continuation of exploratory drilling appears to be assured because of the important discoveries already made and the large number of potential entrapment formations known to exist.

The extent of the petroleum discoveries and production that will result from the exploratory drilling is, of course, unknown but is not expected to be spectacular. Technological advances in automated drilling, production, and transport will limit the number of persons employed in the oil fields and along pipelines to a bare minimum. Thus the petroleum industry is not expected to provide significant new employment or population increases.

Uranium

Uranium mining became important in the study area about 1952 and reached a peak in 1959 when 1,367,000 tons of ore were mined. As the national supply of uranium concentrate grew out of proportion to limited uses of that period, both exploration and mining were curtailed. Mining in the area declined steadily to a production of 530,000 tons of ore in 1965.

Federal permission for private ownership of nuclear materials for peaceful uses has stimulated demand for uranium and created renewed activity in exploration and mining. Approximately 43,000 megawatts of nuclear electric generating capacity were either in operation or under construction in the nation at the end of 1967. The Atomic Energy Commission estimates that 120,000 to 170,000 megawatts will be operating in 1980, while some private forecasts place the figure at 200,000 megawatts. Operation of 170,000 megawatts of capacity would require about 20 million tons of uranium ore annually. National production was only about 4.4 million tons in 1965. Known uranium ore reserves in the area are estimated at about 3 million tons, less than six times the 1965 production.

No doubt the near future will bring a rapidly increasing national demand for uranium. New exploration is already taking place in the study area and elsewhere. Naturally ores that can be mined and processed most economically will be the first developed. Just how extensive new discoveries will be in the San Juan Area or how competitive new finds will

be with deposits elsewhere cannot be foretold. Consequently a reliable estimate cannot be made of future ore production in the area. A qualified estimate suggested by personnel of the Bureau of Mines is that production could advance to about 13 million tons annually by 1990 and then decline to about 7 million tons annually as breeder reactors come into use.

Potash

The Cane Creek Mine of the Texas Gulf Sulphur Company, which began operating near Moab in 1964, produced 450,000 tons of muriate of potash in 1967. The company plans to increase production with present facilities to 550,000 tons annually, or about 9 percent of the nation's output.

About 95 percent of the potash produced in the United States is used as fertilizer. Its increasing use is an important factor in the higher crop output per acre that has characterized American agriculture in recent decades. Market economists estimate demand for potash will increase by as much as 200 percent by 1980. Increases in domestic production capacity have more than kept pace with the increasing use, and a number of mines in the United States have been temporarily closed because of oversupply.

The bedded potash reserve in the Paradox formation within and adjacent to the San Juan study area is one of the largest in the United States. The known reserve in the area above an economic cutoff depth of 4,000 feet is 254 million tons, and an additional 161 million tons are inferred. In the Permian Basin of New Mexico, the source of 94 percent of the United States production in 1964, the known reserve is 85 million tons and the inferred reserve, 400 million tons. These two large domestic reserves are small, however, in comparison with the Saskatchewan, Canada, deposit estimated at 17,500 million tons, of which 6,400 million tons are considered to be recoverable.

Unlike the flat-lying potash salt deposits of New Mexico and Saskatchewan, the Paradox Basin beds have been subject to major and minor folding and consequent flowage and contortion. These structural complexities peculiar to the Paradox Basin are a formidable barrier to exploration and increase mining costs.

Canadian interests are proposing to employ solution-type mining and pipeline transport to various points in the United States. If solution mining proves successful, it could be used in many areas in the Paradox Basin. Problems may be encountered, however, in obtaining sufficient water, and the process may not lend itself to the folded and contorted phosphate beds.

The Cane Creek Mine should be able to successfully compete in a growing phosphate market because of its highly mechanized operation, modern equipment, richness of its ore, and its favorable location with

respect to important midwestern markets. Extensive exploration and the development of new mines in the study area are not expected in the foreseeable future.

Some quantities of other metals are mined in the area but are not a significant economic factor.

Recreation

Lacking an established recreational use pattern from which to project estimates of future use, the National Park Service made an "educated guess" that recreation use in the area would increase gradually from 926,000 days in 1970 to 5,325,000 days in 2020, an increase of nearly 600 percent in 50 years.

Employment attributable to recreation is not separately identified in census data. In a 1962 study referred to in Chapter VII, the University of Utah estimated that recreation accounted directly or indirectly for about 18 percent of the area's employment. Unlike some other industries where increased production can be achieved without a proportional increase in employment, expanding recreation will likely provide new job opportunities at least in proportion to its growth. Even a more than proportional increase in recreational employment may result from the trend toward improved services and accommodations.

A lengthening of the recreational season now underway will be advantageous to both the local people and their visitors. Many of the attractions can be visited in greater comfort and in less congestion in the cool weather of the spring and fall than in hot, dry midsummer. Skiing near Monticello and potentially near Moab will benefit the area. Promotional efforts could well be directed at lengthening the tourist season.

Government employment

The number of persons employed in government services in San Juan and Grand Counties, Utah, according to records of the Utah State Employment Service, is shown below.

Government level	1960	1966	Percent increase
Local	420	585	39
State and Federal	160	315	97
Total	580	900	

State and Federal employment is shown as increasing at a much higher rate than local employment. This trend is expected to continue, although not necessarily at the same rate, in view of the improvement programs planned on government lands, future highway extensions, and the trend

toward more government service in various lines. To the extent that government employment is financed from nonlocal revenues, it has a similar multiplier effect on the local economy as revenues from exporting industries such as agriculture and mining.

Population

Moderate population increases are anticipated in the San Juan Area. This conclusion, reached from consideration of data in this report, is supported by two recent independent studies of San Juan County, Utah. A 1965 county population of 7,700 will increase to about 11,000 by year 2020 according to University of Utah projections.1/ The University's statement follows. "Unless mining and mineral production is rejuvenated, much of the future growth will depend on tourism and outdoor recreation developments . . . . An annual growth rate in the neighborhood of 1 percent is probably not too unrealistic and population projections are made on this basis." A study by Planning and Research Associates, Salt Lake City, led to a somewhat higher forecast of a county population of 12,000 by year 2000.2/

Population increases in the order of those mentioned appear to be well supported by presently discernible or indicated resources and trends. Unforeseen developments such as heavy mineral strikes, establishment of government bases or industries, and the development of large recreation enterprises or retirement centers--possible in this expansive and scenic area--could result in much greater population increases.

1/ Theuel R. Black et al., Population Projections, Utah and Utah Counties, December 1967.

2/ Population and Economic Base Study, San Juan County, Utah January 1968.

CHAPTER II

DESCRIPTION OF STUDY AREA

Location

The San Juan County study area includes all of San Juan County and a part of Grand County, Utah, and minor parts of Dolores, San Miguel, Montrose, and Mesa Counties, Colo., as shown on the frontispiece map. The triangularly shaped area, larger than the State of Massachusetts, lies mostly between the Colorado River and its tributaries, the San Juan and Dolores Rivers. Its 8,960 square miles are distributed by counties as shown below.

	Square miles
San Juan County, Utah	7,884
Grand County, Utah	462
Dolores, San Miguel, Montrose, and Mesa Counties, Colo.	614
Total	8,960

Physical Characteristics

The unique and spectacular geologic features of the San Juan Area are of interest to both the casual visitor and the trained geologist. The landscape provides the best illustration known to man of the geological processes involved in its formation. In approximate historical sequence these processes were (1) deposition of material by wind and water, (2) consolidation, (3) deformation by folding and faulting, and (4) normal erosion, later accelerated by a general uplift. Volcanic action no longer occurs in the area, but the formations are still changing from frost and erosion processes.

The diverse landscapes include arches, spires, needles, broad plains, nearly vertical escarpments, mesas, buttes, and intricately dissected canyons.

The area is near the center of the vast Colorado Plateau Province, which includes major portions of Utah, Colorado, Arizona, and New Mexico. It includes the east-central portion of the Canyonlands subdivision of the province. A characteristic feature of the Canyonlands is its horizontal rock structure wasting at the edges by erosional processes, leaving steep escarpments. In places a series of beds up to 1,000 feet thick has eroded away for miles while the remaining portion has remained largely intact. Usually the retreating escarpment is not a straight, vertical front but is fringed by numerous canyon tributaries. Thus, weathering

forces attack not only from the front but also from the flanks and rear. A common result is an isolated mass left standing for a while in front of the line. In their long-range erosion cycle the colorful canyons of this area are about at their maximum of grandeur. The escarpments continue to recede while intricate canyons continue to increase in depth and number.

The Great Sage Plain in the southeast portion is one of the study area's distinctive features. In distant views from the Abajo Mountains, the plain appears as a broad expanse of level land, sage covered except for parts that have been cleared and cultivated. Although there are occasional canyons hundreds of feet deep in the plain, these escape notice from high level views unless they are in the immediate foreground. From the bottom of these interlaced canyons the country seems to be made up of cliffs and gorges that would justify the term "mountains." The substructure of this wide flat is the strong Dakota sandstone from which most of the higher and weaker cretaceous beds have been stripped.

The Dakota sandstone is a poor soil maker so that the Great Sage Plain is mostly barren. Exceptions are small areas, as near the Abajo Mountains, where the overlying Mancos shale has not been wholly carried away, and larger areas farther east where deep red soils have been carried in by winds from the southwest. In these places the topography is faintly rolling and the soils are fertile. Irrigation farming is practiced on fertile lands that can be served from the small streams that flow from the mountains. Beans and wheat are grown without irrigation on the deep aeolian soils.

West of the Great Sage Plain, astride the Utah-Arizona border, is the Monument Uplift 100 miles long from north to south and 40 to 50 miles wide. Structurally this large area of horizontal rocks is raised several thousand feet. The landscape on the part of this uplift that is south of the San Juan River is characterized by great steep-sided mesas and buttes of red Triassic rocks. These are the "monuments" that give name to the district.

Extending southward from the base of the Abajo Mountains into Arizona is a sharply defined fault known as Comb Ridge. The portion of the ridge north of the San Juan River forms a demarcation line between areas of different topography. The area west of the ridge is characterized by deep, colorful gorges while the east side has rolling hills, numerous washes and gullies, and is less scenic.

Within the study area are a number of volcanic and orographic features in which the country deviates from a typical plateau character. The La Sal and Abajo Mountains are a group of laccoliths rising above the plateau surface. Of similar character are mountains near the border of the study area, including Ute Peak near Mesa Verde, the Carrizo Mountains in the northeast corner of Arizona, and Navajo Mountain on the Utah-Arizona

boundary. The Navajo Mountain, at an elevation of 10,388 feet and standing about 5,000 feet above the surrounding plateau, is of special interest because it is so young that its igneous rocks are still entirely covered with sedimentary material.

Elevations within the study area range from 13,089 feet on top of Mt. Peale in the La Sal Mountains to 3,160 feet near the point now inundated by Lake Powell, where the Colorado River crosses into Arizona.

The Colorado River, forming the northwest boundary of most of the study area, flows in a deep, rugged canyon with many beautiful entrenched meanders receiving tributaries in similar canyons. The San Juan, Dolores, and Green Rivers flowing on or near other boundaries of the area are also deeply entrenched. The headwaters of these rivers are in mountains located great distances north and east of the study area. Streams originating within the area are small and most of them flow only intermittently.

Soil Erosion

Soil erosion caused by both wind and water is a serious problem in many parts of the study area. Both causes of erosion have had a pronounced effect over long periods of time in shaping the topography. The aeolian soils of the Monticello Area extending many miles eastward from the base of the Abajo Mountains have been carried there from wind-carved locations such as Monument Valley. While the rapid erosion rate that characterizes this region is troublesome to modern residents and planners of resource developments, it is largely the erosive forces operating over the centuries that have carved out the unique and scenic landscape.

Wind erosion occurs particularly in areas of sparse vegetation and low precipitation. It is most active in the south and west parts of San Juan County in (1) the vicinity of Bluff and Mexican Hat and extending south of the San Juan River, (2) an area extending northeast from the junction of the San Juan and Colorado Rivers, (3) an area immediately east of the Colorado River and adjacent to Utah Highway 95, and (4) Lockhart Basin east of Canyonlands National Park.

Water erosion is prevalent throughout the study area. It is generally caused by spring runoff and by torrential but brief rainstorms that commonly occur during the late summer and early fall. Great volumes of soil are carried away by water. Illustrative of this is the fact that the sediment load carried by the San Juan River at Bluff averaged about 46 million tons annually for the 1930-48 period. This is equivalent to an average of 1.46 acre-feet of sediment annually from each square mile of the river's drainage area above Bluff. Of course, only a small part of the drainage area above Bluff is in the study area. About the same erosion rate per square mile, however, is estimated for White Canyon, an intermittent stream entirely within the study area that enters the Colorado

River near Hite, Utah. Erosion caused by flood flows frequently cuts out diversion structures, deposits sediment in canals, ditches, and on developed lands, or washes away from farm lands near the streams. Sediment deposition in reservoirs is a factor requiring special consideration in planning new water resource developments.

Man's activities also influence erosion rates. Problems are created in places by excessive removal of vegetation and by wanton cutting of the land. On the other hand improved land management programs and water storage projects reduce erosion. Activities such as these have reduced the sediment load of the San Juan River in recent years as discussed in connection with the potential Mexican Hat Project in Chapter VIII.

Climate

The San Juan Area has a dry climate except in the high mountains. Summers are hot and dry with daily temperatures usually reaching highs in the 90's and lows in the 50's and 60's. Maximum temperatures reach 100° almost every year and 105° in about half of the years. Winters are dry and cold but usually not severe. As a rule snowfall amounts to only a few inches during the winter, but freakish storms occasionally deposit much more.

Heaviest rainfall occurs in the spring and fall. Storms from the Pacific Ocean move through the area in March and April while in August and September the area is occasionally subjected to thunderstorms associated with moist air masses moving in from the Gulf of Mexico. A map showing the location of climatological stations and isohyitals of annual precipitation appears on the following page.

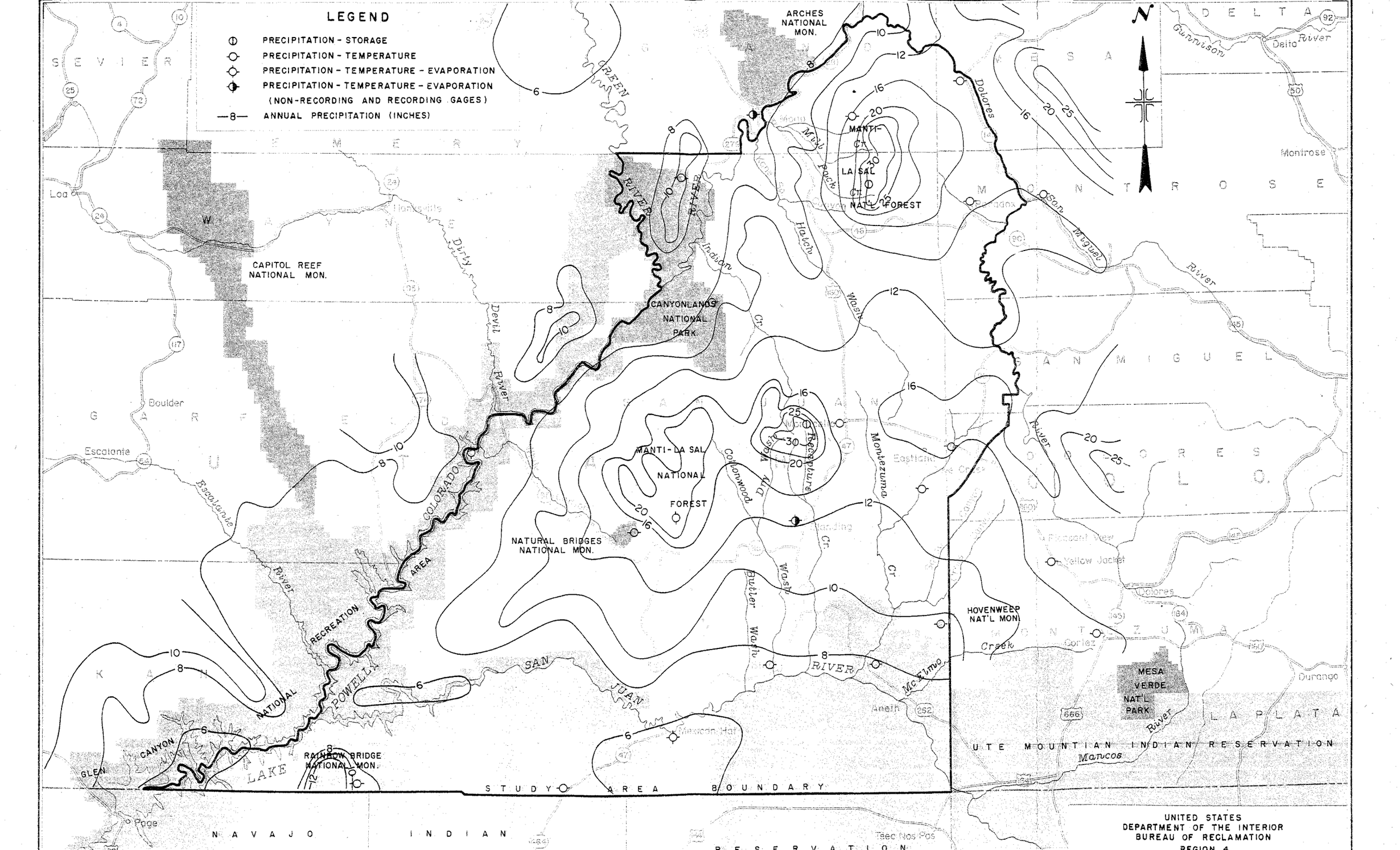
Water year precipitation (October through the following September) at Bluff, Utah, ranged from 3.17 inches to 11.73 inches in all years from 1912 through 1963 except in one year (1941) when it shot up to 18.05 inches. The precipitation at Mexican Hat, Utah, for the 1946-63 period ranged from 2.72 to 9.62 inches.

Evaporation rates are highest at the lower elevations which receive the least precipitation. Generally evaporation rates increase toward the southwestern part of the area.

National forest lands in the La Sal and Abajo Mountains have greater precipitation and lower temperatures than other lands of the study area and provide correspondingly greater amounts of stream runoff.

Native Plant and Animal Life

The dominant plant growth includes Douglas fir, ponderosa pine, and mountain shrub on the Abajo and La Sal Mountains, pinon pine, juniper,


LEGEND
PRECIPITATION - STORAGE
PRECIPITATION - TEMPERATURE
PRECIPITATION - TEMPERATURE - EVAPORATION
PRECIPITATION - TEMPERATURE - EVAPORATION (NON-RECORDING AND RECORDING GAGES)
—8— ANNUAL PRECIPITATION (INCHES)
ARCHES NATIONAL MON.
CAPITOL REEF NATIONAL MON.
CANYONLANDS NATIONAL PARK
MANTI-LA SAL NATIONAL FOREST
NATURAL BRIDGES NATIONAL MON.
GLEN CANYON NATIONAL RECREATION AREA
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and grass flats on the plateaus, and desert shrub and thin grass on the lower benches. Trees are generally confined to the mountains except for wet areas in canyons or around seeps where such varieties as cottonwood, ash, tamarisk, western redbud, and serviceberry may be found. Large areas are sparsely covered with sagebrush, cacti, yucca, and other semidesert plants and grasses. There are also extensive reaches of bare rock and sand.

Mule deer, rodents, birds, and reptiles are typical of the animal life. Bighorn sheep are seen occasionally in or near the canyons of the Green and Colorado Rivers.

Historical Sketch

Human occupancy of the San Juan Area dates back at least to the time of Christ and probably to several centuries B.C. The first known inhabitants were Indians of the Basketmaker or Desert Archaic type. Their original primitive culture appears to have been influenced by evolution from within and from contacts from the south. It thus gradually changed into a culture of the Pueblo II type which reached its height in the period between 900 and 1200 A.D. The people of this period, popularly referred to as Cliff Dwellers, lived by farming and hunting. Evidence of their irrigation practices is found in abandoned ditches and check dams. The Cliff Dwellers withdrew from the area around 1200 A.D., probably migrating to the Kayenta Anasazi Area of northeastern Arizona. Their withdrawal may have been due to encroachment of the Paiute Indians who occupied the region in historic times or possibly to a period of prolonged drouth. The present Indian population is predominantly Navajo.

White men first entered the region when Spanish explorers came in search of gold and Catholic missionaries came to bring Christianity to the Indians. They were followed by other explorers, trappers, railroad surveyors, and men seeking a water route to California. Travelers along the Old Spanish Trail traversed the area. Cattle grazing along the trail continued until about 1850. At times the trail herd numbered in the thousands.

The first settlers were Mormon colonists sent out from northern Utah. An 1855 attempt to settle at Moab failed because of conflict with Indians. A second effort in 1877 established Moab as a permanent community. Bluff was established in 1880 by an expedition of 250 Mormons recruited in south-central Utah. The expedition's difficult 6-month trek in a route across Glen Canyon of the Colorado River at the Hole-in-the-Rock is famous as a remarkable pioneering achievement. The Bluff settlers did not prosper at general farming and turned to cattle raising which became the principal economic activity of the area. Some of the settlers moved northward, founding Monticello in 1888. Blanding was settled in 1905 when irrigation water was brought from the Abajo (Blue) Mountains.

Prospectors rushed into the area in the 1880's, searching for gold and silver. No significant discoveries were made. There have been a

number of active periods of exploration and development of radium, vanadium, and uranium since 1900. The peak of activity was reached with the uranium boom of the 1950's.

The first drilling for oil was done in 1907. Intermittent exploration continued without significant success until the 1950's when the Aneth field was discovered and developed, followed by the Lisbon field a few years later. Oil production is now providing the greater part of the mineral revenues in the area.

Population

The 1968 population of the San Juan County study area is estimated at approximately 16,000. About 70 percent of the people live in the three Utah towns of Moab, Monticello, and Blanding. The area as a whole has less than two people per square mile compared with about 11 for Utah and 17 for Colorado. Vast reaches are completely uninhabited. The population trend line has been gradually upward since 1900 with occasional vibrations caused by excitement in oil and metal developments. For instance, the population of San Juan County, Utah, increased from 5,300 in 1950 to 9,100 in 1960 but fell back to 7,700 by 1964 and rebounded to 9,000 by 1967.

The area population includes about 4,000 Indians living in the Navajo Reservation in Utah. The total population of the Utah portion of the reservation, including non-Indians, is now approximately 5,000 compared with about 2,000 in 1940.

Scenic and Recreational Attractions

The colorful San Juan Area is a wonderland of scenic and recreational attractions. Remote from large population centers, railroads, or heavily traveled highways and mostly lacking good local access roads, the attractions of the area have received widespread attention only in recent years. Two large national recreational reservations made in this decade have contributed to the greater current interest. One is the Canyonlands National Park. The other is an area surrounding Lake Powell that is commonly referred to as the Glen Canyon National Recreation Area. This area of public land, withdrawn by the Bureau of Reclamation, is by agreement administered jointly by the Bureau and the National Park Service. Legislation that would establish the area as the Glen Canyon National Recreation Area is pending before the 91st Congress. Among other recreational attractions are Rainbow Bridge, Hovenweep and Natural Bridges National Monuments, La Sal Division of the Manti-La Sal National Forest, and Dead Horse Point, Indian Creek, and Goosenecks State Parks. Monument Valley and numerous other points of interest are also widely known scenic and recreational attractions. Many western movies have been filmed in the area because of colorful and majestically shaped rock formations. The Utah portion of the Navajo Indian Reservation is also in the study area.

Glen Canyon National Recreation Area

When established by legislation the Glen Canyon National Recreation Area will include more than a million acres of land along the 257-mile reach of the Colorado River extending upstream from the area around Glen Canyon Dam. It will also include the north side of a 75-mile section of the San Juan River above the river's confluence with the Colorado River. The reserved area facilitates administration by the National Park Service of recreation at Lake Powell, formed by Glen Canyon Dam. The dam was constructed by the Bureau of Reclamation in the 1957-64 period. The lake, when filled, will be 186 miles long, the longest man-made lake in the United States, with 1,800 miles of canyon-indented shoreline.

Although only a few years old and not yet filled to capacity or easily accessible at many points, Lake Powell is widely acclaimed for its unique beauty. Its bluish-green water, deep and clear, is set between steep, picturesque walls of rust-colored sandstone, with watery fingers winding through scores of narrow side canyons. Boat excursioners into the new canyons occasionally locate previously undiscovered cliff dwellings, pictographs, rock paintings, arches, and waterfalls. Visitors to the recreation area numbered 359,660 in 1966. Until recently, recreational access to Lake Powell has been largely limited to the highly developed Wahweap Area near Glen Canyon Dam. The important Bullfrog Basin, midway up the reservoir, was made more easily accessible by the 1968 completion of Utah Highway 276 which connects the basin with Utah Highway 95 which is also being improved. Unimproved roads in San Juan County extend westward to Lake Powell at Red Canyon and Halls Crossing.

Canyonlands National Park

Created in 1964, Canyonlands is one of America's newest national parks. It covers 257,000 acres in San Juan, Wayne, and Garfield Counties, Utah, in an area surrounding the junction of the Green and Colorado Rivers. The park provides some of the Nation's most unusual and most undisturbed scenery. The landscape includes arches, needles, spires, broad plains, steep escarpments, bold mesas, and crenelated buttes. The Colorado and Green Rivers which slice through the park have been the greatest shapers of the scenery. Both rivers are entrenched in labyrinthine gorges and below their confluence the rivers enter the roaring depths of Cataract Canyon.

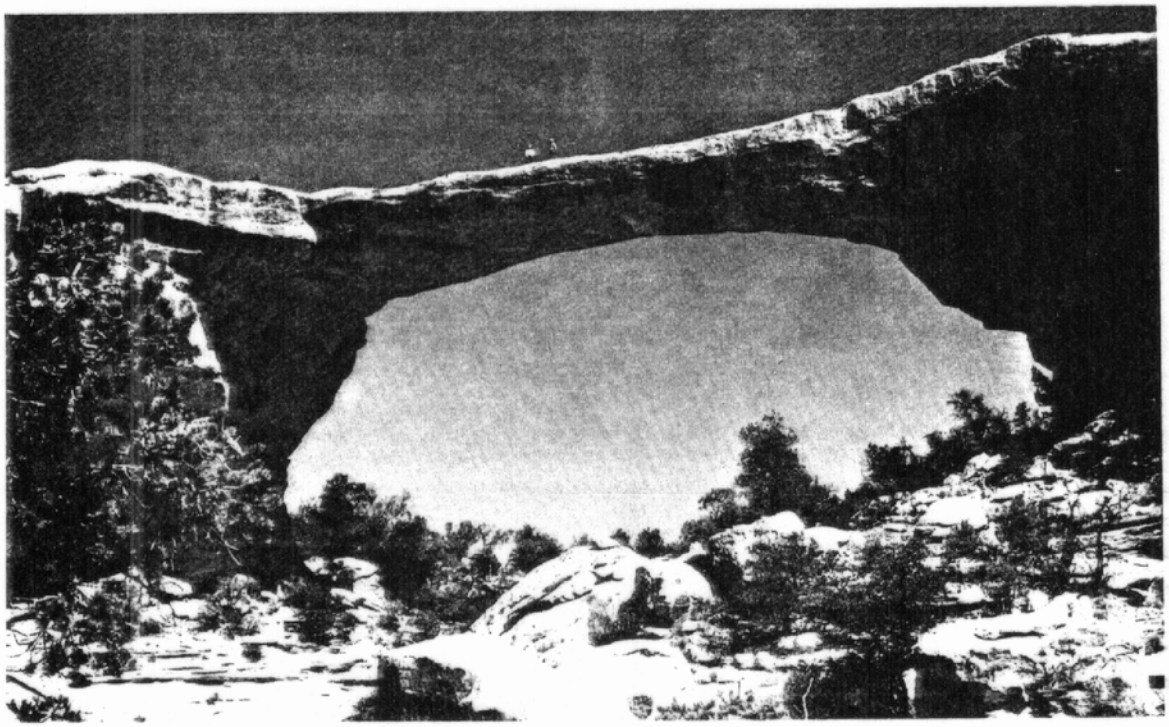
Throughout the park adventurous visitors can make trips by jeep or by foot into the intricate canyons or around imposing rock formations. Parts of the park will remain wild back country, suitable for pack trip explorations on horseback. Since Canyonlands National Park is a recent addition to the National Park system, the work of constructing improvements and visitor facilities is only beginning. Camping and picnicking sites are being developed, trails marked for hiking, and roads constructed for auto and jeep trips.

Rainbow Bridge National Monument

The 278-foot span of Rainbow Bridge arches gracefully to a height of 309 feet above Bridge Canyon, making it large enough to straddle the nation's Capitol Building in Washington, D.C. Following its discovery in 1909, the bridge was designated a national monument in 1910. Until creation of Lake Powell, Rainbow Bridge had limited accessibility, but many boaters now tie up at the lake's edge and make the short hike to the bridge. Guided boat tours to the bridge are available from concession sites on the lake.

Natural Bridges National Monument

Natural Bridges National Monument located near the center of San Juan County is an area of brilliantly colored cliffs, tortuous box canyons, pinnacles, and arches. Three natural bridges within the monument with spans of 180, 206, and 268 feet are among the largest known. One of the bridges spans a 600-foot-deep canyon. The Hopi names of Kachina, Owachomo, and Sipapu have been given these features. A new loop road now permits easy auto access to points overlooking the bridges. Visitors to the monument increased 360 percent in a 6-year period, from 6,500 in 1960 to 29,780 in 1966. The bridges were discovered by Cass Hite, a prospector, in 1883. National publicity was given the area in 1904, and in 1908 President Theodore Roosevelt proclaimed the area a national monument.



Shortest in both height and span of the three bridges in the Natural Bridges National Monument, the Owachomo Bridge, shown above, has a shorter life expectancy than the other two.

Hovenweep National Monument

Hovenweep National Monument, partly in Utah and partly in Colorado, contains six groups of prehistoric towers, pueblos, and cliff dwellings built by Pueblo Indians. The small, 500-acre monument, lying in a lonely canyon country, appropriately takes its name from an Indian word for "deserted valley." Indians who settled here about 400 A.D. were slowly driven from their farm lands into this more fortified location by later nomadic tribes. Continued pressures from other tribes or possibly a prolonged drouth forced them to completely abandon their "deserted valley" about 1200 A.D. Even today, the area remains comparatively untouched by contemporary civilization, having no paved roads, stores, or tourist accommodations except campgrounds.

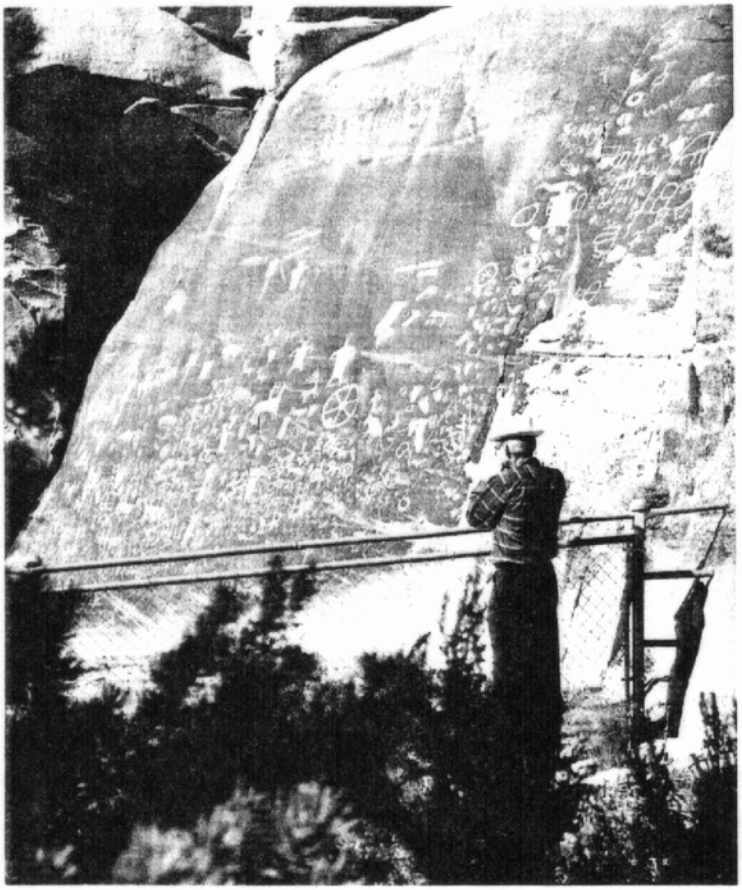
State parks

Three Utah State Parks are in San Juan County. Of the three only the Dead Horse Point State Park is currently developed.

Dead Horse Point State Park offers a panorama of Canyonlands National Park seen from a commanding plateau overlook. The magnificent view from the point shows all three levels of the Canyonlands--the Rim, the Intermediate Plateau, and the Colorado River. The view extends to the forested Elk Ridge and the distant Abajo Mountains.

View of Colorado River from Dead Horse Point State Park. Road in picture is Shafer Trail, recommended only for four-wheel drive travel.

Newspaper Rock is the feature attraction of Indian Creek State Park located about 20 airline miles northwest of Monticello. Here the literary contributions of three early cultures are displayed over many square yards of sandstone.



Indian petroglyphs cover Newspaper Rock in Indian Creek State Park.

The Goosenecks State Park provides a commanding view of the Great Goosenecks of the San Juan River. From an observation level 1,200 feet above the river the visitor sees a classic example of erosion cut by a meandering stream. This phenomenon of nature cuts through many centuries of time and is discussed in most textbooks on geology. Across the river from the viewpoint are the Navajo Indian Reservation and Monument Valley.

Archeological sites

Places of archeological interest are distributed throughout the study area. One, located in Grand Gulch, an intermittent south-flowing tributary of the San Juan River, is a "type site" for Basketmaker culture. It was first recognized in the 1890's by Richard Wetherill. A number of points of archeological interest are also concentrated in the Hovenweep National Monument and in nearby Squaw Point and Montezuma Areas. These are essentially an extension of the Mesa Verde Area of southwestern Colorado. Numerous other sites in the study area are generally small and rather widely dispersed. A number are located in the Monticello Ranger District of the Manti-La Sal National Forest. An inventory by the Bureau of Land Management and the University of Colorado, as yet only two-thirds complete, has turned up 1,400 archeological sites in the 158,000-acre McElmo Unit in southwestern Colorado adjacent to the study area.

Other important attractions

Many important scenic and recreational attractions in addition to those described above are located in the extensive public land area administered by the Bureau of Land Management or the Forest Service or are within the Navajo Indian Reservation. Further reference to these attractions is made in Chapters IV and VII.

Economic Development

Until the 1940's agriculture was the principal industry in the San Juan Area. At about that time agricultural development leveled off and, following the national trend, farms have increased in size and decreased in number. Agricultural employment dropped from around 2,200 people in 1940 to 500 in 1965, according to estimates based on Utah State Employment Service data. About 160,000 acres are cultivated in rotation, but only about 40,000 acres are cropped annually. The noncropped cultivated land is in pasture or fallow or is idle. About 17,500 acres are under irrigation systems but only about 13,000 acres are usually irrigated. There are probably less than 200 full-time farms, mostly of the cash-grain or sheep and cattle type. There is little dairying or intensive-type production in such crops as fruit and vegetables.

Mining is an important industry in the area but is subject to wide fluctuations in activity, as discussed in Chapter VI. The value of mineral production in the area in the last 10 years has varied between $75 million and $150 million and has been dominated by petroleum and uranium. Petroleum currently accounts for 75 to 80 percent of the production value, uranium and vanadium 7 to 15 percent, and potash 5 percent. Employment in mining grew from 125 people in 1940 to around 2,000 in 1960. It has since fallen off to about 1,200 at present but still exceeds the employment in any other single industry.

Recreation or tourism in the area is in an increasing trend and is making an important contribution to the local economy. A 1962 study by the University of Utah indicated that as much as 18 percent of the employment is directly or indirectly dependent upon recreation.

With more than 80 percent of the land in the San Juan Area in government ownership or in an Indian reservation, government employment is relatively high, and among industries it is second only to mining in the number of people employed. Government employment extends into the several national parks, monuments, recreational areas, forests, and other public land areas. Some of it also relates to roads and highways which are lengthy in proportion to the sparse population.

Trade, service, and transportation industries are also important in the area's economy and provide employment for many people.

CHAPTER III

ARABLE LANDS

Approximately 400,000 acres of arable land are estimated to be located in the San Juan study area, mostly in the eastern portion. This acreage was estimated by delineating lands that appeared to be arable on 15-minute quadrangle sheets of the Geological Survey. The gross acreage of each area was then reduced by a certain percentage to arrive at an acreage expected to be found arable if a detailed land classification were made.1/ The Bureau of Indian Affairs participated in estimating arable acreages in the Navajo Indian Reservation. Approximately 17,500 acres of the arable land are under irrigation systems but only about 13,000 acres are usually irrigated. Only about 4,000 acres have a full irrigation water supply. Approximately 160,000 acres are dry-farmed. The dry farm land is located in the vicinity of Monticello, Blanding, and La Sal, Utah, and Northdale, Colo.

Locations of the land areas are shown on the map on the following page. A tabulation of the arable land acreages by separate areas is shown on page 25. The approximate average annual frost-free period above 32° is also shown in the table for each area.

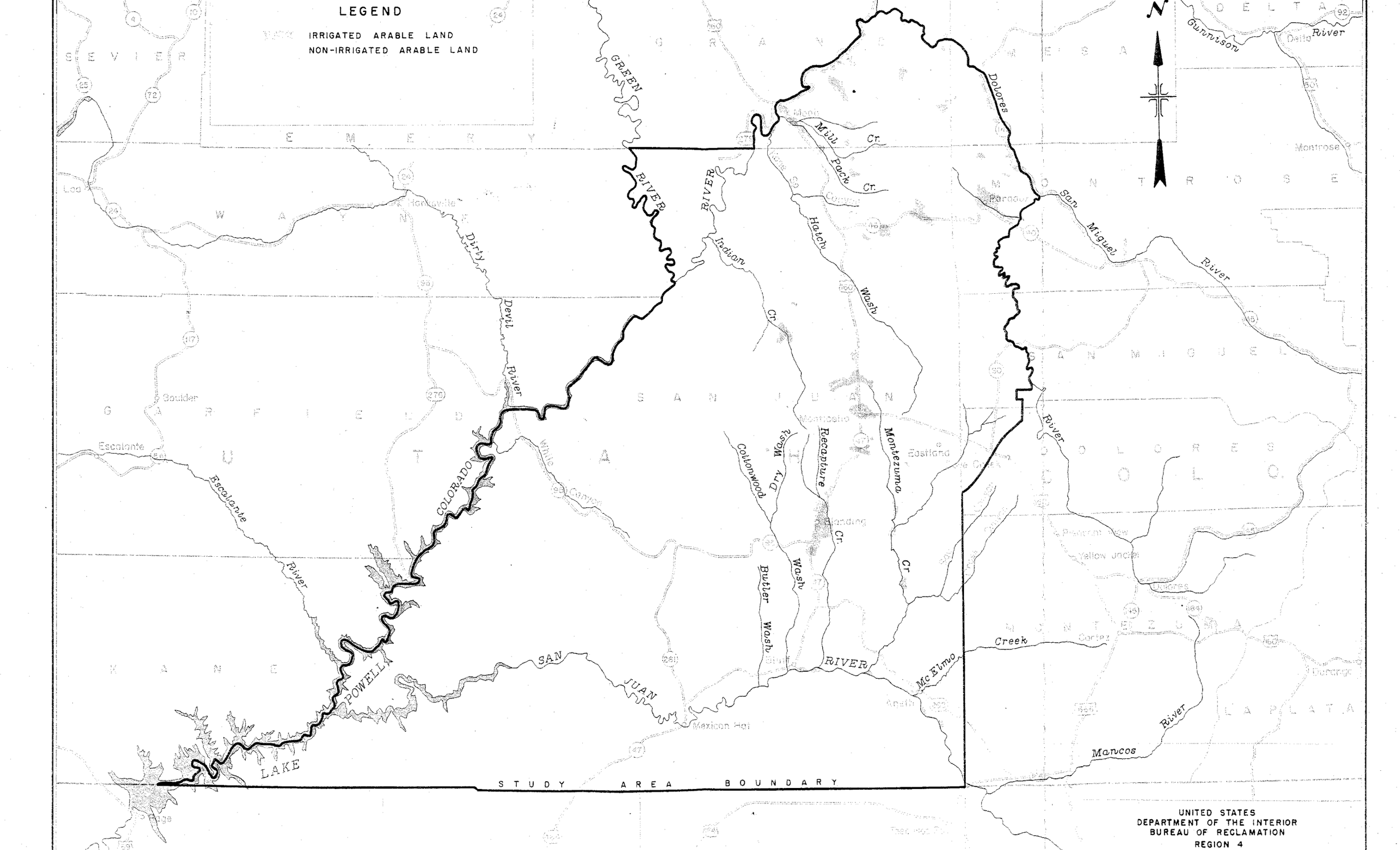
Land drainage characteristics of the Spanish Valley, Bluff, and West Paradox Areas were determined from semidetailed studies made for earlier project investigations. Rough drainage appraisals of other arable land areas were made by field inspection.

Dolores Area

The Dolores Area consists of scattered tracts of arable land extending along the lower 45 miles of the Dolores River in Utah and Colorado. Also included are lands in Sinbad Valley on Salt Creek and lands along Roc Creek, both tributaries of the Dolores River in Colorado. Data for the Utah and Colorado portions of the Dolores Area are separately tabulated on page 25.

Except for a larger land area in Sinbad Valley, most of the arable lands are in strips 300 to 1,500 feet wide on both sides of the Dolores

1/ Reduction percentages were based on experience gained from earlier land classification surveys of small parts of the area. These included surveys made for the potential Dolores, San Miguel, and Pack Creek Projects and for lands in the Bluff, Utah, Area. Although land classes were determined in these surveys, no attempt was made to project land classes into the study area as a whole.


LEGEND
IRRIGATED ARABLE LAND
NON-IRRIGATED ARABLE LAND
GREEN RIVER
COLORADO RIVER
Dirty Devil River
Escalante River
POWELL LAKE
SAN JUAN RIVER
Indian Cr.
Hatch Wash
Dry Wash
Recapture Cr.
Montezuma Cr.
Butler Wash
Cottonwood
Mill Cr.
Pack Cr.
Dolores River
San Miguel River
McElmo Creek
Marcos River
Gunnison River
Delta
Montrose
Ouray
Escalante
Boulder
Mexican Hat
Cortez
Durango
La Plata
Montezuma
Dolores
San Miguel
Garfield
Kane
Wayne
Sevier
Emery
Grand
Mesa
Delta
Ouray
Montrose
STUDY AREA BOUNDARY
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
REGION 4

Estimated arable land area and frost-free period

Name of area	Arable lands (acres)			Average frost-free period (days)
	Irrigation rotation[1]	Non-irrigated	Total	
Utah				
Dolores	120	480	600	175
Fisher Valley	420	1,180	1,600	125-175
Castleton	1,000	1,300	2,300	50-180
Spanish Valley	2,430	1,570	4,000	125-190
Lisbon Valley	2,600	28,500	31,100	136
Dry Valley	90	39,710	39,800	125-150
Indian Creek	570	1,430	2,000	150
Monticello	3,000	118,200	121,200	100-134
Blanding	2,350	57,950	60,300	149
Montezuma Creek	420	18,180	18,600	130-150
Aneth	90	1,910	2,000	190
Bluff	170	36,430	36,600	167
Natural Bridges	0	32,300	32,300	150
Subtotal--Utah	13,260	339,140	352,400	
Colorado				
Dolores	540	860	1,400	130-175
West Paradox	3,600	4,000	7,600	130
Little Gypsum	100	4,800	4,900	130-140
Northdale		33,700	33,700	100-150
Subtotal--Colorado	4,240	43,360	47,600	
Total	17,500	382,500	400,000	

1/ Some of this land is not irrigated every year.

River in places where its canyon is broad enough to permit cultivation. Most tracts occupy alluvial fans formed at the mouths of small side drainages. The soils, derived from surrounding sandstone formations, are medium to coarse textured and are generally low in salts and alkali. The lands are gently to moderately sloping and are dissected by occasional gullies extending toward the river. Land elevations range from 4,200 to 5,800 feet. The lands have adequate natural drainage into the Dolores River.

Fisher Valley Area

The Fisher Valley Area includes lands in Fisher and Professor Valleys and along the Colorado River near the mouths of Onion and Professor Creeks. Soils of the area have been formed from alluvial outwash eroded from sandstone formations. They are mostly medium to coarse textured. Land elevations range from 4,200 feet near the river to 6,000 feet in Fisher Valley. If developed for irrigation, lands in Fisher and Professor Valleys would require provisions for drainage.

Castleton Area

The Castleton Area is south of the Fisher Area and includes Castle Valley northwest of the La Sal Mountains and Kirks Basin and Taylor Flat on the northeast slope of the mountains.

Castle Valley soils are mostly coarse textured and contain sandstone fragments and boulders on the upper fans. Irrigated soils in the valley are well leached of salt and are moderately or highly productive when well supplied with water and fertilizer. Land elevations range from 4,400 to 6,800 feet. Only a moderate drainage requirement would develop with additional irrigation.

Kirks Basin and Taylor Flat lands have elevations of from 8,000 to 8,500 feet. Soils of these mountain lands are highly organic loams, clay loams, and clays intermixed on Taylor Flat with stones. Because of the short frost-free period, irrigated crops would be limited to pasture or to one cutting of alfalfa. There would be no requirement for drainage under this cropping pattern.

Spanish Valley Area

The Spanish Valley Area includes lands in Spanish and Moab Valleys at elevations of from 4,000 to 5,500 feet and lands on Wilson and South Mesas at elevations of 7,000 feet. Spanish Valley is the upper portion and Moab Valley the lower portion of the same valley. The alluvial valley soils were derived from surrounding sandstone formations. They are

predominantly deep, sandy loams and loamy sands and have good permeability, restricted available moisture capacity, and low saline-sodic content. With sufficient irrigation water and fertilizers they are moderately or highly productive. The long growing season is favorable to the production of a wide range of diversified crops. The Wilson and South Mesa lands lie high above the valley on the west slope of the La Sal Mountains. Mesa soils are medium to fine textured, high in organic matter, and are almost free of salt and alkali. The short growing season on the mesas restricts crops to alfalfa, small grains, pasture, and other livestock feeds.

The deep, permeable valley soils have a high irrigation water requirement. Much of any new irrigation water applied to the land would seep into the gravel substrata and move down the valley toward the Colorado River. At locations where the ground water movement would be impeded, waterlogging would result, creating a major requirement for drainage. This situation would be likely to occur in the lower reaches of Spanish Valley and in Moab Valley. Drainage conditions on mesa lands have not been appraised.

Lisbon Valley Area

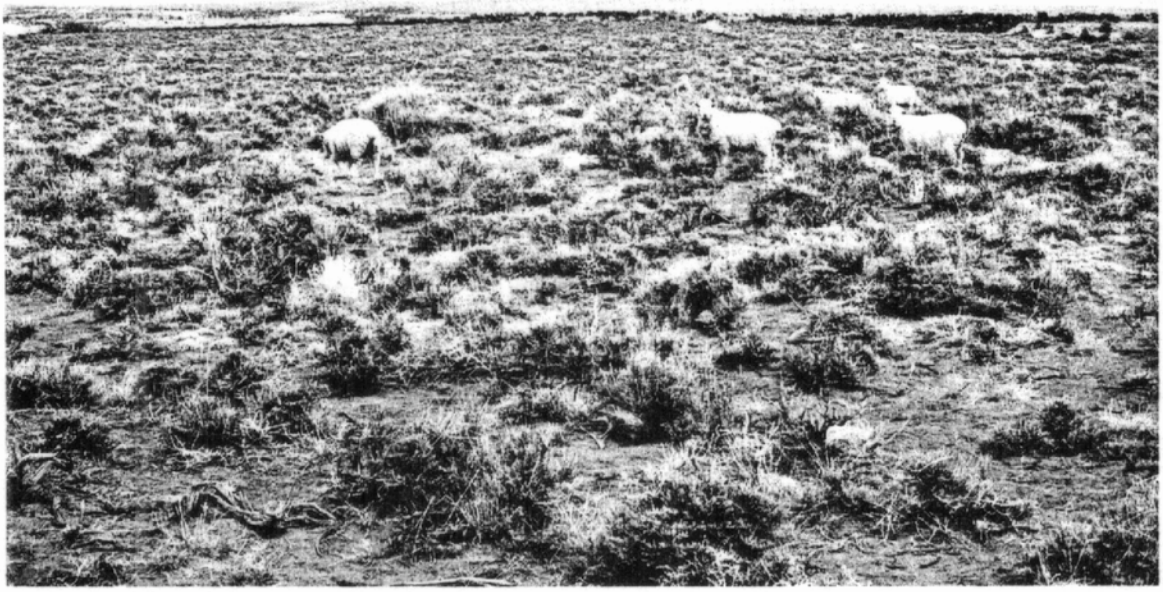
Included in the Lisbon Valley Area are lands (1) in Lisbon and Big Indian Valleys, (2) on the southern foot slopes of the La Sal Mountains near La Sal and Old La Sal, Utah, and (3) on Wray, Middle, and Island Mesas. The valleys include about 4,700 acres of arable land and the remainder of the area, about 26,400 acres, is on the foot slopes and mesas. Land elevations range from 6,000 to 7,500 feet.

Valley lands have deep alluvial soils derived from sandstone and some shale materials. The soils, located mostly on moderately sloping fans, are coarse to medium textured and are low in salt and alkali. Other lands of the area have medium-textured soils that are underlain at moderate depths by sandstone or occasionally by cobble on the lower slopes of the La Sal Mountains. Arable lands of the area would have a moderate to low drainage requirement under full irrigation.

Dry Valley Area

The Dry Valley Area is located west of the Lisbon Valley Area. Elevations range from 5,500 to 6,500 feet. Soils are moderately shallow over massive, crossbedded Jurassic sandstone, which is exposed in many places. On alluvial fans the soils are mostly coarse textured, and on narrow flood plains of Hatch and East Canyon washes soils are medium to fine textured. The lands are quite free of salt and alkali except for accumulations along these washes. The undulating surface has resulted partly from wind action. Most of the arable lands would require

extensive drainage facilities under irrigation because of the flat terrain and underlying impermeable sandstone barrier.



Arable dry lands used as grazing range for sheep in Dry Valley Area. La Sal Mountains in background.

Indian Creek Area

The Indian Creek Area includes lands along both sides of Indian Creek and its tributary, Cottonwood Creek, which drain the north and west slopes of the Abajo Mountains. The lands, at elevations of 5,000 to 6,000 feet, occur in narrow tracts where the stream canyons are wide enough to permit cultivation. Soils are coarse- or medium-textured alluviums derived from surrounding sandstone. The lands would have a moderate to low drainage requirement under full irrigation.

Monticello Area

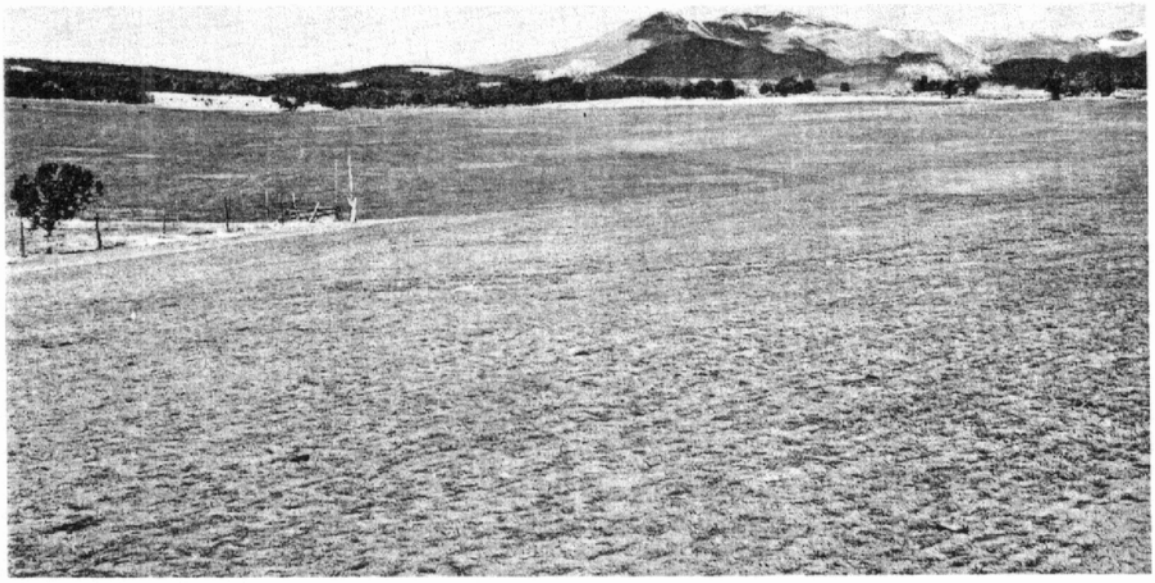
The greatest land resources in San Juan County are in the Monticello Area. Area lands extend from the Abajo Mountains eastward to the

Utah-Colorado State line. Approximately 3,000 acres of arable land near Monticello are irrigated from small mountain streams, about 70,000 acres farther east are dry-farmed, and the remaining 48,000 acres are not cultivated. Almost all of the Monticello Area lands are on the Great Sage Plain. The surface of the plain is undulating or rolling with a wind-created swale and ridge type of topography. The southern sections are dissected by steep-walled canyons of intermittent streams tributary to the San Juan River. Medium-textured, reddish-brown aeolian soils occur over the greater part of the area. The soils are underlain mostly by creviced Dakota sandstone. Lands near the base of the Abajo Mountains are underlain by cobble, and lands in the bottom of a broad syncline or trough extending eastward through the center of the area from a point about 4 miles east of Monticello are underlain by Mancos shale. Soils in the syncline are derived mainly from the gray shale but are mixed with reddish-brown, wind-laid material.

The aeolian soils of the area have good moisture-holding capacity, high inherent fertility, and are free from harmful quantities of salts or alkali. The general area has good air drainage and a favorable growing season for such a high elevation (7,100 feet at Monticello). Soils in the bottom of the syncline have slow permeability, low fertility, and sufficient salt to cause severe problems under irrigation. Air drainage in this part of the area is poor and the growing season shorter than in other parts. Higher lands of the area that lie on the portions of the synclinal slopes that are deeply dissected by streams would have a low drainage requirement. Lands on the lightly dissected slopes would have a moderate to high drainage requirement with irrigation. Drainage deficiencies increase downslope on all lands, becoming unrectifiable in the bottom of the syncline and in some of the swales.

Blanding Area

Blanding Area lands lie on a series of finger-like mesas between deep parallel canyons of intermittent tributaries of the San Juan River. These lands are an extension of the Monticello Area lands and are similar to lands in the southern part of that area. The swale and ridge type of topography is less pronounced in the Blanding Area, however, and the aeolian soils are more yellowish brown with less structural development because of lower rainfall. The soils are moderately deep over creviced Dakota sandstone. They are permeable, fertile, and easy to till. They have high moisture absorption and retention capacity and would present no problems of salt or alkali content. Approximately 20,000 acres in the northern part of the area are dry-farmed but low rainfall prevents dryfarming in the southern part. Land elevations range from 5,200 to 7,200 feet. Under irrigation lands on the ridges or mesas would have light to moderate drainage requirements except lands in swales or other low areas where the drainage deficiency would be unrectifiable.



Dry-farmed lands on White Mesa north of Blanding, Utah, in Blanding Area.

Montezuma Creek Area

The Montezuma Creek Area includes lands in the deep canyons of Montezuma Creek and tributaries and on two mesas near the creek's mouth. McCracken Mesa is on the west side and Cajon Mesa, which includes part of Hovenweep National Monument, is on the east side of the creek. Part of the land is in the Navajo Indian Reservation.

The creek bottom lands are in narrow, discontinuous tracts of alluvium in the broader portions of the canyons. Soils are coarse to medium textured and in places contain moderate amounts of salt and alkali which could be leached under irrigation. The lands would have a low drainage requirement. Of about 1,700 acres of arable creek bottom lands approximately 420 acres are presently irrigated. The lands range in elevation from 4,800 to 5,500 feet.

Arable lands on the two mesas total about 16,900 acres, none of which is presently cultivated. Soils are yellowish-red loams and clay loams overlying massive sandstone or shale. They are shallow in the swales and drainage channels but slightly deeper on the intervening gently rolling ridges. Only lands on the crowns of the ridges have a rectifiable drainage deficiency and their drainage requirement would be high with irrigation. Elevations range from 5,000 to 5,500 feet.

Aneth Area

Aneth Area lands extend about 22 miles along both sides of the San Juan River from the Four Corners area downstream to near the mouth of Montezuma Creek. The lands are mostly in small, scattered, irregularly shaped tracts on river flood plain, terrace, and alluvial fan positions. They would have a low drainage requirement with irrigation. Only about 90 acres of the arable land are presently irrigated. Irrigation of the remaining land would require numerous diversions or low pump lifts from the river.

Bluff Area

The Bluff Area includes widely dispersed valley and bench lands centered near Bluff and Mexican Hat, Utah. The larger portion of the land is south of the San Juan River in the Navajo Indian Reservation. The valley lands extend in narrow strips about 20 miles along the river and 15 miles along Comb Wash, a south-flowing tributary. Bench lands are on Bluff, Big, and Lime Ridge Benches north of the river and on reservation lands south of the river. The larger areas of Indian land have been inventoried by the Bureau of Indian Affairs.

The valley lands are similar in character and drainage requirements to those of the Aneth Area. Most of the bench lands have little potential for irrigation because of coarse-textured, shallow soils and hummocky and unstable surfaces resulting from wind action. Bench lands would have a high drainage requirement. Lands in the area range in elevation from 4,300 to 5,200 feet.

Natural Bridges Area

Arable lands of the Natural Bridges Area extend southward from near the Natural Bridges National Monument to near the San Juan River, a distance of about 25 miles. The lands are on a series of mesas known as Cedar and Polly Mesas and Harmony, Grand, and Mormon Flats. Elevations range from 5,800 to 7,000 feet. Under irrigation the lands would likely have only a moderate drainage requirement.

West Paradox Area

West Paradox Valley in Colorado is about 3 miles wide and 8 miles long. It is traversed by West Paradox Creek which heads in the La Sal Mountains of Utah and extends to the Dolores River in Colorado. The deep alluvial valley soils are derived directly from bordering sandstone cliffs and vary from fine sandy loams to loamy fine sands. The

CHAPTER IV

LAND ADMINISTRATION AND SERVICES

About 4,688,000 acres or more than 80 percent of the land in the San Juan Area is either in Federal ownership or in the Navajo Indian Reservation. Federal lands are administered by the National Park Service, the Forest Service, and the Bureau of Land Management. Indian reservation lands are owned by the Navajo Tribe or individual Indians, but assistance in the administration of these lands is provided by the Bureau of Indian Affairs. The approximate acreage involving each agency is shown below.

	Acres
Bureau of Land Management	2,368,000
Forest Service	540,000
National Park Service	780,000
Bureau of Indian Affairs	1,000,000
Total	4,688,000

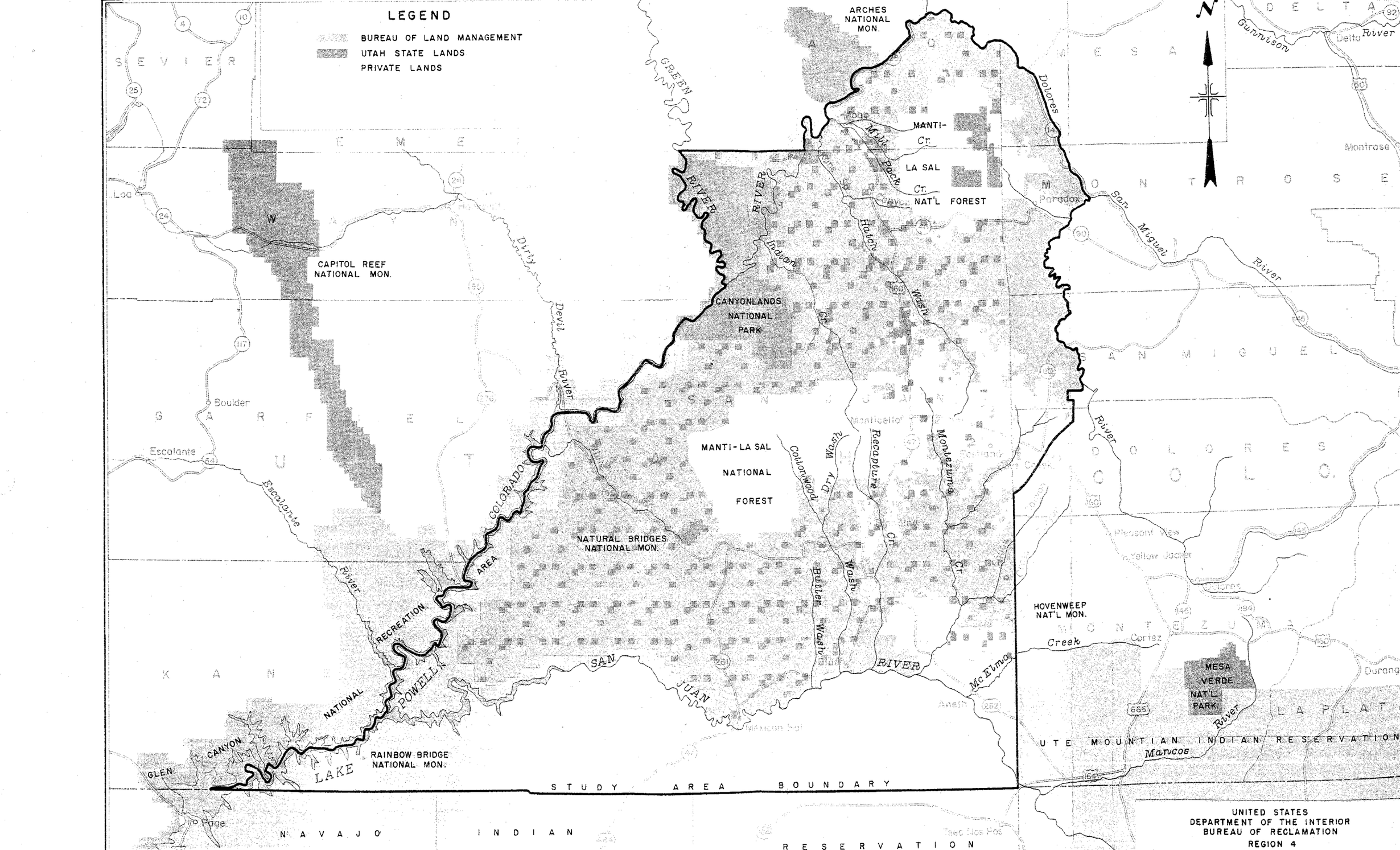
The acreage shown for the National Park Service includes all national monuments in the study area and the portions of Canyonlands National Park and Glen Canyon National Recreation Area that are east of the Colorado and Green Rivers which form the western boundary of the area. If portions of the park and recreation area that are west of these rivers were included, the National Park Service acreage would be almost doubled to 1,370,000 acres. Until the recreation area is established by legislation, the Bureau of Land Management has primary responsibility for land uses within the area except recreation.

The responsibilities of each of the administering agencies and the resources under the care of these agencies are so important in the San Juan Area as to warrant discussion. Although the Soil Conservation Service does not administer Federal lands but provides services in the private sector, its program is also discussed. A land status map of the area is on the following page.

Bureau of Land Management

The Bureau of Land Management (BLM) administers 2,207,000 acres of land within the Utah portion of the San Juan study area or 41 percent of the Utah portion. A similar percentage probably applies to the small part of the study area in Colorado, bringing the total to 2,368,000 acres.

Wildlife in great variety is distributed throughout the area. Diverse recreational attractions, ranging from high quality developed sites in scenic areas with paved access roads to the solitude of primitive and roadless tracts, make recreation a major land use. Large acreages of public domain are under lease for oil, gas, and other mineral explorations


LEGEND
BUREAU OF LAND MANAGEMENT
UTAH STATE LANDS
PRIVATE LANDS
ARCHES NATIONAL MON.
CAPITOL REEF NATIONAL MON.
CANYONLANDS NATIONAL PARK
MANTI-LA SAL NATIONAL FOREST
MANTI-LA SAL NAT'L FOREST
NATURAL BRIDGES NATIONAL MON.
RAINBOW BRIDGE NATIONAL MON.
HOVENWEEP NAT'L MON.
MESA VERDE NAT'L PARK
GLEN CANYON NATIONAL RECREATION AREA
LAKE POWELL
COLORADO RIVER
GREEN RIVER
DOLORES RIVER
SAN JUAN RIVER
SAN MIGUEL RIVER
DIRTY DEVIL RIVER
ESCALANTE RIVER
GUNNISON RIVER
MILL CREEK
PACK CREEK
LA SAL CREEK
INDIAN CREEK
HATCH WASH
COTTONWOOD WASH
DRY WASH
RECAPTURE CREEK
MONTEZUMA CREEK
BUTLER WASH
McELMO CREEK
MARCOS CREEK
SEVIER
EMERY
WAYNE
GARFIELD
KANE
SAN JUAN
MONTROSE
SAN MIGUEL
DOLORES
MONTEZUMA
LA PLATA
MESA
DELTA
UTE MOUNTIAN INDIAN RESERVATION
NAVAJO INDIAN RESERVATION
STUDY AREA BOUNDARY
Loa
Boulder
Escalante
Dirty Devil
Montrose
Paradox
Monticello
Pleasant View
Yellow Jacket
Cortez
Durango
Delta
Gunnison
Aneth
Mexican Hat
Red Mesa
To Page
UNITED STATES
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BUREAU OF RECLAMATION
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or are available for mineral location. Actual production areas are relatively small, involving oil and gas fields and sites near underground mines.

Remote areas administered by BLM were anciently the home of Anasazi Indians whose culture is evidenced in some of the most significant archaeological findings in Utah. The quality and extent of the findings add significant value to the recreation program in the study area as do many other historical sites. An important but not extensive use of public land is for transportation systems and utility lines.

The BLM has responsibility for resource management of public lands under its administration. This includes the administration and improvement of grazing districts to insure an orderly use and development of grazing lands. It also includes responsibility for conducting soil and watershed conservation operations on lands under the jurisdiction of the Department of the Interior. Under the Watershed Protection and Flood Prevention Act, BLM cooperates with the Department of Agriculture, states, and local organizations in carrying out the act's purpose whenever BLM-administered lands and programs are affected.

Two Federal laws pertaining to BLM-administered lands, enacted in 1964, are being tested over a 7-year period to see how well they meet modern needs. The Classification and Multiple Use Act and the Public Land Sale Act are interim legislation pending a report by the Land Law Review Commission. The Classification and Multiple Use Act provides a system for determining which public lands are to be disposed of under applicable public laws and which are to be retained in Federal ownership. Lands retained are to be managed under multiple-use principles to best meet present and future needs of the American people. The BLM is presently making an extensive inventory of public land and its resources and is classifying the land for disposal or retention. About 95 percent of the inventory has been completed in the San Juan study area. The inventory phase will be followed by development of a land use plan. A comprehensive management framework plan for public domain lands in Colorado along Dolores Canyon and in Little Gypsum and West Paradox Valleys is scheduled for completion before 1972. Work done to date has indicated numerous recreation assets along the Dolores River.

In the field of watershed protection it is BLM's goal to maintain and develop a balance between soils, water, and vegetation by preventing or controlling rapid runoff and erosion. Measures are taken to reduce peak stream discharges to improve water quality and preserve future use opportunities on deteriorating land areas with recovery potential. Resource management practices are used whenever possible in lieu of more costly developments. All resource management activities within the San Juan Area affect the watersheds. BLM is working with livestock operators to obtain proper distribution and seasonal use of livestock, road locations are being carefully engineered, efforts are being made to control off-road recreational use, and cooperation is being solicited from exploiters of mineral resources.

Production and utilization of forage are closely related to other management programs on public lands. Allotment management plans are being developed in cooperation with range users. The plans are made in consideration of impacts of livestock on available forage and on wildlife and watershed relationships. Range management is accomplished mainly through management techniques. Capital investments with relation to livestock grazing are generally limited to fences and water developments.

Timber production from public lands in the San Juan Area is minimal. There is a small steady demand for woodland products such as firewood, posts, and poles which will continue to be met from pinon-juniper forests in the area.

Opportunities for outdoor recreation are extensive in this unusual canyonlands country. Development of Glen Canyon Dam and Reservoir and creation of the Canyonlands National Park will draw people into the area and increase recreational pressure on all public lands. BLM provides facilities designed to meet current and anticipated needs for extensive recreational uses such as rockhounding, hunting, sightseeing, and hiking. BLM's recreational program will be coordinated with programs of the National Park Service, Forest Service, and Indian reservations and with state and local programs with a view of accommodating public needs consistent with relationships of other land uses.

BLM considers ecological needs of all fish and wildlife species, including nongame animals and birds. Its responsibility is for management of wildlife habitat on public lands rather than for management of resident wildlife itself.

The study area contains the most significant remaining bighorn sheep habitat in Utah. Management efforts are directed toward maintaining the quality of this habitat to sustain a viable sheep population. There are a number of critical deer winter ranges within the San Juan study area. BLM is working cooperatively with the Utah Division of Fish and Game to mitigate problems of range depletion by deer.

BLM is concerned with improvement and maintenance of aesthetics of the public lands. Consideration is given to preservation and protection of natural beauty in land management decisions. Efforts are being made to educate and supervise the public in prevention of littering which creates an intrusion on natural beauty. Management efforts are also concerned with preservation and interpretation of archaeological, historical, and cultural features of the public lands.

BLM administers the mineral resources on all public lands in the area. Administered activities include location and patenting of mining claims, competitive and noncompetitive mineral leasing, and sale and free use disposal of mineral materials not subject to mining or leasing laws.

Forest Service

The La Sal National Forest was established early in the century and in 1949 was combined with the Manti National Forest in central Utah into the Manti-La Sal National Forest. The La Sal Division of the forest is in the San Juan County study area. The division's two Ranger Districts, Monticello and Moab, stand out like a huge green oasis in the surrounding desert. The forests of aspen, ponderosa pine, spruce, and fir are not far distant from surrounding lower areas of dry mesas and deeply cut, spectacular canyonlands. The Moab Ranger District encompasses about 175,100 acres and includes the entire La Sal Mountain range in Grand and San Juan Counties in Utah and Montrose County in Colorado. The Monticello Ranger District embraces about 365,350 acres in the Abajo Mountain area near the center of San Juan County.

The natural resources of these forest lands are managed in accordance with the principle of multiple use for sustained yields of wood, water, forage, wildlife, and recreation.

Timber has become an economically important resource in the La Sal Division in recent years. Large-scale cutting commenced in 1958 with the development of active markets for saw timber. Lumbering is now an important industry in the area. During 1967 the saw timber cut on the La Sal Division amounted to approximately 15 million board feet. This volume reflects a program of accelerated cut for the removal of overmature timber. Upon completion of this program the annual cut will be approximately 5 million feet of saw timber for the division.

Cutting in the Moab District in 1967 amounted to 1.5 million board feet. One of Utah's largest saw mills, with a capacity of 15 million board feet per year, is operating near Blanding. Three smaller sawmills in the general area also process La Sal Division saw timber. Ponderosa pine, an excellent commercial timber, is currently the principal tree species cut on the La Sal Division.

Forest lands provide summer grazing for cattle and sheep. The Forest Service is working continually with grazing allotment permittees to improve forage conditions by balancing grazing allotment use with available forage supplies on ranges suitable for grazing. In 1967 the La Sal Division furnished summer grazing for 7,365 cattle and 2,762 sheep.

Development of the Canyonlands National Park, Glen Canyon National Recreation Area, Natural Bridges National Monument, and the Arches National Monument, along with better roads, has attracted an ever-increasing number of visitors. The uses of the La Sal Division's recreational resources are increasing proportionally with this influx of tourists. The scenic, archaeological, and recreation values of the forest are especially high when the high elevations, cool climate, and spectacular forest-land

beauty are considered in contrast to the hot, dry, desert aspect of the surrounding lowlands.

Throughout the forest are ghosts of once highly developed Indian civilizations. In many areas, there are pictographs and petroglyphs in caves and along cliff walls, arrowheads, stone grinding bowls, and other artifacts. These things combine with spectacular forest scenery to attract visitors and recreationists in ever-increasing numbers. Eight camp and picnic areas are now maintained in the La Sal Division. More are planned to meet the growing demand.

Wildlife and fish on the area's forests lure numerous hunters and fishermen each year. In 1967, 18,300 hunters and 8,800 fishermen visited the La Sal Division. Hunters harvested about 8,410 deer and 9 elk from these forest lands in 1967. Hunting is regulated to maintain a proper balance between each game species and its habitat and the forage requirements of domestic livestock.

Other wildlife found on the forests are black bear, mountain lion, bobcat, rabbit, hare, sage grouse, and bandtailed pigeon. In addition, the rare Abert or "Tassel-ear" squirrel is found on the La Sal Division. The mourning dove is the most prevalent game bird and receives the greatest hunting pressure. Wild turkeys were introduced into the La Sal Division a number of years ago by the Utah State Fish and Game Department and have been hunted since 1963.

Large areas of forest lands are under lease for oil and gas exploration. Uranium and potash are among the important mineral resources underlying forest areas that are continually being explored for on and under national forest lands.

National Park Service

The National Park Service administers five recreational reservations within the study area--Canyonlands National Park; Natural Bridges, Hovenweep, and Rainbow Bridge National Monuments; and Glen Canyon National Recreation Area. It is primarily responsible for managing the resources of these areas for recreational use. This use is regulated in such a manner as to conserve the scenery, natural and historic objects, and the wildlife in order that these values will remain unimpaired for the enjoyment of future generations.

Three distinct types of areas--natural, historical, and recreational--are included in the national park system.

In natural areas, such as Canyonlands National Park, management is directed toward maintaining and, where necessary, reestablishing indigenous plant and animal life. Physical developments are limited to those

that are necessary so that the least damage possible will be caused to park values.

Within historical areas, such as Hovenweep National Monument, the objective of management is to maintain and, where necessary, restore the historical integrity of structures, sites, and objects significant to the historical story. Physical developments are those necessary to meet management and use objectives without detriment to historical values.

In recreational areas, typified by Glen Canyon National Recreation Area, outdoor recreation is recognized as the primary management objective. Scenic, historical, and other resources within recreational areas are managed compatibly with the primary recreation mission of the area.

An appraisal of present and potential recreation in the San Juan study area by the National Park Service is summarized in Chapter VII.

Bureau of Indian Affairs

The Utah portion of the Navajo Indian Reservation is in the San Juan study area, accounting for about 17 percent of the area's acreage. It is the largest Indian reservation in Utah. Approximately 5,000 people live in this portion of the reservation, including about 4,000 Indians and 1,000 others. A few of the inhabitants reside in the five small communities in the area with the remainder scattered over the entire area.

Nearly all of the reservation lands are tribally owned, with only a small portion owned by individual Indians. Indians use their land to graze livestock, grow crops, develop oil, gas, and other minerals, and provide recreational opportunity. The Bureau of Indian Affairs assists the Indians in developing the economic potential of their land and water resources.

Oil and gas development accounts for most of the mineral activity although prospecting for uranium and other metals has occurred in recent years. Oil and gas discoveries were made in the Aneth extension of the Navajo Reservation following World War II. Subsequent exploration and leasing have made the area one of the principle producing fields in the nation.

Livestock grazing is important on the Navajo lands. About 44 percent of the reservation is range land, providing open grazing for sheep. Cultivated areas are small and are mostly devoted to hay and forage for pasture. Farmers also cultivate small garden tracts.

A Navajo sheepherder has finished the daily watering of his flock among the colorful sandstone formations of Monument Valley.

The Navajo Indians have recently begun to recognize the profit potential of tourist developments on their reservation. Completion of Navajo Route 1 (U.S. 164) in September 1962 opened up the highly scenic northern portion of the reservation for the first time. Connecting U.S. 89 near Tuba City, Ariz., with U.S. 666 at Shiprock, N. Mex., and Cortez, Colo., the new road quickly proved a boon to tourists and commercial travel in the Southwest. No road now exists from Navajo Route 1 to the south shoreline of Lake Powell, but one is planned as explained in Chapter VIII. In addition to providing access to remote areas for school location purposes, the road would offer direct benefit to the Indians by providing land access to recreation sites planned to be developed on the lake shore by the Navajos.

In addition to resource conservation and development work on Indian land, the Bureau of Indian Affairs assists Indians in other forms of

economic development and provides them with community services in the fields of education, welfare, employment assistance, and law enforcement.

Although Utah has assumed responsibility for educating its Indian citizens, the Bureau of Indian Affairs operates three schools and a dormitory for Navajo children from isolated areas. The Intermountain Boarding School at Brigham City, Utah, enrolls over 2,000 Navajo pupils from Arizona, New Mexico, and Utah who lack adequate educational opportunities on the reservation. It includes elementary and secondary grades, as well as special accelerated courses required by over-age, undereducated children. It also assists Indians in obtaining temporary and seasonal employment. Two other boarding schools serve the needs of Navajo children on the Utah portion of the reservation, and a Bureau-operated dormitory at Richfield provides boarding accommodations for Navajo pupils attending local public schools. Two Utah school districts, Uintah and Sevier, enroll Indian children from nontaxable lands since the districts receive financial assistance for the purpose from the Bureau of Indian Affairs.

The Bureau conducts a welfare program on the Utah portion of the Navajo Reservation. General assistance is provided to needy Indians who do not meet eligibility requirements for the various public assistance programs. There is also a tribal welfare program on the Navajo Reservation which offers emergency assistance, school clothing, work projects, and meets certain medical needs.

Unsanitary conditions exist in many Indian homes and communities because of a lack of potable water and sanitary facilities. A project to provide water for a number of Navajo homes near Aneth, Utah, was partially constructed in 1962 as a joint effort of the Public Health Service and Utah Indian Affairs Commission. Completion of the project was planned in 1968. Public Health and Navajo Tribal officials are hopeful that the Aneth Project will set the stage for a continuation of a program reaching throughout the reservation area in Utah. It is believed that about 80 percent of the 4,000 Indians living in this area can be served with running water, on-premise sanitary facilities, and individual waste disposal facilities. The remaining 20 percent will be provided protected water supplies within the areas in which they reside. The construction cost of this program is estimated at $2,000,000. The normal procedure under the Indian Sanitation Facilities Act of 1959 (P.L. 86-121) is for the Public Health Service to provide funds for the purchase of materials and employment of engineering service and skilled labor required for installation. The Navajo Tribe provides funds for labor and construction equipment.

Soil Conservation Service

The Soil Conservation Service is the technical soil and water conservation agency of the Department of Agriculture. It helps land owners

individually or in groups do conservation work on the land. It provides this assistance mainly through locally organized soil conservation districts. Such work is a foundation for watershed protection and other soil and water conservation activities in rural areas.

The San Juan Area is covered by the Grand and San Juan Soil Conservation Districts in Utah and in the Dove Creek, Glade Park, and San Miguel Basin Districts in Colorado. Work unit offices are maintained in Monticello, Utah, and Dove Creek and Norwood, Colo. The program of the Soil Conservation Service has been actively carried out in these districts. One of the activities was a feasibility investigation of the West Paradox Project, reported in Chapter IX.

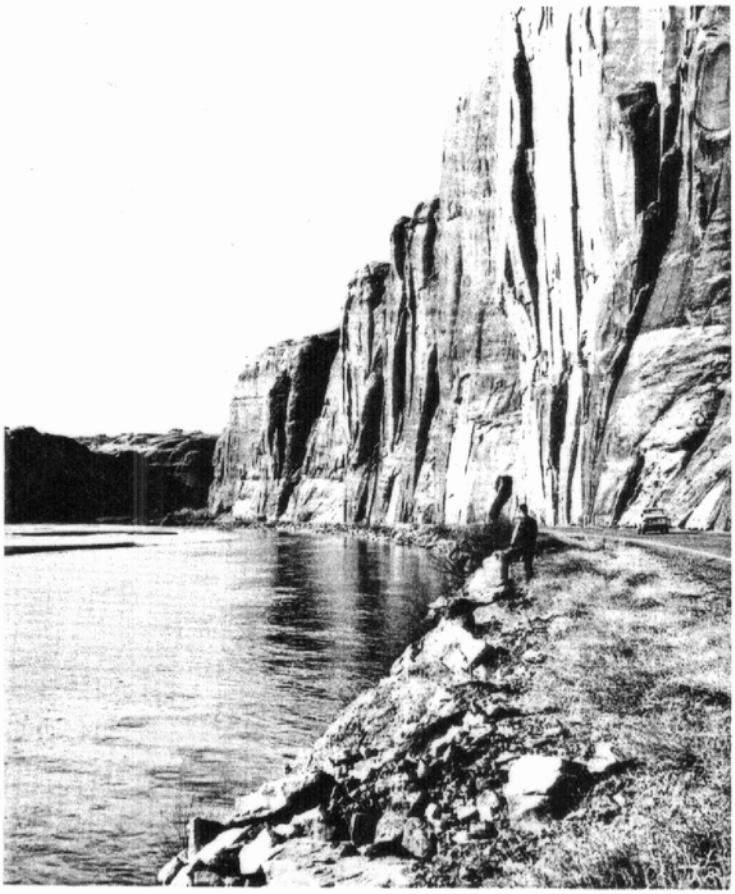
Seven major categories of outdoor recreation on private land are recognized by the Soil Conservation Service. These are: (1) vacation farms, (2) picnic and sports centers, (3) fishing waters, (4) camping, scenery, natural recreation areas and wildlife refuges, (5) hunting areas, (6) hunting preserves, and (7) selling recreational land or recreation-use rights. Although assistance is primarily related to the soil, water, and plant aspects of recreational land use, the Service also advises individuals and groups on the availability of assistance from other agencies.

CHAPTER V

WATER RESOURCES

Water Supply

The Colorado River and two of its tributaries, the Green and Dolores Rivers, form much of the boundary of the San Juan study area. The San Juan River, another tributary of the Colorado, flows through the southern part of the area. These four are the only streams within or bordering the area large enough to be named "rivers." Because most of the sections of these rivers are entrenched in deep canyons, their waters are generally inaccessible to places of need. Creeks originating within the study area in the La Sal and Abajo Mountains provide most of the water presently used.



Scenic State Highway No. 279 west of Moab, Utah, extends along the Colorado River to Texas Gulf Sulphur potash mine.

River flows

River flows vary widely from season to season and to a lesser extent from year to year. They are affected by upstream diversion and storage developments, a number of which have been constructed in recent years or are now in progress as units of the Colorado River Storage Project or participating projects. Average annual flows at certain points on each of the four rivers are shown in the following table. The gage locations are shown on the map on page 45.

Historic flows, Colorado River and tributaries

Gaging station Number	Location	Period of record	Drainage area (square miles)	Average annual runoff (acre-feet)
	Colorado River			
9-1635	Near Colo.-Utah line	1951-67	17,900	4,048,000
9-1805	Near Cisco, Utah	1911-67	24,100	5,619,000
9-3350	Hite, Utah	1947-58	76,600	9,775,000
9-3800	Lees Ferry, Ariz.	1911-62	108,335	12,923,000
	Dolores River			
9-1795	Gateway, Colo.	1936-54	4,350	679,100
9-1800	Near Cisco, Utah	1950-67	4,580	480,000
	Green River			
9-3150	Green River, Utah	1/1894-1967	40,600	4,611,000
	San Juan River			
9-3795	Near Bluff, Utah	1914-67	23,000	1,919,000

1/ No record available for 1900-03 period.

Historical flows were modified to reflect present and anticipated future conditions of upstream development in a Department of Interior report of January 1967 entitled "Progress Report No. 3, Quality of Water, Colorado River Basin." The anticipated developments include all Federal projects now being developed or authorized plus private and other projects with equivalent prospects of realization. These developments plus present uses will approach full upstream water utilization under existing rights without potential flow augmentation. The historic and estimated modified flows based on flow records for the 24-year period 1941 through 1964 are shown on the following table.

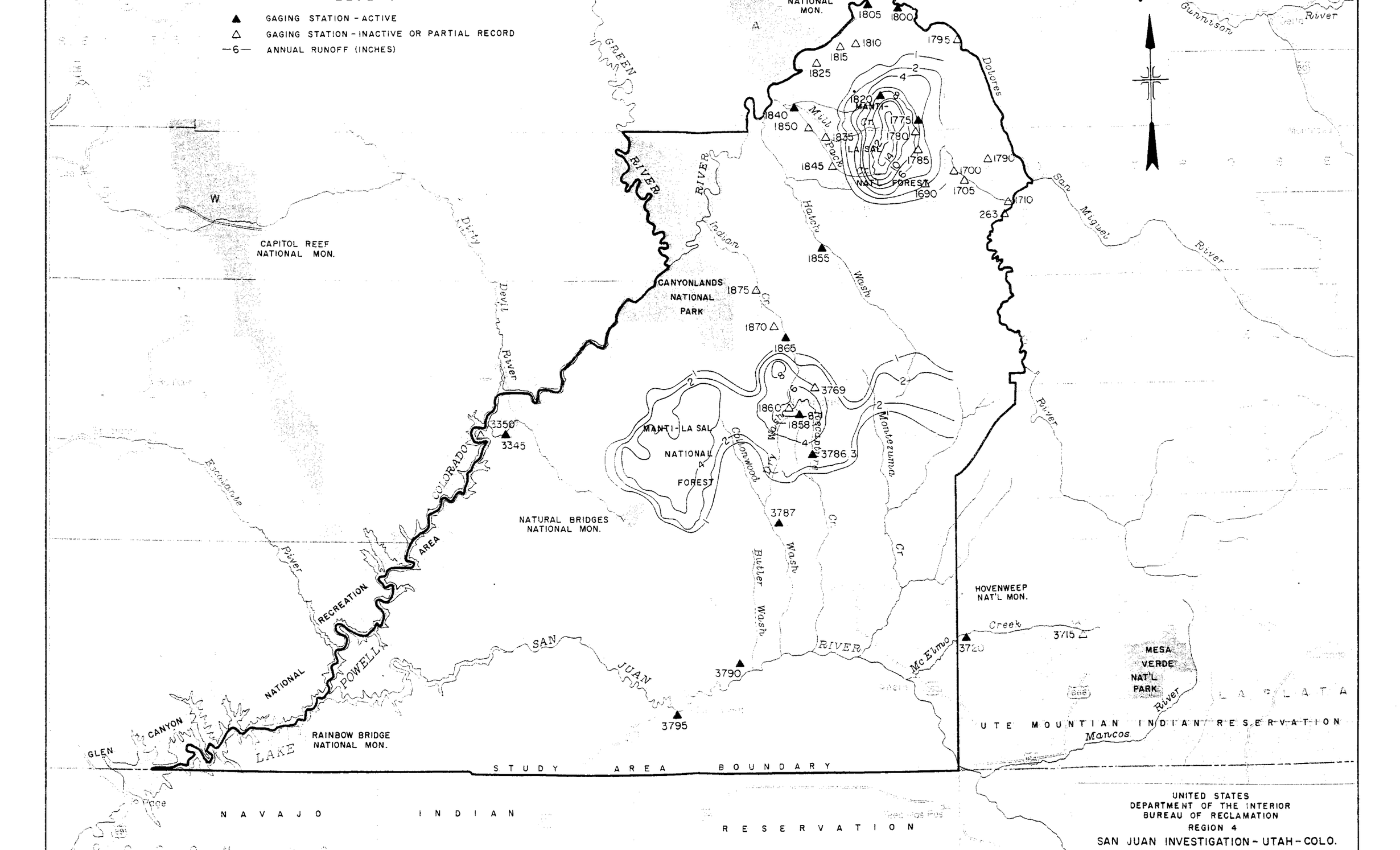
Historic and modified river flows

Gage location	Flows (acre-feet) Historic 1941-64	Present modified	Future modified
Green River at Green River	4,102,000	3,995,000	3,554,000
San Juan River near Bluff	1,633,000	1,580,000	1,129,000
Colorado River near Cisco	5,029,000	4,810,000	3,984,000

Creek flows

The most valuable water supply used within the San Juan Area comes from La Sal and Abajo Mountain areas above 9,000 feet in elevation. This water comes mainly from the spring melting of winter snows. Creeks on the south side of the mountains reach their peak spring flows several weeks before those on the north side.

Runoff from areas below elevation 7,000 feet is erratic. Much of it results from thunderstorms which occur mostly in the late summer or early fall. This type of runoff is characterized by high flows of short


▲ GAGING STATION - ACTIVE
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—6— ANNUAL RUNOFF (INCHES)
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LA SAL
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Mill Creek
Pack Creek
GREEN RIVER
Dolores
Gunnison River
San Miguel River
Dirty Devil River
Indian Creek
Hatch Wash
Montezuma Cr
Coyote Wash
Butler Wash
McElmo Creek
CAPITOL REEF NATIONAL MON.
CANYONLANDS NATIONAL PARK
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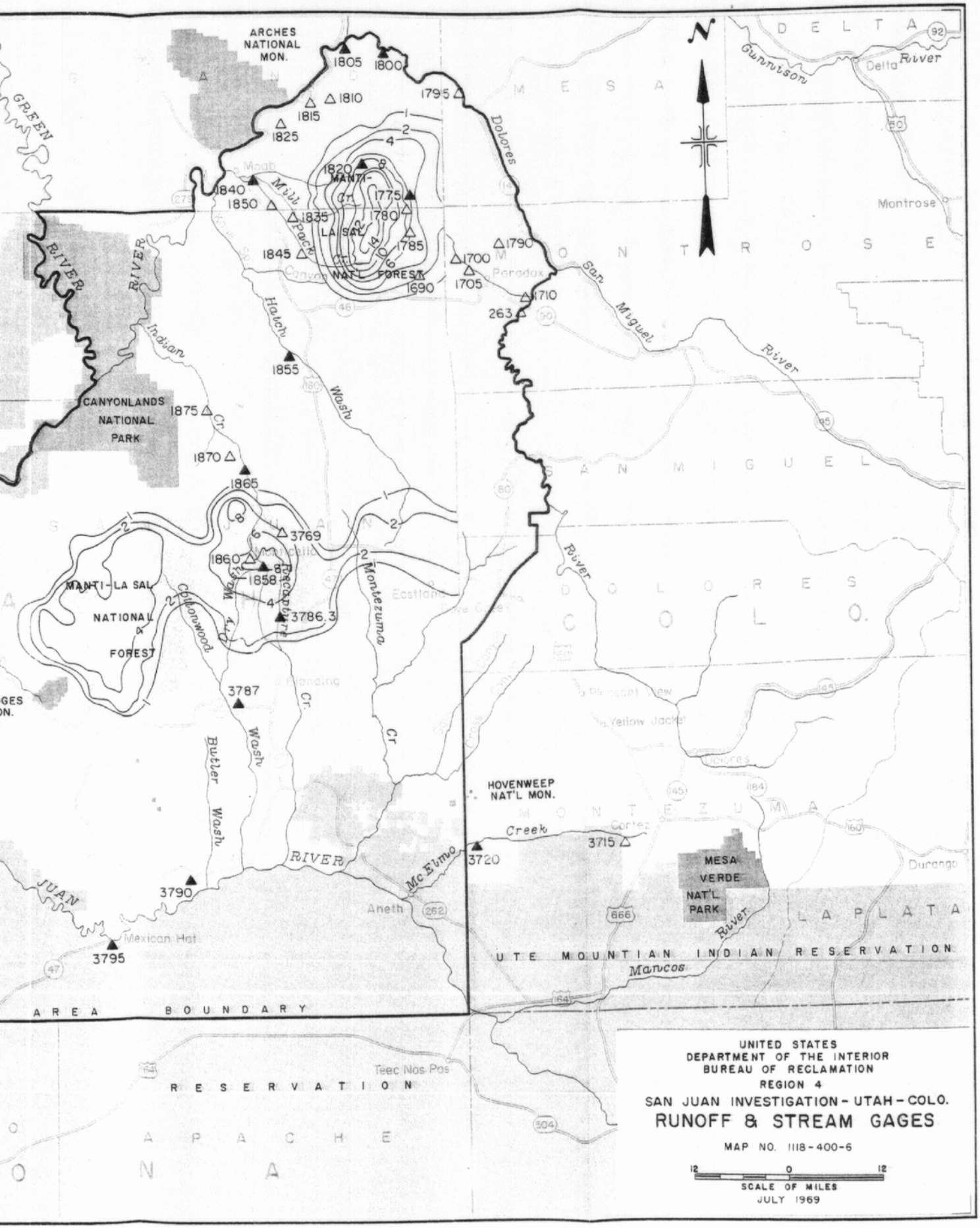
SAN JUAN INVESTIGATION - UTAH - COLO.


ARCHES NATIONAL MON.
CANYONLANDS NATIONAL PARK
MANTI-LA SAL NATIONAL FOREST
HOVENWEEP NAT'L MON.
MESA VERDE NAT'L PARK
UTE MOUNTIAN INDIAN RESERVATION
AREA BOUNDARY
RESERVATION
GREEN RIVER
COLORADO RIVER
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Hatch Wash
Dolores River
San Miguel River
Montezuma Cr
Butler Wash
McElmo Creek
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UNITED STATES
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REGION 4
SAN JUAN INVESTIGATION - UTAH - COLO.
RUNOFF & STREAM GAGES
MAP NO. 1118-400-6
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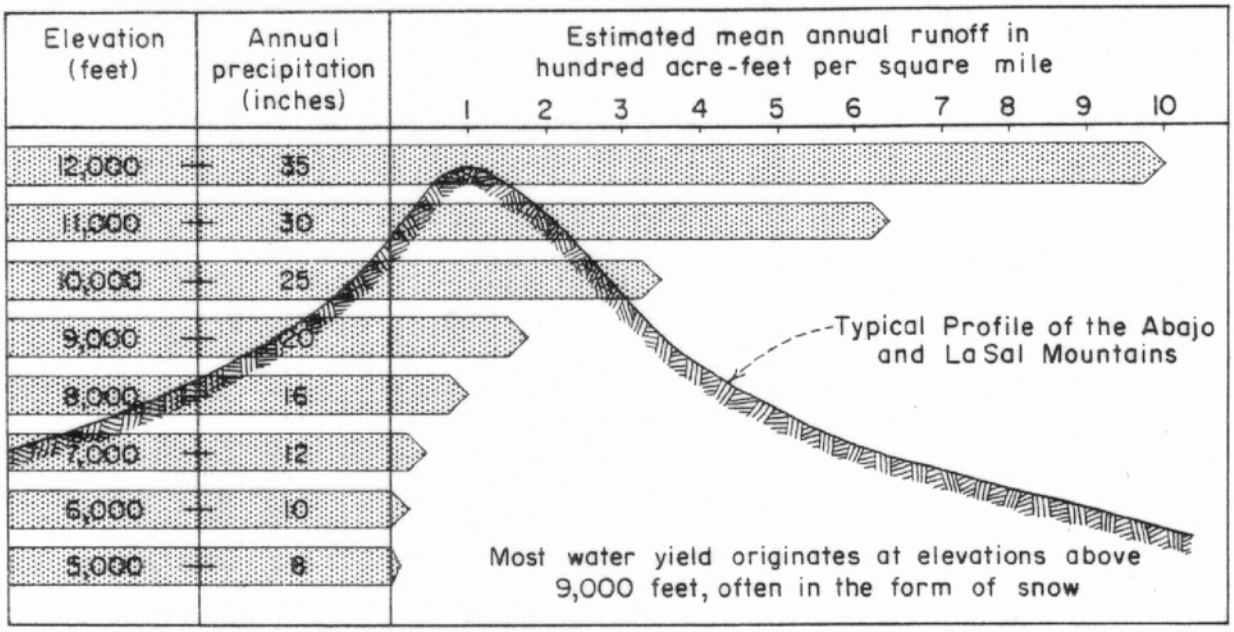
SCALE OF MILES
JULY 1969

duration, with a heavy load of sediment and debris. Only a small part of the runoff from the lower areas can be controlled and utilized. The erratic flows cannot generally be measured at reasonable cost.

Both precipitation and the portion of the precipitation that contributes to runoff are greater on the mountain areas than on the lower lands. The relation of elevation to water yield, typical of the La Sal and Abajo Mountains, is illustrated in the chart below.

RELATIONSHIP OF ELEVATION TO PRECIPITATION AND WATER YIELD



Flow records of area creeks are shown in the table on the following page. At minimum flows all of the streams are dry or nearly dry while maximum flows of many streams have reached thousands of second-feet. In most instances some water is diverted from the streams above the gaging station. Locations of the gaging stations are shown on the map on page 45.

Streamflow records and other data were used in a study of water yields of the La Sal and Abajo Mountains and other areas of Utah made by the Utah Agricultural Experiment Station in cooperation with the Utah Water and Power Board. Precipitation, vegetative cover, and the physiography and geology of the mountain areas were also considered in estimating water yields in a September 1964 report entitled "Water Yields in Utah" published as Special Report 18 of the Experiment Station.

Streamflow records

Gaging station Number	Location	Drainage area (square miles)	Period of record From	To[1]	Number of years	Flows during period of record (second-feet) High	Low	Average	Average annual runoff (acre-feet)
9-1690	Twomile Creek near La Sal	21.9	1944	1951	7	96	0.1	2.22	1,610
9-1700	Buckeye Reservoir Outlet near Paradox		1944	1951	7	59	0	6.66	4,820
9-1705	West Paradox Creek near Paradox	25	1944	1952	8	678	.1	8.61	6,230
9-1710	West Paradox Creek near Bedrock	55	1944	1952	8	N.A.	0	4.41	3,190
9-1775	Taylor Creek near Gateway	12	1944	1966	22	555	0	3.26	2,360
9-1780	Deep Creek near Paradox		1944	1953	9	29	0	1.80	1,300
9-1785	Geyser Creek near Paradox		1944	1951	7	134	0	.28	203
9-1790	Rock Creek near Uranium	69.5	1944	1952	8	885	0	10.50	7,600
9-1810	Onion Creek near Moab	18.8	1950	1955	5	2,100	0	1.13	818
9-1815	Professor Creek near Moab	33.6	1950	1953	3	3,330	0	N.A.	N.A.
9-1820	Castle Creek above diversions near Moab	7.58	(1950 1955) (1957 1968)		16	27	0	1.04	753
9-1825	Castle Creek near Moab	53.1	(1950 1955) (1957 1958)		6	11,000	0	5.25	3,800
9-1835	Mill Creek at Sheley Tunnel near Moab	27.4	1954	1959	5	204	2.1	11.40	8,250
9-1840	Mill Creek near Moab	74.9	1949	1968	19	5,110	.2	14.00	10,140
9-1845	Pack Creek at Mt. Ranch	15.8	1954	1959	5	1,200	.3	2.54	1,840
9-1850	Pack Creek near Moab	57.4	1954	1959	5	510	.7	4.02	2,910
9-1855	Hatch Wash near La Sal	378	1950	1968	18	3,210	0	1.56	1,130
9-1858	Indian Creek Tunnel near Monticello		(1957 1959) (1960 1968)		10	18	0	1.50	1,090
9-1860	Indian Creek near Monticello	4.7	1949	1957	8	122	0	2.88	2,090
9-1865	Indian Creek above Cottonwood Creek near Monticello	31.2	1949	1968	19	709	0	4.51	3,270
9-1870	Cottonwood Creek near Monticello	115	1949	1957	8	2,140	0	3.10	2,240
9-1875	Indian Creek above Harts Draw near Monticello	258	1949	1957	8	3,120	0	5.99	4,340
9-3345	White Canyon near Hite	276	1950	1968	18	7,390	0	5.33	3,860
9-3715	McElmo Creek near Cortez	233	(1926 1929) (1940 1945) (1950 1954)		12	5,560	N.A.	52.40	37,940
9-3720	McElmo Creek near Colorado-Utah State line	350	1951	1966	15	1,700	.1	40.90	29,610
9-3787	Cottonwood Wash near Blanding	205	1964	1968	4	20,500	0		
9-3786.3	Recapture Creek near Blanding	3.77	1965	1968	3	20	0		
9-3769	Spring Creek above diversion near Monticello	4.95	1965	1968	3	18	0		
9-3790	Comb Wash near Bluff	280	1959	1968	9	8,390	0	2.78	2,010

1/ 1968 data based on unpublished records of the Geological Survey.

Isolines of mean annual runoff for the 1920-59 period, taken from that report, appear on the map on page 45.

The isolines indicate that the average annual yield of the 350-square-mile drainage area of the La Sal Mountains is about 100,000 acre-feet and that of the 780-square-mile area of the Abajo Mountains, including Elk Ridge, about 140,000 acre-feet. About 77 square miles of the La Sal Mountain Area and 37 square miles of the Abajo Mountain Area are 9,000 feet or more in elevation.

Runoff from the 7,830 square miles of the study area that is outside of these mountain areas, most of which is below 7,000 feet in elevation, is estimated at only about 5 to 10 percent of the precipitation. The annual runoff would thus average about 0.6-inch depth from the large area of these lower lands, or 250,000 acre-feet. Only a small portion of this water is usable because of its erratic flow, high sediment loads, and the rugged terrain.

Storage Reservoirs

Except for Lake Powell on the Colorado and San Juan Rivers, storage reservoirs are relatively few and of small size in the study area. Lake Powell, located below all area lands, does not contribute to the water supply but does have great recreational value. Unfavorable topographic conditions on the mountain watersheds within the study area above places of water use have limited reservoir construction.

Only 11 reservoirs within the study area have capacities of 100 acre-feet or more. Data on these are tabulated on the following page. In addition to these reservoirs, numerous impoundments of less than 100-acre-foot capacity have been constructed for various purposes, including domestic and stock water, irrigation, recreation, and fish and wildlife.

Ground Water

The principal ground water aquifers in the San Juan Area are in bedrock or consolidated formations which underlie much of the area. Alluvium or other unconsolidated materials are not known to constitute an important ground water source except in Spanish Valley and possibly in Castle Valley, both of which extend northwest from the La Sal Mountains toward the Colorado River.

Existing storage reservoirs

Name	Location	Water source	Purpose	Capacity (acre-feet)
Lake Powell	Colorado River	Colorado River	Multiple	27,000,000
Buckeye	Buckeye Creek	Buckeye, Geyser, and Deep Creeks	Irrigation	1,600
Blanding City	Westwater Creek	Indian and Johnson Creeks	Municipal and recreation	600
Blanding City	2.5 miles north of Blanding	Indian and Johnson Creeks	Municipal	200
Camp Jackson	Near Johnson Creek	Johnson Creek	Municipal	100
Gordon	Near Vega Creek	Vega Creek	Irrigation	160
Dry Wash	Near Johnson Creek	Dry Wash	Irrigation	184
Dugout Ranch	Near Indian Creek	Indian Creek	Irrigation	520
Keller	Near Vega Creek	Vega Creek	Irrigation	206
Pace Lake	John Brown Creek	John Brown Creek	Irrigation	262
East Canyon	Iron Springs Canyon	Vega Creek	1/	1,436

1/ Intended for irrigation but development not completed.

Bedrock aquifers

Except for the La Sal and Abajo Mountain areas where igneous rocks are exposed, the study area is nearly all underlain by a series of consolidated sedimentary formations that will transmit water and yield it to wells and springs. The formations that are aquifers or contain members that are aquifers, listed in the order of youngest geologic age, are: Dakota sandstone; Burrow Canyon and Morrison formation; Bluff, Entrada, Navajo, and Wingate sandstones; the lower part of the Chinle and upper part of the Cutler formation; and the Rico and Hermosa formations. The formations are encountered at depths ranging from surface outcrops to more than 2,000 feet. The Navajo sandstone, being thicker, more extensive, and with better water conductivity than the other formations, has the greatest ground water potential, with the Entrada next in importance. Although these two formations are more than 750 feet below the surface in much of the area, they are usually under sufficient artesian pressure to force well water to or near the surface. The base of the Entrada is 200 to 450 feet nearer to the surface than the Navajo, making it more easily reached.

The bedrock aquifers provide a large ground water reservoir. Recharge to the aquifers occurs in the highland created by the intrusive bodies forming the La Sal and Abajo Mountains and by the Monument Valley upwarp. It is presumed that the recharge to the aquifers was in balance with natural discharges before wells were put down in the area. Only a few wells are now operating so the natural discharge may still approximate the recharge.

Water recoveries from bedrock aquifers are limited by the low transmissivity of the aquifers. Consequently the yield of most wells is limited from a few to 50 gallons per minute. Seldom do yields exceed 200 gallons per minute. A few wells located in fractured zones in the Navajo sandstone where there is high local transmissivity pump up to 2,400 gallons per minute. Pumping from bedrock aquifers will cause a local but continuing drop in water level if the pumping rate exceeds the capacity of the aquifers to convey water to the pump site.

The quality of water from bedrock aquifers varies widely over the area. As a rule the salt content ranges from 200 to 8,000 parts per million. The amount of dissolved solids generally increases with the distance from the recharge area and is less in the more permeable aquifers. Water chemically suitable for culinary use can be obtained from bedrock aquifers over the greater part of the area.

The potential of bedrock aquifers as a source of ground water has not been evaluated. A comprehensive ground water investigation before or concurrent with feasibility studies of a potential surface water

development for any area would be desirable in order that all the water resources may be adequately considered. One objective of the investigation should be to locate fracture zones in the bedrock where productive wells could be developed.

A large-scale development of the bedrock aquifers would involve a planned water-mining operation in which the life of the resource would be influenced by the extent of the annual withdrawal. The great depth of the more productive aquifers would affect the feasibility of mining since their dewatering would require a pump lift approaching 1,000 feet.

Alluvial aquifers

Deposits of alluvial and other unconsolidated materials occur as thin veneers in irregular patches throughout the San Juan Area. The more promising alluvial aquifers are found in outwash fans near the mountains and along stream flood plains. The only proven competent ground water reservoir in unconsolidated alluvium is in Spanish Valley. There is evidence that Castle Valley may also have deep, permeable valley fills.

Spanish Valley is about 13 miles long and 1 to 2 miles wide. It is formed by the sandy-gravelly materials that fill the valley to depths of 80 to 300 feet. These materials were carried into Spanish Valley by flows of Pack and Mill Creeks. A detailed ground water investigation is being conducted in the valley by the Geological Survey which has provided much of the information for this discussion.

Approximately 212 wells have been developed in Spanish Valley, of which about 200 are in alluvium and 12 in bedrock aquifers. The annual withdrawal from both sources is about 4,800 acre-feet, of which 3,500 acre-feet is used for irrigation and 1,300 acre-feet for municipal purposes.

Preliminary indications are that the recharge of ground water is about 20 second-feet or about 14,600 acre-feet annually. The recharge consists of infiltration from Pack and Mill Creeks and from the irrigation of valley land with water from these streams. Some recharge also results from precipitation on the valley floor. A significant water contribution to the valley fill from the underlying Navajo sandstone is also indicated by Geological Survey studies. Increased irrigation in Spanish Valley that would result from the potential Pack Creek Project described in Chapter IX would be expected to increase the ground water recharge.

A large number of applications to appropriate ground water in Spanish Valley have been filed with the Utah State Engineer who is withholding action on them pending completion of the Geological Survey investigation. These applications, together with some early filings already

approved, cover a total of about 126 second-feet of ground water which is far in excess of the indicated recharge, even though many of the rights applied for would be effective only during the irrigation season.

Water from the Spanish Valley alluvium is chemically suitable for livestock and for many industrial uses. It varies from suitable to marginal for human drinking. The total dissolved solids vary from about 200 to 800 parts per million. In many places the water of other alluvial aquifers is of poor quality, containing excessive sulfates.

Water Quality

Surface waters within the study area are generally of suitable chemical quality for irrigation, municipal, and industrial uses. The mineral content of the water increases as the water moves downstream because of natural inflow from lower lands and return flows from irrigation. The chemical quality of ground water differs from place to place. In a number of places ground water is being used successfully as a full or supplemental supply for irrigation.

Five locations within the study area are known to be contributing considerable quantities of dissolved salts to the Colorado River system. Of these the Paradox and Sinbad Valleys are in the Dolores River Drainage Area, the Onion Creek and Castle Creek Areas drain directly into the Colorado River, and the McElmo Creek Area drains into the San Juan River. Other salt areas exist where water is not present to dissolve the salts and carry them into the river system.

Salt and gypsum beds are exposed in the floor of Paradox Valley near Paradox and Bedrock, Colo. Runoff from the valley percolates through these beds in its course toward the Dolores River. Other chemically laden waters reaching the river include ground water, return flows from irrigated lands in West Paradox Valley, and bank storage entering the river at low flow stages. The chemical content of ground water, made more concentrated by evapotranspiration by native vegetation, reaches approximately 25,000 parts per million (p.p.m.).

Sinbad Valley, near Gateway, Colo., drained toward the Dolores River by Salt Creek, is also underlain by soluble minerals. During the fall and winter there is no outflow from the valley. During the spring and summer, however, Salt Creek contributes highly mineralized water into the river. Water samples ranged from 20,100 p.p.m. at a discharge of 110 gallons per minute to 49,300 p.p.m. at a discharge of 13 gallons per minute.

Onion Creek Spring rises through the gypsum and anhydrite of the Paradox formation and enters Onion Creek about 6 miles above its

confluence with the Colorado River at a point about 15 miles northeast of Moab, Utah. When the creek was flowing 55 gallons per minute in June 1966, its salt concentration was 9,120 p.p.m. Onion Creek waters are not used for irrigation because of high salinity.

Salt-laden water seeps into a 200-yard-long section of Castle Creek about 2 miles above the creek's junction with the Colorado River about 10 miles northeast of Moab. About 2.9 tons of dissolved solids daily are estimated to enter the river from this source. While most of the irrigation from Castle Creek is above the point of salt entry, a small area located downstream near the Colorado River is successfully irrigated from the creek.

McElmo Creek, which joins the San Juan River near Aneth, Utah, consists mainly of return flows from irrigated lands in Montezuma Valley, Colo. Although containing relatively high concentrations of soluble salts, the creek water is used successfully for irrigation on lands that have excellent internal drainage characteristics.

Present Water Uses

Waters of the San Juan Area are used primarily for irrigation, municipal, and industrial purposes. Recreation and fish and wildlife uses are also important but as a rule do not consume appreciable quantities of water and are generally incidental to other uses. Stock watering likewise is important. If water for livestock is not otherwise available, it is developed by various means on grazing ranges and other places of need, but quantities are not great.

Irrigation

Approximately 17,500 acres are irrigated in the study area, including 13,300 acres in Utah and 4,200 acres in Colorado. Not all of these lands are irrigated every year. In 1967, for instance, a year of below-normal spring runoff, only about 13,100 acres were irrigated. There has been essentially no expansion of irrigation in the past 30 years.

Surface water is used at times on about 16,350 acres of irrigated land, ground water on 700 acres, and both surface and ground water on 450 acres. Ground water is used on land in West Paradox, Castle, and Spanish Valleys and along Montezuma Creek.

Only about 450 acres are irrigated from rivers of the area--Dolores, San Juan, and Colorado. These lands experience no water shortages. About 10,000 acres are irrigated from streams heading in the La Sal Mountains and 6,350 from streams heading in the Abajo Mountains.

Data on irrigated lands in the study area are tabulated on the following page. The location is designated by area descriptions used in

Irrigated lands and water sources

Area[1]	Water sources	Acres under irrigation rotation: Adequate supply[2]	Partial supply	Total
Utah				
Dolores	Dolores River	97		97
	Beaver Creek	26		26
Fisher Valley	Colorado River	42		42
	Professor Creek	133		133
	Beaver Creek	241		241
Castleton	Colorado River	30		30
	Castle Creek	41		41
	Castle Creek and wells	485	192	677
	John Brown and Taylor Creeks	258		258
Spanish Valley	Mill Creek	827	1,085	1,912
	Pack Creek		338	338
	Wells and springs	175		175
Lisbon Valley	La Sal Creek and tributaries	250	2,338	2,588
Dry Valley	Colorado River	48		48
	Browns Hole--Muleshoe Canyon		29	29
	Hatch Wash		12	12
Indian Creek	Indian Creek	573		573
Monticello	Montezuma Creek	370	2,436	2,806
	Verdure Creek		194	194
Blanding	Bulldog		54	54
	Recapture and Indian Creeks		2,273	2,273
	Allen Canyon		73	73
Montezuma	Montezuma Creek		131	131
	Wells	110		110
	Montezuma Creek and wells	140	36	176
Aneth	San Juan River	15		15
	McElmo Creek	57		57
	Montezuma Creek		14	14
Bluff	San Juan River	169		169
Subtotal		4,087	9,205	13,292
Colorado				
Dolores	Dolores River	47		47
	Tributary of Dolores River	295	200	495
West Paradox	West Paradox, Geyser, and Deep Creeks		3,600	3,600
Little Gypsum	La Sal Creek		102	102
Subtotal		342	3,902	4,244
Total		4,429	13,107	17,536

1/ Corresponds to area descriptions in Chapter III.

2/ Denotes a good early-season water supply and a fair summer supply.

Chapter III. The water supply is designated as adequate on lands having a good early-season supply and a fair summer supply for the crops being grown.

About 98 percent of the irrigated area is devoted to crops that support the livestock industry, such as alfalfa, pasture, and small grains. The remaining 2 percent is used for garden crops and fruits, mostly for local use.

Most of the irrigation is by the land corrugation method, which is well adapted to the topography and crops grown. Sprinkler irrigation is used on about 8 percent of the irrigated land, mostly on systems that require pumping from wells or streams. Sprinkler systems operate in West Paradox, Castle, and Spanish Valleys and along Montezuma Creek and the San Juan River. Sprinklers provide efficient use of water, particularly in areas of uneven topography and coarse-textured soils.

Municipal and industrial use

The principal communities in the area have municipal water systems. The few people living outside of communities pipe water from springs and wells or haul it from nearby sources. Residents of the small community of Eastland, Utah, also haul their water.

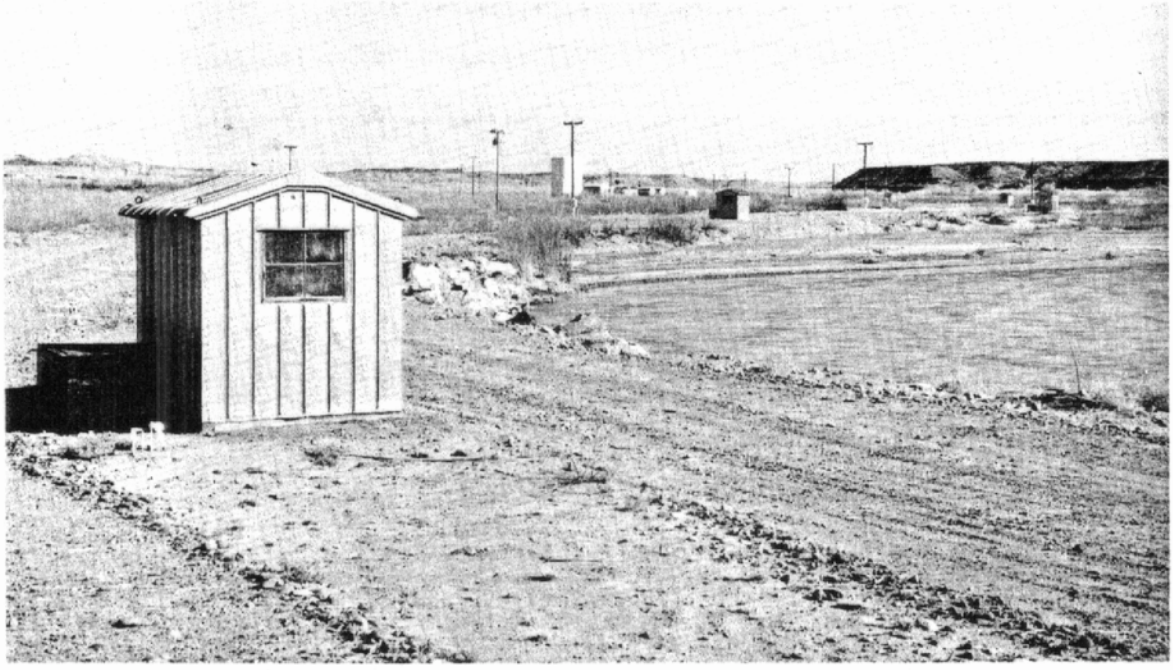
Moab obtains water from springs and wells. The water is of good quality, requiring only chlorination. Measured water use in millions of gallons was 326 in 1964, 298 in 1965, and 347 in 1966. The municipal system also supplied unmeasured water to the city cemetery and a 9-hole golf course. The community water supply is adequate for present needs although system improvements are being made.

At Monticello a network of intakes of springs and streams on the east side of the Abajo Mountains feeds into a pipeline which conveys the water to the city's storage and treatment facilities, including reservoirs with a combined capacity of 65 acre-feet. The city is studying means of increasing its storage capacity to better meet peak use requirements. Water use in millions of gallons was 195 in 1964, 273 in 1965, and 275 in 1966.

Water for Blanding is diverted near the head of Indian and Johnson Creeks and conveyed by a 15-mile pipeline to city storage and treatment units. The city's three reservoirs have a total capacity of 900 acre-feet. Water use in millions of gallons was 178 in 1964, 157 in 1965, and 180 in 1966. The Blanding municipal water system is adequate for present uses and anticipated near-future growth.

Mexican Hat obtains its municipal water from the San Juan River. Bluff, Aneth, and Montezuma Creek obtain water from wells near the San Juan River.

The larger industrial installations in the area have independent water systems. The uranium mill near Moab and the Texas Gulf Sulphur Company's phosphate plant on the Colorado River both pump water from the river. The uranium mill near Mexican Hat pumps from the San Juan River while the El Paso Refinery and the Aneth oil field are served from wells near the San Juan River.



Pumps on wells driven into the gravels along the banks of the San Juan River. The well water is pumped into oil structures at the nearby Aneth field to increase oil recovery.

The amount of water used in Grand and San Juan Counties, Utah, for municipal and industrial purposes in the 1960-61 period was estimated by the University of Utah as a part of a Statewide study. The University's estimates are shown below.1/

Type of water use	Annual water use (acre-feet)	
	Grand County	San Juan County
Public and rural domestic use	2,227	3,043
Self-supplied industrial use	4,696	4,125
Total	6,923	7,168

1/ "Use of Water for Municipal and Industrial Purposes, Utah Counties, 1960-61," Bureau of Economic and Business Research, University of Utah, March 1966.

Water Rights

Rights covering present water uses in the study area have been established in accordance with State law. While details of appropriation procedures differ somewhat in Utah and Colorado, the intent and objectives of the water laws are similar.

As is commonly the case in the western States, the cumulative rights of the water users generally cover more water than flows naturally in the source. This condition has been permitted to develop so that even the highest streamflows, usually of short duration, can be distributed to the users according to their rights if the water can be used beneficially. Distribution is made under the rule that first in time is first in right. As streamflows recede, diversions to the appropriators are cut off in descending order of priorities. Water distribution is usually supervised by a watermaster employed by the water users.

Even though existing rights may normally exceed the water supply, there are opportunities for further developments on some sources. Spring runoff may exceed the rights or the capacity of the diversion and conveyance works of present appropriators. Streamflows outside the irrigation season, unless already utilized or stored, can be appropriated and stored, if necessary, for later use under new developments. Return flows from lands now irrigated or planned to be irrigated may be further utilized in some locations. A cardinal principle of water law is that a right is limited to the extent the water is beneficially used so that water if continually unused is subject to appropriation for new uses.

Any potential water-consuming development in the area must be considered in the light of the right of the State in which it is located to further deplete the flow of the Colorado River. The waters of the river were divided between the Upper and Lower Colorado River Basins by the Colorado River Compact of 1922. Depletion allowances made to the Upper Basin were apportioned among the Upper Basin States, including Utah and Colorado, by the Upper Colorado River Compact of 1948. All known potentialities for water resource developments in these two States cannot be consummated within the States' allowable depletion. State authorities will no doubt influence the selection of projects for development that can best utilize the remaining water supply.

Potential Weather Modification

Both the La Sal and Abajo Mountain areas present a potential for precipitation management, although not as favorable as the major mountainous areas of the Colorado River Basin. Mountain lands above 9,000 feet in elevation would be the best target for increased precipitation

because of their higher natural precipitation and because they are within the area of maximum cumulus cloud formation in the summer and orographic winter precipitation. Any planning to increase precipitation in mountain areas should take into account the character of the land, soils, and streams and the ability of the landscape to handle increased storage and runoff.

CHAPTER VI

MINERALS

Minerals comprise one of the more important resources of the San Juan Area. A mineral study was made by the Utah Geological and Mineralogical Survey in its Special Study No. 24 of San Juan County, Utah, and adjacent areas. That agency's two-volume report published in 1969 is the basis for the summary information in this chapter.

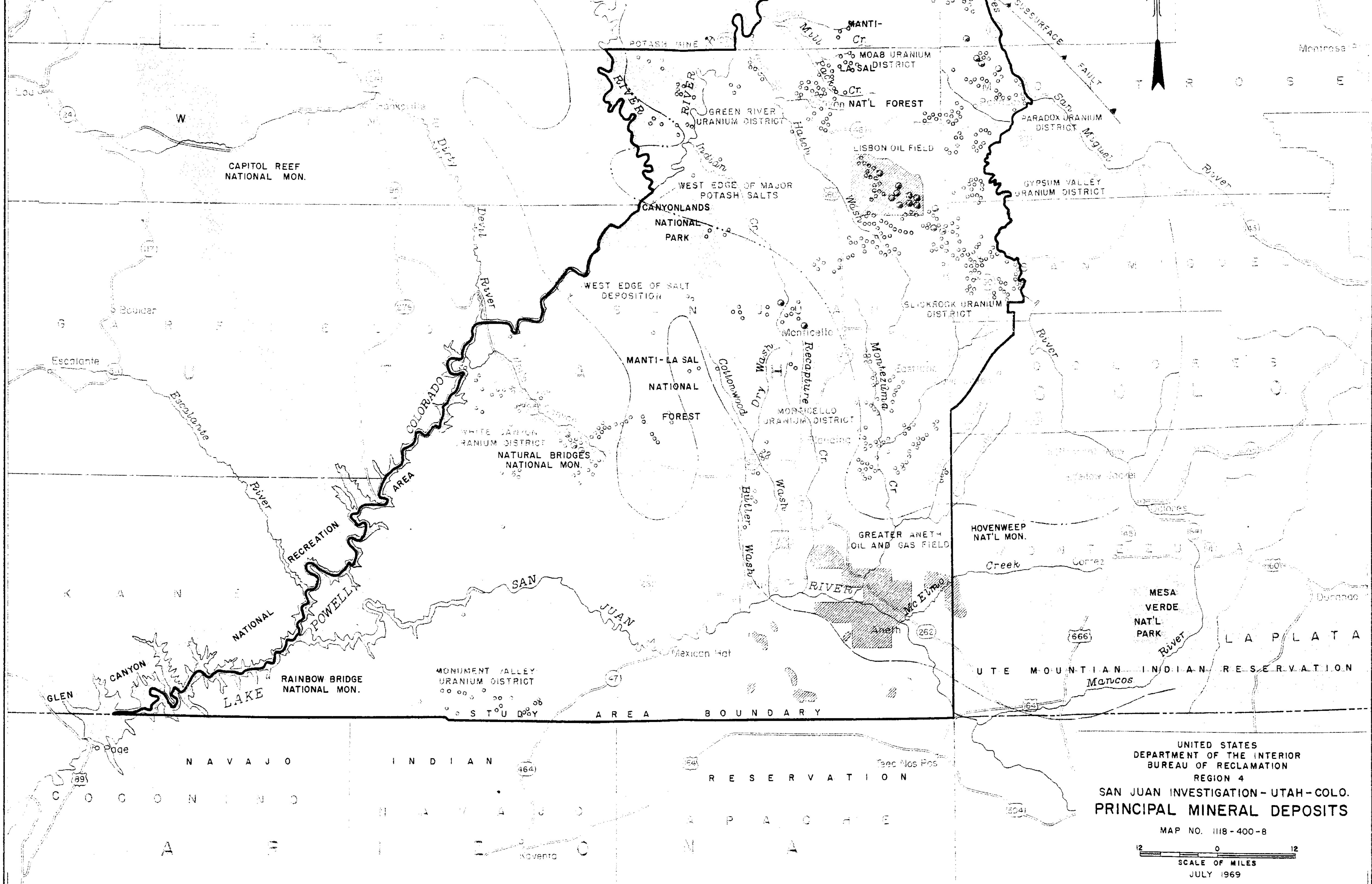
Many minerals of economic value are associated with sedimentary rocks in the study area. These minerals coat fracture surfaces, sand grains, and fossil vegetal material, impregnate spaces between clastic grains and, in many localities, replace the host rock or carbonaceous debris. Metallic constituents of these minerals include vanadium, uranium, radium, copper, lead, zinc, molybdenum, iron, chromium, nickel, cobalt, manganese, arsenic, selenium, yttrium, and silver. Vanadium, uranium, copper, radium, and perhaps manganese have been extracted commercially, and other elements may be recovered in the future as price and technology advance. The major portion of Utah's proven oil and gas reserves is in San Juan County.

Minerals that are currently most important economically in the area are (1) petroleum and natural gas, (2) uranium and associated metals of sedimentary type ores, and (3) potash. The value of mineral production in the area in the last 10 years has fluctuated between $75 million and $150 million annually and has been dominated by petroleum and uranium. Petroleum is presently responsible for 75 to 80 percent of the production value, uranium and vanadium 7 to 15 percent, and potash 5 percent.1/ Other miscellaneous minerals are responsible for about 2 percent of the production value. A map showing the locations of principal known mineral deposits appears on the following page.

Petroleum

Petroleum activity has centered around the Greater Aneth and Lisbon fields. During periods of discovery of these fields in the late 1950's and early 1960's, the industry was spurred into the drilling of numerous development and wildcat wells, creating a petroleum boom. In more recent years many unsuccessful wildcats have been drilled, causing development to proceed more cautiously through a careful step-out drilling program. Drilling density in the San Juan study area is light except for a portion of the Paradox Basin and the Great Aneth Area and vicinity.

1/ Potash is produced at the Texas Gulf Sulphur Company mine from a deposit partly within the study area. The mine shaft is on the opposite bank of the Colorado River from the area.

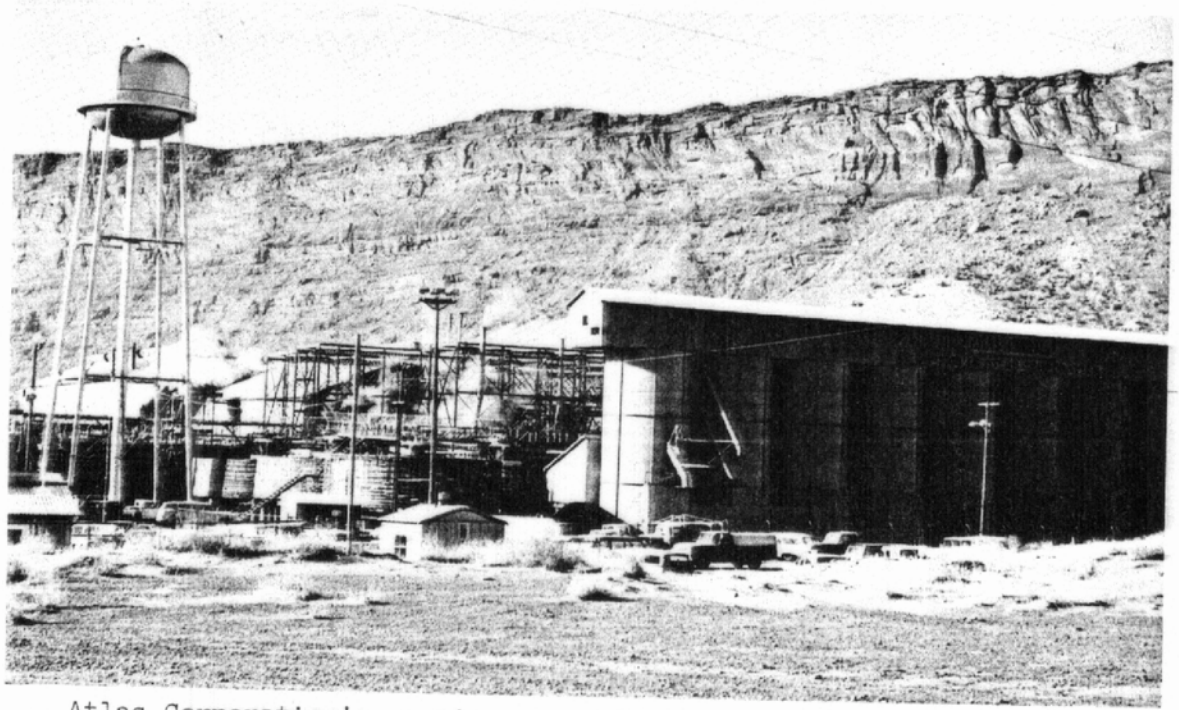


UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
REGION 4
SAN JUAN INVESTIGATION - UTAH - COLO.
PRINCIPAL MINERAL DEPOSITS
MAP NO. 1118-400-8
JULY 1969

Discovery in early 1967 of the prolific Dineh-bi-Keyeh field in Arizona, 30 miles south of the Four Corners, will undoubtedly cause drilling in the San Juan Area to increase in future years. Also the presence of the Greater Aneth oil field and numerous adjoining fields of moderate size and the highly concentrated and prolific Lisbon Field in the northern part of the area indicates that organic source beds within the area have generated major reserves of oil. Known structural and stratigraphic complexities and variations throughout the area provide a large number of potential entrapments for oil and gas. The only missing factor is additional drilling, and this can be expected to take place in future years.

Uranium and Related Metals

Uranium and related metals have been important to the San Juan Area since the beginning of the century when the Curies and others isolated uranium and radium and described their peculiar radioactive properties. Several "boom" periods of exploration and development have been experienced, first for radium, then for vanadium, and finally for uranium. The discovery of the nuclear properties of atoms instigated the uranium boom of the fifties and through Government subsidy many incentives were offered for the discovery and production of these ores. The boom reached such a frenzy that literally all surface outcroppings in the study area were examined by prospectors. Uranium mining spurted to a point where production became more than the Government--really the only customer--could handle. Stretch-out programs were set up whereby the uranium mining industry would be limited but not destroyed.



Atlas Corporation's uranium ore reduction plant near Moab, Utah.

With incentives for finding new ore removed, little exploration work was carried out in the early 1960's and known reserves diminished. Since 1965, however, electric power producers have been ordering increasing numbers of atomic-powered generators to the point that proved uranium reserves do not appear sufficient to meet the expected demand. Thus a new exploration and development "boom" is taking place in the plateau country but not with the enthusiasm of the earlier boom. Since surface outcroppings had been well explored earlier, expensive drilling is left as the only means of finding new reserves. Only the larger companies have the means and facilities to carry out extensive drilling programs. Conditions are favorable for finding subsurface ore reserves but, as with petroleum, it is expected that exploration and development will proceed cautiously.

Copper probably was discovered in the plateau as early as 1880. Activity was stimulated as early as 1906 in the White Canyon and Big Indian Wash Areas when the price of the metal increased. Since that time, several localities have produced intermittently. In the past, some of the ores, notably those of White Canyon, were not accepted at times because of an objectionable accompanying substance, uranium. When uranium mining became profitable in 1948, extraction of byproduct copper was investigated as some of the ores contained considerable quantities of this element. A copper concentrate was shipped to El Paso from the Texas Zone mill at Mexican Hat. Today copper is extracted from uranium ores at the Moab mill, and copper is leached from sandstone at several localities on the plateau.

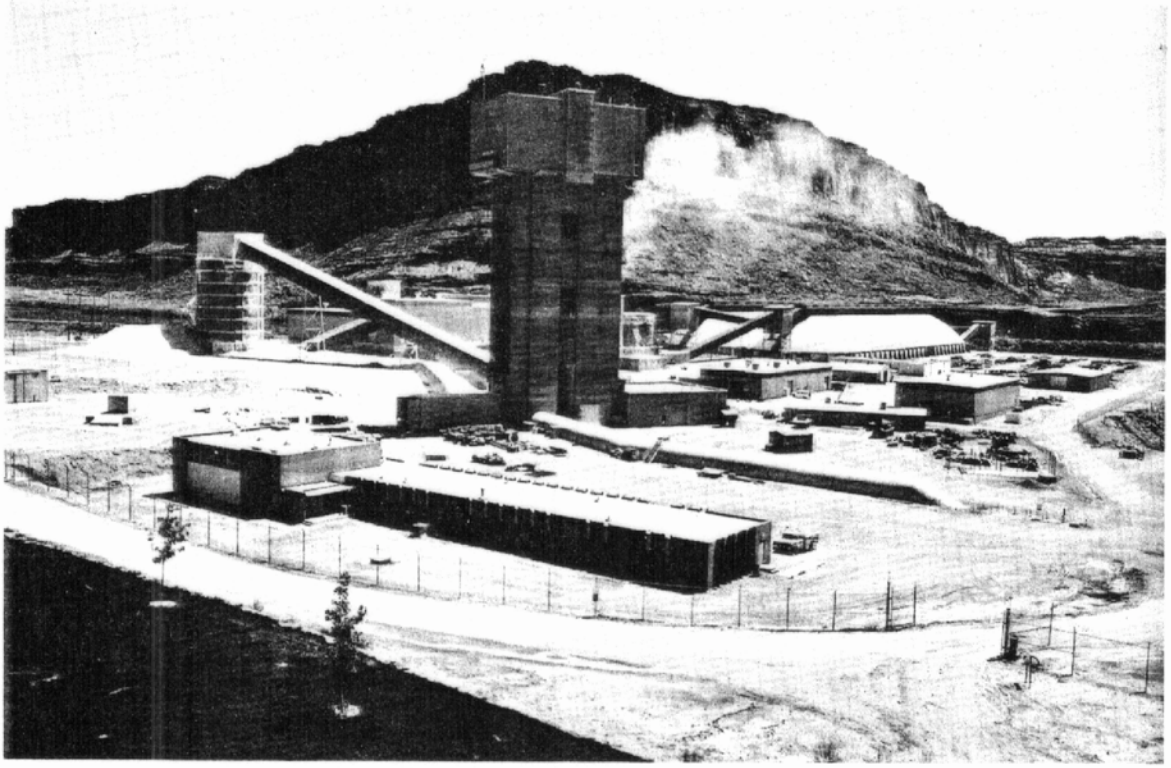
Some manganese may have been mined at two localities in the San Juan Area, one in the Wilson Mesa Area near Moab and the other near Muleshoe Wash near La Sal Junction. Examination of the workings indicates that little or no ore has been shipped.

Potash

Valuable deposits of potash minerals occur in southeast Utah and adjacent Colorado in a thick sequence of saline deposits known as the Paradox Formation. With the potash are potential commercial amounts of magnesium, bromine, boron, lithium, and other elements contained in bedded salt, in brines within the Paradox Formation, and in porous parts of other formations above and below the Paradox where brines have migrated. Several of these deposits are exceptionally large. One is known to be 110 miles long, about 30 miles wide, and with a thickness at one locality of more than 400 feet. However, most of the potash-bearing zones are not thick, and many of the thicker sections probably result from flowage and concentration of salt into crests of folds.

With use of potash as a fertilizer increasing rapidly, the area's salt deposits are a vital resource for the nation. Domestic potash

consumption increased nearly 20 percent in 1966 to about 4 million tons while domestic production rose only about 6 percent. Market economists estimate demand for potash will increase as much as 200 percent by 1980. At present the only operating potash mine in the study area is the Cane Creek Mine of the Texas Gulf Sulphur Company. The company plans to produce about 550,000 tons of muriate of potash annually from this mine or about 9 percent of the nation's production. It is thought that planned mine improvements and better operating efficiencies will maintain or increase this percentage as production elsewhere increases.



Surface facilities of Texas Gulf Sulphur Company's potash mine on banks of Colorado River southwest of Moab, Utah.

Consideration has been given to obtaining potash by solution mining. If perfected this method may make underground operations unnecessary, and it could open many areas of the Paradox Basin where depth to potash is too great to permit mining by mechanical methods. Technological difficulties include the problem of water supply since by evaporation of the brines large quantities of water would be lost. If evaporation or mineral precipitation were conducted under controlled conditions to retain the fresh water, then specialized equipment would be needed and probably a heat source as well.

Coal

Bituminous coal deposits are found in the Dakota sandstone of Cretaceous age in the San Juan Area. The coal is in the middle shaly member of the Dakota where the seams are short, discontinuous, and thin, ranging up to 3 feet in thickness. The coal is normally high in ash and weathers into small fragments and fine powder.

Only a few coal mines have been opened in the area. All were small and have been abandoned. Development has been discouraged by the high ash content, the thin, discontinuous seams, and the poor market area. A thicker deposit of higher quality bituminous coal is reported to have been encountered near the surface in the eastern part of San Juan County in the course of exploratory drilling for other minerals. The extent and significance of the deposit have not yet been appraised.

Miscellaneous Minerals

Other types of mineral deposits found in the San Juan study area include clay, construction materials, dimension stone, gold, silver, gypsum, iron, limestone, and semiprecious stones. Except for construction materials, the impact of these minerals upon the economy of the region has been slight, some of them never having achieved production. Because of such factors as distance to market, small size of the deposits, or low value per ton, many may not be developed within the foreseeable future. The production of construction materials for local use will increase and become progressively more important as the population of the region increases.

CHAPTER VII

RECREATION, FISH, AND WILDLIFE

The material in this chapter was drawn largely from reports furnished by the Southwest Region, National Park Service, and Region 2 of the Bureau of Sport Fisheries and Wildlife. Minor changes in the data provided by these agencies have been made for correlation with other chapters of this volume. Some descriptive and background information from the National Park Service report has also been used in earlier chapters of this volume. Bureau of Sport Fisheries and Wildlife appraisals of the effect of potential reclamation projects in the area are used in the project discussions in Chapter IX.

Recreation

National policy on outdoor recreation

Outdoor recreation in the San Juan Area must be viewed in the light of the following national policy promulgated May 28, 1963, in Public Law 88-29:

> "That the Congress finds and declares it to be desirable that all American people of present and future generations be assured adequate outdoor recreation resources, and that it is desirable for all levels of government and private interests to take prompt and coordinated action to the extent practicable without diminishing or affecting their respective powers and functions to conserve, develop, and utilize such resources for the benefit and enjoyment of the American people."

This policy was prompted in part by a 1962 report of the Outdoor Recreation Resources Review Commission. The Commission found that existing recreation opportunities in the United States fall short of meeting current needs. The needs are expanding as a result of trends on the part of the American people toward increasing incomes, leisure time, mobility, and urbanization.

Federal recreation programs

The Federal Government manages or assists in the management of much of the recreation land in the study area. The roles of the Bureau of Land Management, Forest Service, National Park Service, Bureau of Indian Affairs, and Soil Conservation Service are discussed in Chapter IV. The participation of certain other agencies is mentioned below.

The Bureau of Sport Fisheries and Wildlife in cooperation with State fish and game departments assists in the planning of water development projects, making recommendations for the preservation and enhancement of fish and wildlife resources and for hunting and fishing on project areas. It aids the States in enforcement of Federal laws and regulations for the protection of migratory birds. It also provides fishery management service to the Navajo Indian Tribe.

The Bureau of Reclamation constructs and operates water development projects for multiple uses that include recreation and fish and wildlife preservation. Land acquisitions for reservoir sites usually include adjacent areas needed for recreation and fish and wildlife facilities. Usually this agency shares the cost of recreational developments. Actual management of recreational facilities is usually assumed by some agency other than the Bureau of Reclamation.

Since its establishment in May 1962 the Bureau of Outdoor Recreation has been responsible for coordinating Federal plans and programs relating to outdoor recreation on public lands. It is also responsible for the preparation of a nationwide outdoor recreation plan. All Federal agencies are directed by Public Law 88-29 to conduct their programs in general conformance with this plan.

Other recreation programs

Both the Navajo Tribe and the States of Utah and Colorado are involved in recreation in the San Juan Area. The tribe has established parks throughout its reservation but as yet has had limited funds for development or operation. The tribe's policies for development are generally similar to those of the National Park Service. The State of Utah, through the Utah Outdoor Recreation Assistance Agency, develops a State recreation plan and administers Land and Water Conservation Fund grants.

Through the Park and Recreation Commission the State develops and operates State parks for multiple uses and formulates plans for, and implements development of, public use areas. The Utah State Division of Fish and Game is responsible for the conservation of fish and wildlife. Its programs include the purchase of minimum pools in reservoirs and construction of lakes for fish conservation, rehabilitation of big-game winter ranges, and construction of hunter access roads. The Utah Department of Highways implements the highway beautification program and, together with county road departments, provides access to all resources. Colorado has similar programs to those of Utah that are applicable to the minor portion of the study area that is within Colorado.

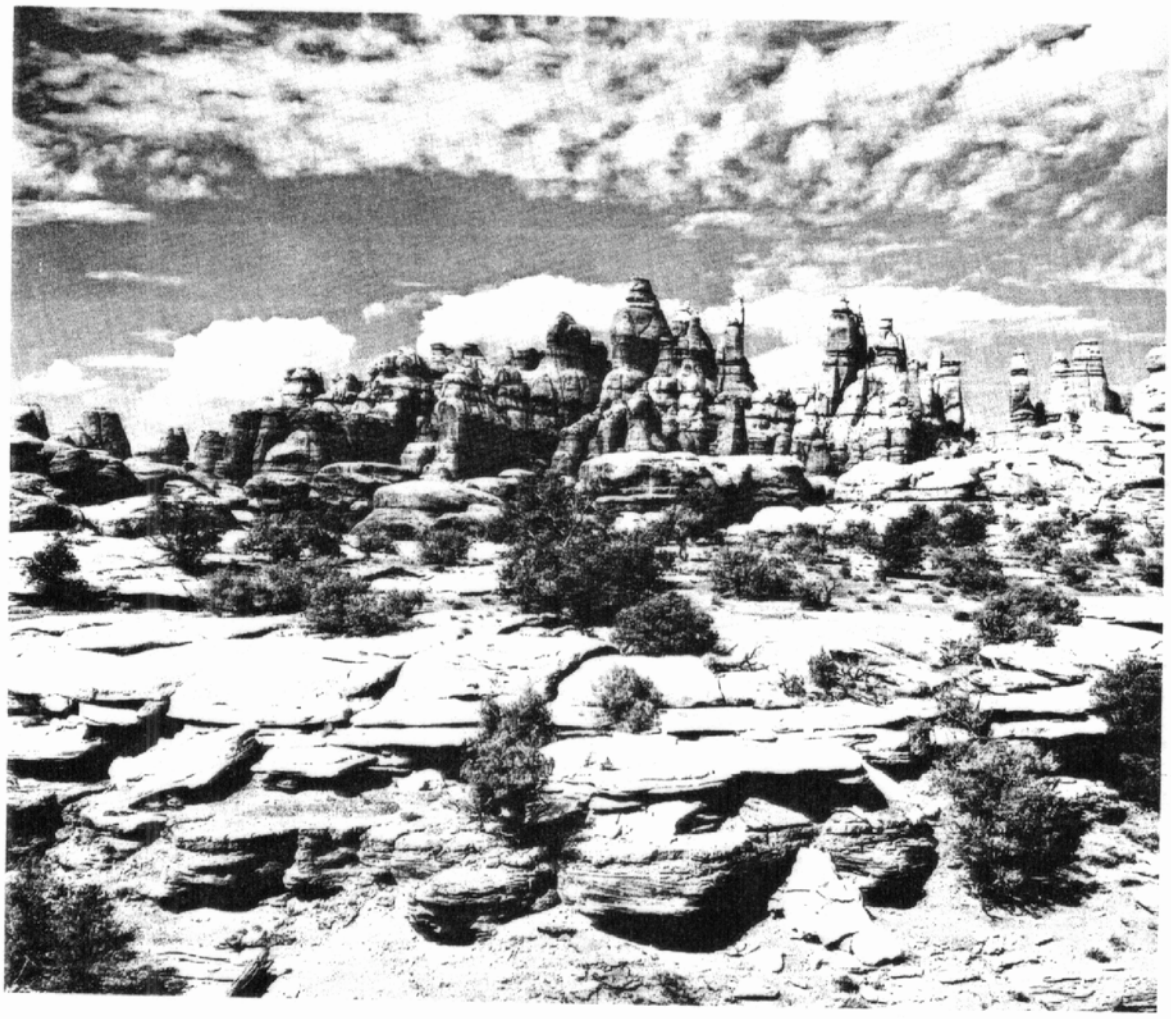
Present outdoor recreation demand

Outdoor recreation demand in the study area is limited at present by the sparse local population, the area's remote location, and undeveloped

access. Despite the light overall recreational use, visitors tend to cluster at the better known and more popular places, overcrowding existing camping facilities, whereas campgrounds in other places may have never been fully utilized.

Existing recreation development

Recreation development in the San Juan Area is in its infancy. Rainbow Bridge, Natural Bridges, and Hovenweep National Monuments were established many years ago but have been visited only by the hardy. The completion of Glen Canyon Dam and the creation of Canyonlands National Park have added two new but undeveloped areas to the recreation picture. Canyonlands, Natural Bridges, and Hovenweep are examples of the canyon country available for future generations. Glen Canyon will be developed as a major recreation complex.



View of "The Needles" in Canyonlands National Park.

The Bureau of Land Management will continue its recently begun program of recreation improvements which will complement and enhance developments of the National Park Service. The eight National Forest Service recreation areas are unique in the canyon country because they occupy the higher elevations which offer tree cover and cooler temperatures. State parks, except Dead Horse Point, are undeveloped and probably will remain so until more funds become available. Private recreation development is limited but includes the Lions Club and KOA (Campgrounds of America) Campgrounds at Moab. Commercial developments such as Canyonlands Resort and River Tours, Moab, Utah, are examples of what can be done if capital is available. Data on the size of and visitation at existing recreational developments are tabulated on the following page.

Future outdoor recreation demand

Because of its sparse population and a growth rate somewhat below the national average, the San Juan Area must depend upon nonresidents to support development of a recreation complex. Recreation use from outside the area should greatly increase. The increase will result from the well established trends of income, leisure time, and other factors previously mentioned. A summary report of the Outdoor Recreation Resources Review Commission states: "Vast as the demand for outdoor recreation is, it pales beside what may be expected in future years."

Pointing out that estimates of future recreation use in the San Juan study area are unusually hazardous because of the uniqueness of the canyon country and the lack of an established use pattern, the National Park Service made the following estimate of future recreation days of use annually as an "educated guess" based upon existing use at the Glen Canyon National Recreation Area.

1970	1980	2000	2020
926,000	1,624,800	3,248,300	5,325,000

As a basis for projecting future recreation facility needs in the San Juan Area, the National Park Service estimated the breakdown by activity on the basis of figures for Glen Canyon National Recreation Area in 1966. Although the use by activity will vary among different parts of the study area, it is expected that Lake Powell, as the major water-oriented resource, will be the major factor in determining the type of recreation use. Anticipated use by activity is shown below.

Activity	Percent of total use	Activity	Percent of total use
Boating	9.62	Campground	25.97
Fishing	21.48	Back country	14.15
Water skiing	3.60	Swimming	10.28
Picnicking	7.55	Sightseeing	7.35
		Total	100.00

Water and developed land acreage at existing recreation locations

Name of area	Area in acres: Water surface	Area in acres: Developed land	Annual visitations[1]: 1965	Annual visitations[1]: 1966
National Park Service				
Arches National Monument	0	2,100	143,900	127,990
Canyonlands National Park	2,860	4,275	19,400	20,200
Hovenweep National Monument	0	100	7,570	7,050
Natural Bridges National Monument	0	30	19,280	29,780
Glen Canyon National Recreation Area[2]	65,345	204,065	303,500	359,660
Bureau of Land Management				
Needles Overlook	0	120	2,100	2,350
Anticline	0	200	225	847
Windwhistle Campground	0	10	[3]	[3]
Hatch Point Campground	0	10	820	634
Forest Service				
Oowah Lake		6	3,000	8,300
Warner		10	1,500	2,800
Pack Creek		5	2,000	2,800
Buckboard		6	6,000	3,500
Dalton Springs	[4]/113	5	3,800	1,200
Red Bluff		6	500	[3]
Devils Canyon		41	800	7,200
Buckeye		10	[5]	[5]
State of Utah Parks				
Dead Horse Point	0	[5]	26,000	40,311
Indian Creek	0	1	[5]	[5]
Goosenecks	0	[5]	[2]	6,735

[1] National forest visitations are reported in terms of visitor-days.
[2] Includes areas and visitations on both sides of Colorado River.
[3] Facilities not yet constructed.
[4] Total water surface for all Forest Service recreation locations.
[5] Data not available.

Recreation facilities needed

Existing facilities are considered to be adequate for present use. A projection has been made of facilities that will need to be added by 1970 and in succeeding periods to 1980, 2000, and 2020. Costs of the facilities are roughly estimated based on today's prices. There is little doubt that costs will rise in the future, but no attempt was made to estimate the extent of the increase. The estimates are tabulated below. Noteworthy is the fact that the circulatory access roads to recreational facilities will cost slightly more than all other types of facilities.

Estimated cost of needed recreation facilities

	1970	1980	2000	2020
Marinas				
Concrete ramps (average length 1,000 feet)		$333,300	$1,056,000	$1,353,000
Car-trailer parking		50,000	160,000	205,100
Marina facilities[1]		161,250	356,250	445,500
Comfort stations		48,000	132,000	168,000
Picnicking family units[2]			193,000	360,000
Camping				
Family units[2]		1,472,000	3,584,000	4,746,000
Trailer sewage waste stations		12,000	16,500	9,000
Swimming				
Beach	$31,440	30,975	68,915	91,330
Parking	20,200	15,800	35,400	46,900
Comfort stations	24,000	36,000	84,000	108,000
Sightseeing				
Parking	4,800	7,200	8,400	11,000
Subtotal	80,400	2,166,525	5,694,465	7,543,730
Circulatory roads[3]	[4]	2,240,790	5,898,052	7,812,270
Total	80,400	4,407,315	11,592,517	15,356,000

1/ Includes floating facilities, normal dredging, boardwalk bulkhead, and service area.

2/ Includes furniture; costs include pro rata share of such facilities as secondary circulatory roads and utilities.

3/ Road costs assumed to be 4 percent higher than cost of buildings and utilities.

4/ Costs not estimated; present roads grossly inadequate.

Space requirement for recreation

An estimate of future land and water space requirements for recreation is given in the following tabulation. The land areas shown are for the physical development of facilities and do not include the additional space required to provide a quality environment.

Space required for recreation

Activity	Standard	Area needed (acres) 1970	1980	2000	2020
Boating					
Water area	4 acres per boat	1,512	2,629	5,352	8,868
Car-trailer parking	75 spaces per acre		3	14	27
Car parking	150 spaces per acre		1	5	8
Water skiing (water)	20 acres per boat	3,300	5,980	11,680	19,360
Picnicking	8 units per acre	18	33	65	108
Campground	3 units per acre	340	606	1,204	1,995
Swimming					
Beach area	100 square feet per person	1.6	2.9	5.7	9.5
Car parking	150 spaces per acre	2	3	6	9
Sightseeing					
Parking	150 spaces per acre	1	2	3	4
Total water area		4,812	8,609	17,032	28,228
Total land area		363	651	1,303	2,160

Potential recreation development

A total of 75 recreation sites in the San Juan Area is being considered for development by four agencies, indicating the vast potential of the area. The name of each site and its sponsoring agency are shown below, and site locations are indicated by number on the map on page 73.

National Park Service

1. Gunsight Bench
2. Navajo Point
3. Escalante
4. The Rincon[1/]
5. Nakai Dome[1/2/]
6. San Juan[2/]
7. Castle Butte
8. Muley Point[1/2/]

Navajo Tribe

9. Padre Point
10. Oak Island
11. Nasjo Bench
12. Trail Canyon
13. Nakai Canyon
14. Clay Hills Crossing

1/ Interpretive treatment only--no recreation facilities.
2/ Plans to develop these sites on the north side of the San Juan River by the National Park Service may be abandoned in favor of development of corresponding sites on the south side of the river by the Navajo Indian Tribe.

Forest Service

Moab Ranger District

15. Turkey Campground
16. Little Forest
17. Webb Hollow
18. Warner
19. Oowah Lake
20. Brumley Ridge
21. Mud Lake
22. Horse Creek
23. Boundary
24. Willow Springs
25. Buckeye Reservoir
26. Carpenter Ridge
27. Buckeye
28. Uranium
29. Reservoir
30. Medicine Lake
31. South Beaver
32. Hot Dog
33. La Sal
34. State Line Draw
35. M.B. 95
36. Two Mile Creek

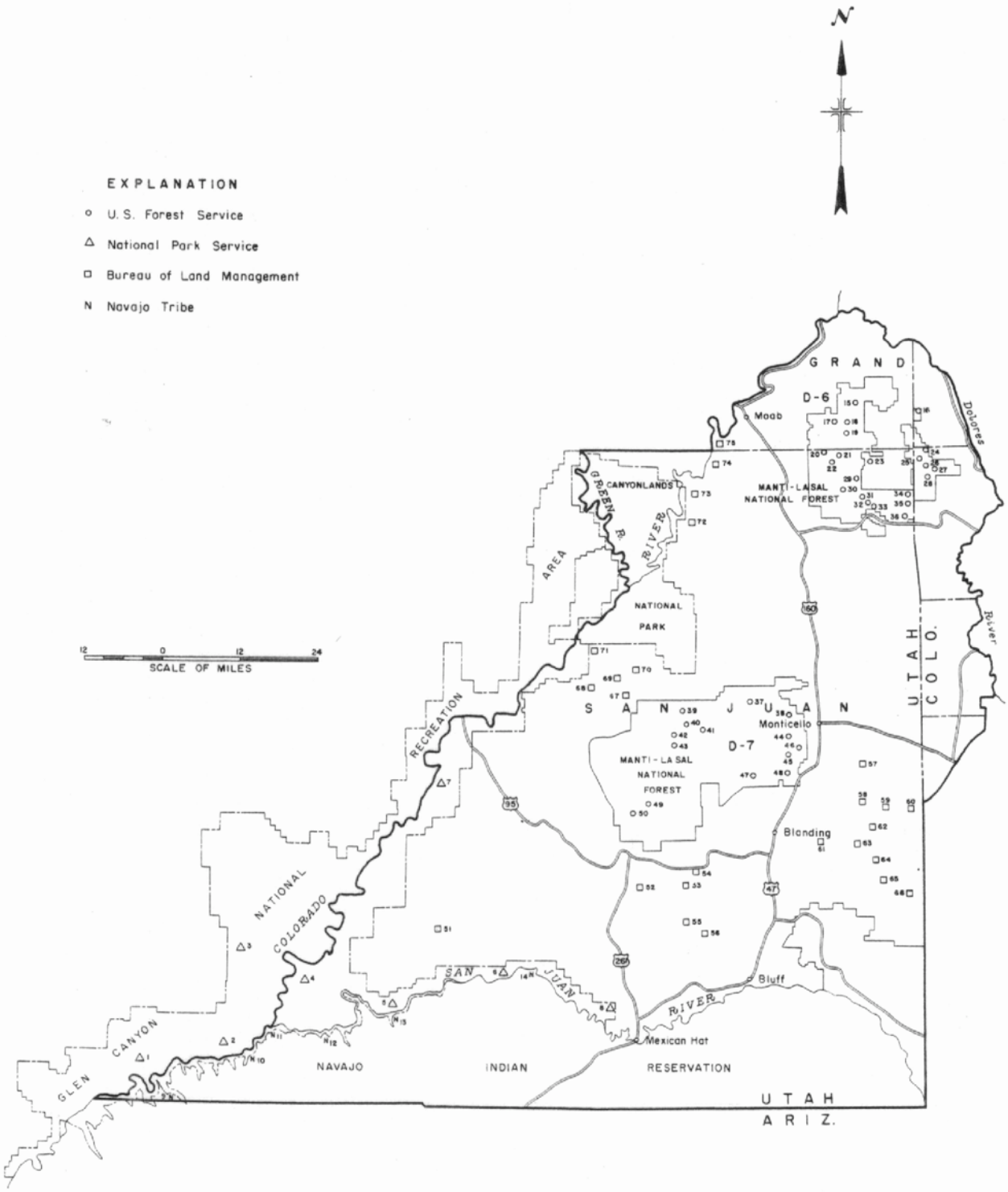
Monticello Ranger District

37. Indian Creek
38. Dalton Spring
39. Davis Canyon
40. Reef
41. Round Mountain
42. Duck Lake
43. Township
44. South Peak
45. Blue Mountain
46. Dude
47. Boundary
48. Devils Canyon
49. Little Notch
50. Twin Spring

Bureau of Land Management

51. Green Water
52. Pine Springs
53. Mule Canyon
54. Arch Canyon
55. Comb Wash
56. Cold Springs Ruins
57. Bull Hollow
58. Montezuma Village
59. Upper Coal-Bed Canyon
60. Wilson Ruins
61. Alkali Point
62. Coal-Bed Canyon
63. Bradford Canyon
64. Monument Canyon
65. Bug Canyon
66. Squaw Point Ruin
67. Sweet Alice Spring
68. Youngs Canyon Campground
69. Fable Spring Camp
70. Stanley Spring
71. Gypsum Canyon Campground
72. Lockhart Basin Overlook
73. Canyonlands Overlook
74. Hurrah Pass Overlook
75. Kane Springs Campground

Completion of BLM management framework efforts by 1972 will result in the listing of numerous additional sites along the Dolores River in Colorado.

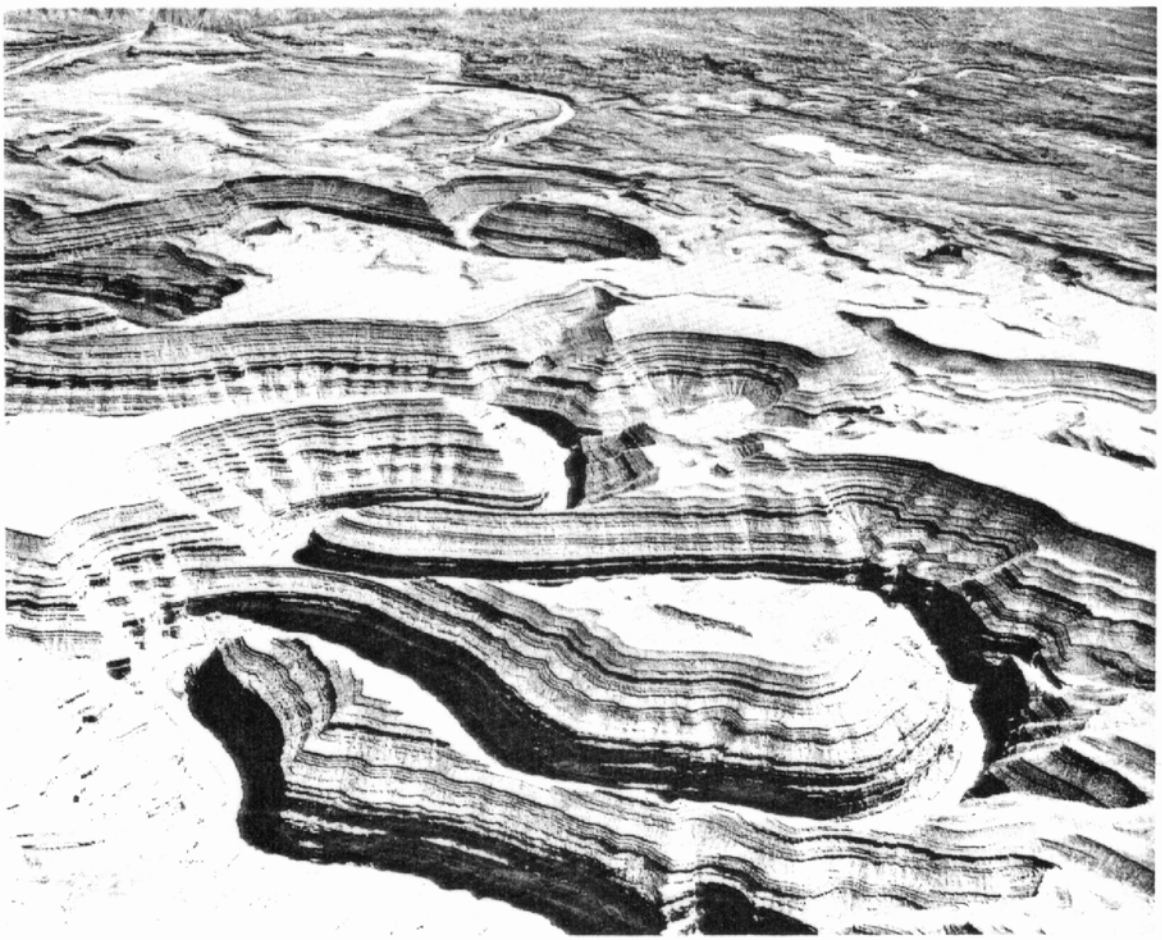


PROPOSED RECREATION DEVELOPMENT

Economic importance of recreation

Recreation, or tourism, now has a significant economic impact on the study area. It accounts directly or indirectly for about 18 percent of the area's employment according to a 1962 report by the University of Utah entitled "An Economic Study of the Proposed Canyonlands National Park and Related Recreation Resources."

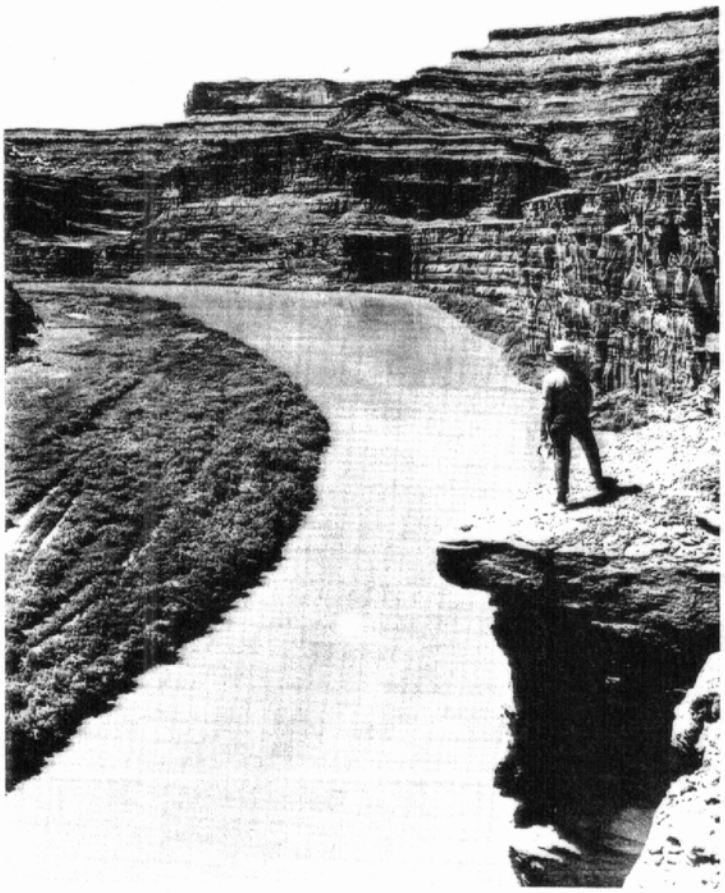
Tourism is a basic industry that is virtually certain to expand in the area. The establishment and development of Lake Powell and Canyonlands National Park, the completion of scheduled highways and roads in the area, and planned improvements at other recreation sites in the surrounding area known as the Golden Circle will increase tourists' visits considerably. Today many of the recreation sites can be reached only by circuitous and costly trips which tend to keep tourists away.



Goosenecks of the San Juan River in Goosenecks State Park. The river, flowing toward the viewer, has cut through 1,000 feet of sedimentary formations in these meanders.

What tourism will mean to the future economy of the area will depend largely upon the facilities and services provided not only in the area but also in adjacent areas which will tend to compete for the tourists' attention and spending. There is little doubt that an influx of travelers in future years will be a factor in strengthening the economic base.

The uniqueness of the study area is beyond question. However, it is only a portion of the Golden Circle complex. Many other areas of national significance are within the circle. These areas and the support facilities accompanying them will compete with the study area. They will not be competitors in the sense of detractors but they will siphon off recreationists unless comparable facilities are developed. Thus it is imperative that quality development be made in recognition of the unique character of the canyon country. Every development, no matter the size, should be related to the whole. The present undeveloped state of the area makes such an approach attainable.



View of Colorado River from vantage point on Shafer Trail below Dead Horse Point.

Few regions are as interesting geologically as the canyon country, nor do many areas offer such interesting history and prehistory, considered in light of the ruggedness of the land. Today, however, the canyon country lacks a unified road network and an interpretive program. A parkway would provide opportunities for interpreting the historical and archaeological stories, as well as the all-encompassing geologic story, and would serve as a backbone for a road network. The recreation facilities of Glen Canyon could provide the necessary adjunct to the parkway. A shared administration would provide the correlation of the various agencies involved.

Legislation has been pending in Congress for an appropriation to study the possibilities of a Golden Circle Scenic Parkway Road

Complex. The Golden Circle and Southern Utah National Scenic Parkway Complex would link the national parks, monuments, and recreation areas in southern Utah with those of northern Arizona, northeastern New Mexico, and southwestern Colorado.

The Utah State Department of Highways has made preliminary proposals for what may eventually be a road network to connect the recreational resources of not only San Juan County but also all of southern Utah. The department will continue to seek the counsel and advice of all involved agencies.

Fish and Wildlife

Except for Lake Powell, fishing opportunities within the San Juan Area are limited at present. Game fish are confined largely to the Colorado, San Juan, and Dolores Rivers, Recapture and Mill Creeks, several small lakes in the La Sal Mountains, and several small reservoirs in the vicinity of Blanding, Utah. Fishing success is not high in most of these waters. Consequently, fishing pressure from the local population is not great and visitors are not presently attracted into the area by fishing opportunities. There is a distinct need for more fishing opportunities for residents of Moab, while additional fishing waters in the vicinity of Monticello and Blanding would also be welcomed.

The fishing potential of Lake Powell is great as a supplement to the other recreational resources in attracting visitors to the San Juan Area. The potential will be realized as access is improved. Reservoirs that may be constructed primarily for reclamation or water conservation purposes, as discussed in Chapter IX, would contribute, fulfilling the need for water-oriented recreation and fishing in the area.

Mule deer are common throughout the area. They attract large numbers of out-of-state hunters, generally from California, Texas, Oklahoma, and New Mexico. Their most common habitat is mountains, canyons, and ridges with pinon and juniper cover.

Bighorn sheep occupy the drier canyons and ridges to the west toward Lake Powell. Their numbers have increased to the point that a limited number of hunting permits for trophy rams are now offered by the State of Utah. Elk inhabit the La Sal Mountains. About 10 elk hunting permits are issued annually. Turkeys also live in the La Sal Mountain area and both spring and fall hunts are allowed.

Upland game birds found in the area include sage grouse on the open benches north of Monticello, pheasants on irrigated lands near Moab and elsewhere, mourning doves throughout the area, and Gambel quail in river bottoms and other areas where permanent water is found. Chukar partridge

are found in some areas. None of these game birds provide a significant amount of hunting.

Cottontails are found where habitat is suitable throughout the area and are hunted when local populations of them noticeably increase. Waterfowl are seldom seen in this generally arid area except along major rivers and Lake Powell. Fur animals are relatively scarce and there is little trapping except for coyote and bobcat.

Without water resource development, conditions for wildlife are expected to remain about as at present. The Utah State Division of Fish and Game, however, has programs for increasing the populations of certain wildlife species, especially bighorn sheep and turkey.

Some natural wildlife habitat would be lost through inundation by project reservoirs. The irrigation of new lands, however, often encourages increases in pheasant populations.

Several of the potential reclamation projects described later in this report have potential for providing important fisheries. Full use of them, however, would depend on development for use by tourists. Many of the projects would be located near or en route to tourist centers. Reservoirs planned for multiple-purpose uses should have adequate permanent pools for fish conservation, and whenever feasible trout streams should be preserved or enhanced. Developments on the main stem of the Colorado River should not be planned until adequate study is made of the effect of development on the habitat of certain endangered fish species as designated by the Secretary of the Interior. Species designated to date include the humpback chub and the Colorado River squawfish.

CHAPTER VIII

TRANSPORTATION

Roads

The greatest need of the San Juan Area is for an extended and improved road network. This is almost the unanimous view of those who are actively interested in development of the area. This need has been brought into sharp focus in recent years by the establishment of the largely inaccessible Glen Canyon National Recreation Area and Canyonlands National Park. Scores of other recreational attractions have been known but difficult to reach for many years.

While more and better roads are needed mostly to open the unique geological, historical, and scenic features of the country for the enjoyment of vacationers and tourists, an improved road system would also contribute to the development of the mineral, agricultural, and other resources of the area. In all of these aspects the road improvements would stimulate the local economy and through higher incomes and better communications would contribute to the cultural advancement of the people.

Interests of many agencies are involved in the planning and construction of a highway system for the San Juan Area and in coordinating it into a regional network. A good start toward a cooperative program has already been made. Utah's highway needs were the subject of a 3-year study made for the Utah State Department of Highways by Wilbur Smith and Associates, reported in 1965. With this study as a base and with the cooperation of a number of Federal and State agencies, the Utah Department of Highways prepared a report on "Access Roads for the Golden Circle." Although the report covered all of southern Utah, the major construction projects recommended were for roads within or leading to the San Juan Area. The report tied together a coordinated road network including sections proposed by the State Highway Department, State Parks and Recreation Department, Bureau of Land Management, Forest Service, and National Park Service. Roads in the Navajo Indian Reservation in San Juan County, proposed as part of a plan being promoted jointly by the States of Utah, Colorado, Arizona, and New Mexico, were also endorsed by the Utah State Department of Highways.

The Golden Circle access road report includes the following statement concerning its scope and purpose.

> "It almost goes without saying this is not a finalized plan. The routes included are subject to continued study by involved agencies. This report does provide the basis for

the development of an overall road plan for the Golden Circle of national parks, monuments, forests, and other scenic attractions. Continued meetings and field surveys held by the interested agencies will enable the provision of the services required and yet preserve the integrity of the various agencies."

An existing hard-surfaced highway extending generally north and south through the San Juan Area is the trunkline for the present road system. The portion of this highway extending north and southeast of Monticello is U.S. Highway 160. Utah Highway 47 extends southwest from Monticello via Blanding, Bluff, and Mexican Hat to a junction with Arizona Highway 464 at the State line.

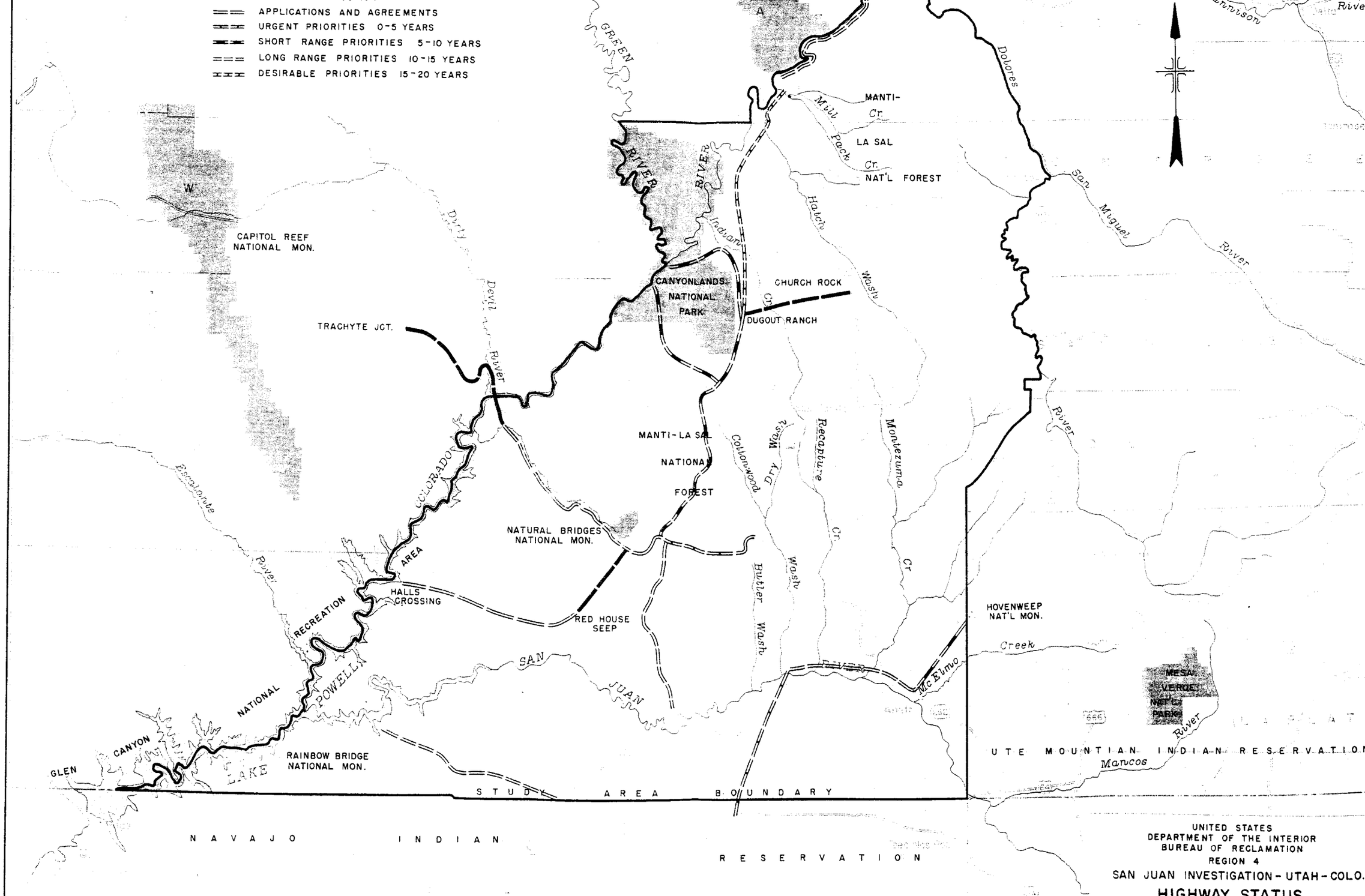
The 133-mile-long Utah Highway 95 that extends northwest from Blanding to Hanksville, Utah, is recognized as the backbone route for a basic road network. It provides the only highway crossing of the Colorado River in the 150-mile (straight line) reach between Moab and Glen Canyon Dam. Until recent years sections of this road over difficult terrain were extremely hazardous and sometimes impassable. The Colorado River crossing was by ferry at Hite, Utah. In North Wash, a narrow canyon through high red sandstone cliffs, the road trail crossed and recrossed the stream channel 46 times without benefit of bridges or culverts. At Comb Ridge it traversed the 800-foot-high face of the escarpment with very steep grades and sharp curves and in most places with single-lane widths.

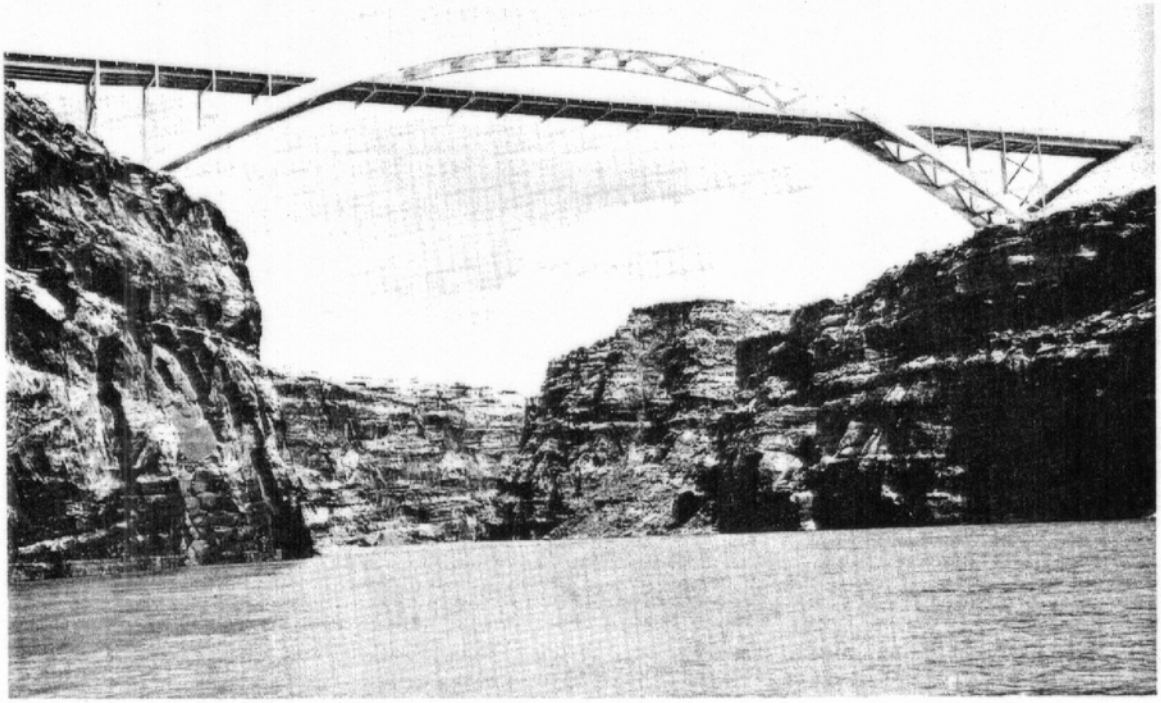
Improvement of U-95 has been high on the priority list of the Utah Highway Department in recent years. The section crossing the Colorado River from White Canyon to North Wash has recently been improved, including high bridges over the Colorado and Dirty Devil Rivers and White Canyon. A 29-mile section from North Wash to Hanksville was recently completed, and early work on other sections is scheduled. Also recently completed is the 37-mile-long U-276 extending south from U-95 just above North Wash to Bullfrog Basin, one of the most favorable recreation sites on Lake Powell in the Glen Canyon National Recreation Area. A road extending southwest from U-95 at Natural Bridges National Monument to Halls Crossing near Bullfrog Basin is scheduled for early improvement. This road will provide the principal access to Lake Powell from the San Juan Area.

The Utah State Department of Highways has recently modified its tentative list of priorities for Golden Circle access roads in Utah. The new listing has no official sanction although it is intended to reflect the view of all involved Federal, State, and local governmental agencies. While it is subject to revision, it forms a beginning point for an overall road development plan. The list with estimated costs appears on the following page. Locations of those roads that are within the San Juan Area are shown on the map on page 81.

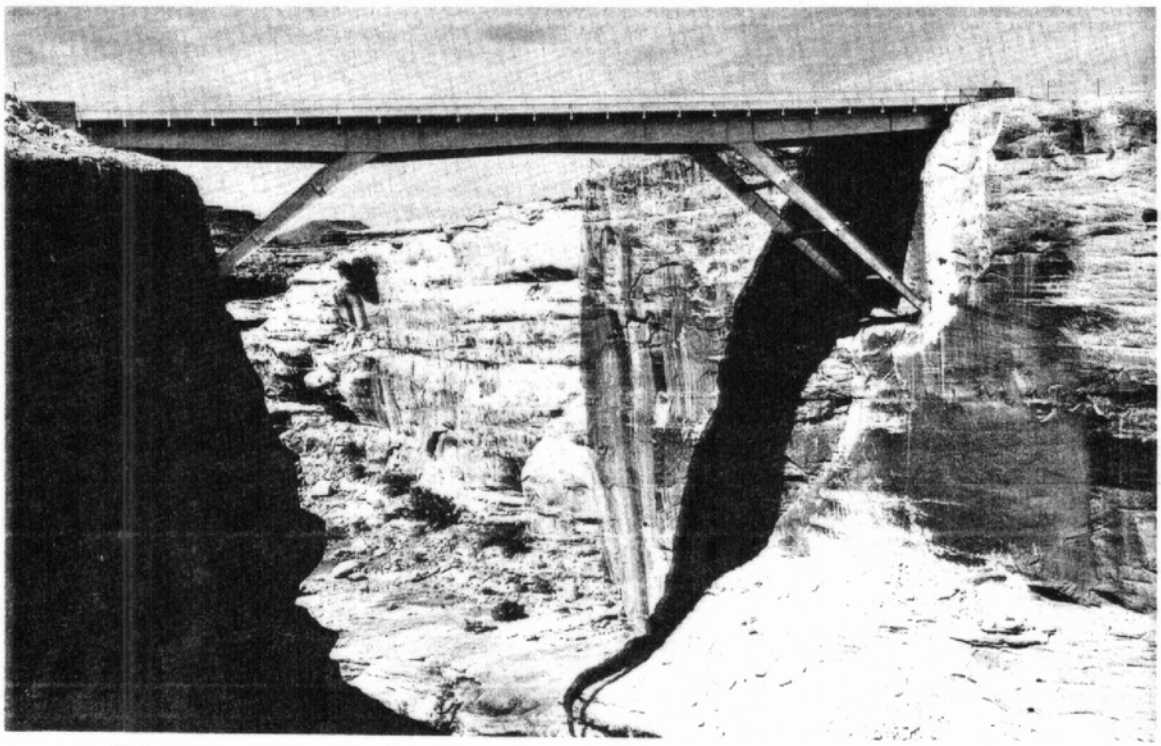
Tentative priorities for
Golden Circle roads in Utah

Road identification	Length (miles)	Estimated cost
Recently Completed		
U-95 Hanksville southeast to Trachyte Junction	27	$2,000,000
U-95 Trachyte Junction southeast to White Canyon (grading)	25	6,500,000
U-276 Trachyte Junction south to Bullfrog Basin	37	3,900,000
Under Construction		
U-95 Trachyte Junction southeast to White Canyon (surface)	25	700,000
Church rock on U.S. 160 west to Dugout Ranch	20	200,000
Natural Bridges National Monument south to Red House Seep (grading)	10	300,000
Applications and Agreements		
U-95 White Canyon southeast to Cottonwood Wash	65	7,500,000
Halls Crossing east to Red House Seep	32	3,875,000
Natural Bridges National Monument south to Red House Seep (surface)	10	350,000
Urgent Priorities (0 to 5 Years)		
Bullfrog Basin south to Hole-in-the-Rock	37	7,000,000
Hole-in-the-Rock northwest to Escalante	50	3,200,000
Bluff south to Mexican Water (Utah portion)	20	2,500,000
Moab southwest to Hite	83	8,000,000
Short Range Priorities (5 to 10 Years)		
Hole-in-the-Rock southwest to Glen Canyon City	73	9,000,000
Glen Canyon City northeast to Gun Site Butte	28	2,700,000
Boulder north to U-24	60	6,000,000
Natural Bridges National Monument north to Canyonlands National Park (Kigalia Parkway)	52	5,500,000
Aneth-Hovenweep-Cortez, Colo. (Utah portion)	18	2,500,000
Long Range Priorities (10 to 15 Years)		
Mexican Hat north to Natural Bridges National Monument	33	2,500,000
Cisco south to Moab	38	2,800,000
Colorado National Monument southeast to Dewey Bridge (Utah portion)	20	2,000,000
Fremont Junction to Hanksville	49	4,400,000
Molly Castle south to Goblin Valley	7	500,000
Bluff east to Aneth	15	2,250,000
Monument Valley northwest to Lake Powell at Copper Canyon	30	3,100,000
Fremont Junction south to Loa	36	3,200,000
Desirable Priorities (15 to 20 Years)		
Cisco north to Vernal	98	10,000,000
Cannonville south to Paria	40	4,000,000
Alton Jct. east to Bryce Canyon National Park	17	2,500,000
Bryce Canyon National Park east to Paria State Park	20	2,500,000
St. George south to Grand Canyon National Monument (Utah portion)	8	600,000
Taylor Creek to Springdale	25	3,000,000
Moab south to Dugout Ranch	50	4,500,000


APPLICATIONS AND AGREEMENTS
URGENT PRIORITIES 0-5 YEARS
SHORT RANGE PRIORITIES 5-10 YEARS
LONG RANGE PRIORITIES 10-15 YEARS
DESIRABLE PRIORITIES 15-20 YEARS
CAPITOL REEF NATIONAL MON.
TRACHYTE JCT.
CANYONLANDS NATIONAL PARK
CHURCH ROCK
DUGOUT RANCH
MANTI-LA SAL NATIONAL FOREST
MANTI-
LA SAL
NAT'L FOREST
NATURAL BRIDGES NATIONAL MON.
HALLS CROSSING
RED HOUSE SEEP
RAINBOW BRIDGE NATIONAL MON.
GLEN CANYON NATIONAL RECREATION AREA
LAKE POWELL
HOVENWEEP NAT'L MON.
MESA VERDE NAT'L PARK
UTE MOUNTIAN INDIAN RESERVATION
NAVAJO INDIAN RESERVATION
STUDY AREA BOUNDARY
Green River
Colorado River
Devil Creek
Indian Creek
Hatch Wash
San Miguel River
Dolores River
Dry Wash
Cottonwood Wash
Recapture Creek
Montezuma Cr
Butler Wash
McElmo Creek
Marcos River
San Juan River
Escalante River
Mill Pack Cr.
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
REGION 4
SAN JUAN INVESTIGATION - UTAH - COLO.
HIGHWAY STATUS



This new bridge on Utah Highway 95 crosses the Colorado River near the point where the river enters Lake Powell.



The White Canyon Bridge on Utah Highway 95 crosses the deeply sculptured White Canyon just upstream from Lake Powell.

Most of the road sections in the list, including many with early priorities, are either within or closely related to the San Juan Area. Roads serving local area developments are not included in the basic list. Examples of those omitted are short access stubs such as the one to Hatch Point now being developed by the Bureau of Land Management and the one to Upheaval Dome within the borders of Canyonlands National Park. Such short local development roads are considered to be within the province of the involved agencies.

The overall road development plan was formulated without regard to agency responsibility. A number of alternative means of financing certain roads are sometimes available. The Kigalia Parkway connecting Canyonlands National Park to Natural Bridges National Monument may for instance be constructed with forest highway funds, forest roads and trails development funds, National Park access funds, Federal Aid secondary funds, Utah State highway funds, San Juan County funds, or some combination of these. It is too early, in the opinion of highway officials, to conclude final responsibility for many of the potential roads. The important thing is that the highway need is recognized, a tentative plan has been made cooperatively, and development is proceeding in an orderly manner.

Air Transportation

Air transportation, still in its infancy in the San Juan Area, gives promise of becoming an important factor in recreation and other aspects of the economy. At present only limited air service extends into the area from the outside. Moab is connected with Grand Junction, Colo., by a branch of Frontier Airlines while Monticello and Blanding since August 1968 have had daily service to Salt Lake City, Price, and Kanab over the Pacific Western Airways. Chartered flights may be arranged from Moab, Monticello, and Blanding.

Air strips are maintained at Bluff and at the edge of Canyonlands National Park. Air strips are also located at Bullfrog and Halls Crossing on opposite sides of Lake Powell.

Much of the area's beautifully rugged scenery, difficult to reach on the ground, can be viewed to advantage from the air. Scenic air flights are becoming more popular each year, indicating an expansion that will require more equipment and improved terminal facilities.

CHAPTER IX

POTENTIAL RECLAMATION PROJECTS

Purpose of Studies

All known potentialities for water resource developments within the study area are discussed in this chapter in varying detail. Preliminary economic appraisals were made and are reported for most of the potential projects. Economic appraisals were not made of potential large storage developments on the Colorado and San Juan Rivers, except the Mexican Hat Project. These developments, possible units of the Colorado River Storage Project, must be considered in relation to factors outside the geographical study area and beyond the scope of this investigation.

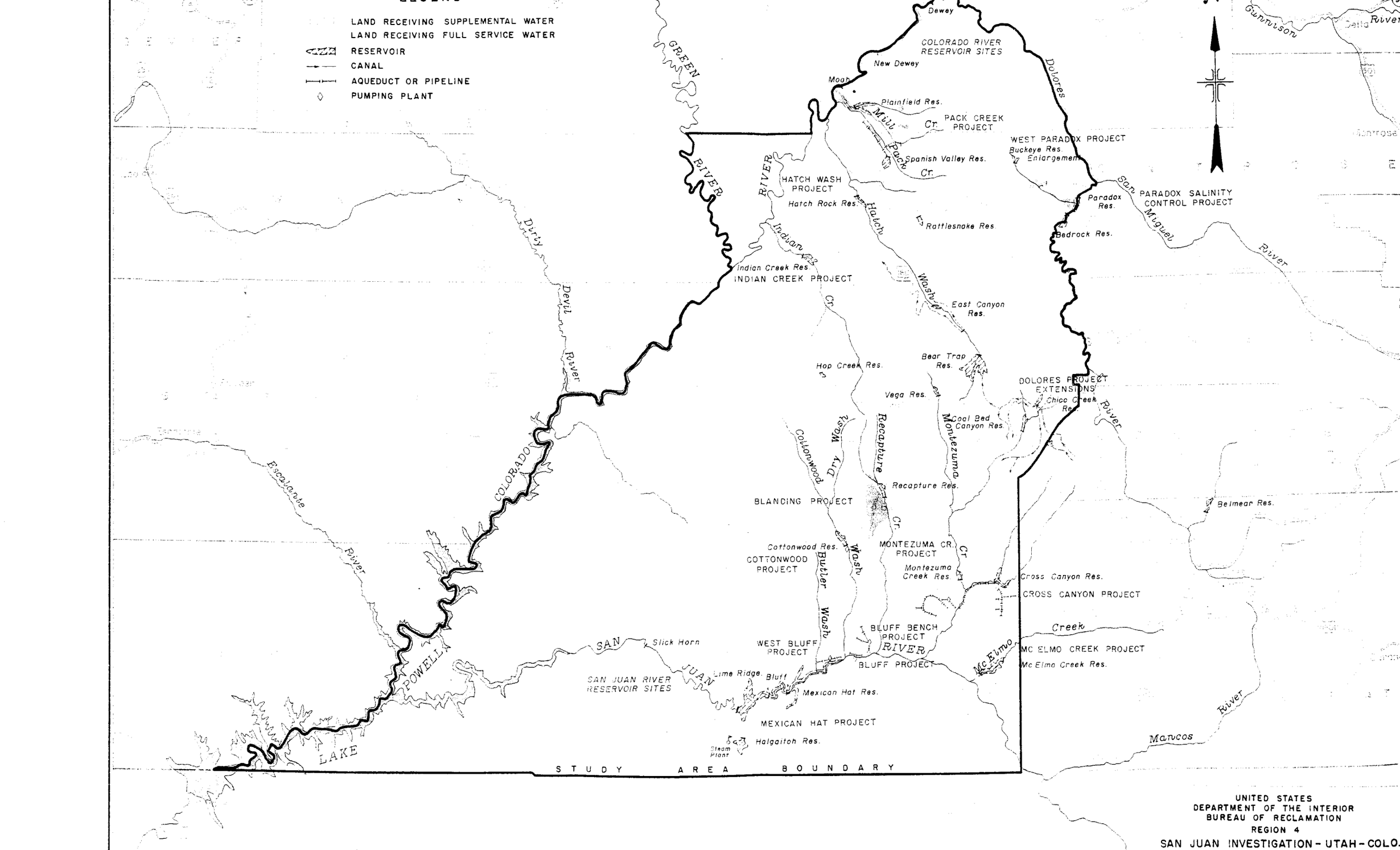
A number of the projects described in this report were also discussed briefly in the basin-type report entitled "The Colorado River," prepared in 1946 by the Bureau of Reclamation. Some projects outlined in the 1946 report have been constructed, some are precluded from construction by other developments, and others are still under consideration. The status of each is reported in this chapter.

Hopefully, this broad-scale presentation of potential projects will be useful to those who will be responsible for the selection of projects for further investigation or construction. All selections, of course, must be weighed in the light of depletions to the Colorado River permitted in the respective State by existing compacts. Other potentialities for water resource developments may be expected under changed conditions of the future and as additional information becomes available.

A map showing the location of the potential projects appears on the following page. Summary data on potential projects and reservoir sites in the area are tabulated on pages 86 and 87.

Scope of Investigations

Most of the project investigations have been made by the Bureau of Reclamation to preliminary standards. An exception is the West Paradox Project in Colorado which has been investigated in detailed scope by the Soil Conservation Service. Plans and estimates for the Bluff, Cottonwood, Lime Ridge Reservoir, and Vega Reservoir Projects were made by consulting engineers for the San Juan County Water Conservancy District. The Bureau of Outdoor Recreation appraised the recreational aspects of projects investigated by the Bureau of Reclamation and estimated the cost of recommended recreation facilities. Fish and wildlife values of potential projects were estimated by the Bureau of Sport Fisheries


LEGEND
LAND RECEIVING SUPPLEMENTAL WATER
LAND RECEIVING FULL SERVICE WATER
RESERVOIR
CANAL
AQUEDUCT OR PIPELINE
PUMPING PLANT
COLORADO RIVER RESERVOIR SITES
New Dewey
Dewey
Moab
Plainfield Res.
Mill Creek
PACK CREEK PROJECT
WEST PARADOX PROJECT
Buckeye Res. Enlargement
Spanish Valley Res.
Pack Cr.
HATCH WASH PROJECT
Hatch Rock Res.
Hatch Wash
Rattlesnake Res.
Paradox Res.
PARADOX SALINITY CONTROL PROJECT
Bedrock Res.
San Miguel River
Indian Creek Res.
INDIAN CREEK PROJECT
Indian Cr.
East Canyon Res.
Hop Creek Res.
Bear Trap Res.
DOLORES PROJECT EXTENSIONS
Chico Creek Res.
Vega Res.
Cool Bed Canyon Res.
Montezuma Cr.
Cottonwood Dry Wash
Recapture Wash
Recapture Res.
BLANDING PROJECT
Belmear Res.
Cottonwood Res.
COTTONWOOD PROJECT
Butler Wash
MONTEZUMA CR. PROJECT
Montezuma Creek Res.
Cross Canyon Res.
CROSS CANYON PROJECT
BLUFF BENCH PROJECT
WEST BLUFF PROJECT
SAN JUAN RIVER RESERVOIR SITES
Slick Horn
Lime Ridge
Bluff
Mexican Hat Res.
MEXICAN HAT PROJECT
Halgaitoh Res.
Steam Plant
McElmo Creek
McElmo Creek Res.
Marcos
LAKE POWELL
STUDY AREA BOUNDARY
GREEN RIVER
COLORADO RIVER
Dirty Devil River
Escalante River
Dolores River
Gunnison
Delta
Montrose
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
REGION 4
SAN JUAN INVESTIGATION - UTAH - COLO.

Summary of potential reclamation projects

Project name	Water source	Purposes served[1]	Irrigable acreage: Full service	Irrigable acreage: Supplemental service	Municipal and industrial water (acre-feet annually)	Hydroelectric power capacity (kilowatts)	Stream depletion (acre-feet annually)	Project construction cost
Blanding	Indian, Johnson, Recapture Creeks	I,R,H		2,300			750	$2,760,000
Bluff	San Juan River	I	442				1,440	208,750
Bluff Bench	San Juan River	I	2,600				6,500	3,180,000
Colorado River Storage								
Moab	Colorado River	P,R,F,S				60,000	NA	NA
Dewey	Colorado River	P,R,F,S				140,000	NA	NA
New Dewey	Colorado River	P,R,F,S				NA	NA	NA
Slick Horn Canyon	San Juan River	P,R				30,000	NA	NA
Bluff	San Juan River	P,R,S				52,000	NA	NA
Lime Ridge	San Juan River	P,R,M				NA	NA	NA
Cottonwood	Cottonwood Wash	I,R,S	1,200				2,950	3,960,000
Cross Canyon (Plan 3)	Cross Canyon (return flows)	I,R,S	7,000				18,200	16,970,000
Dolores Project extensions								
Bear Trap Reservoir	Dolores River	I,R	3,750				22,600	13,180,000
Chico Creek Reservoir	Dolores River	I,R	14,960				29,000	24,780,000
Coal Bed Canyon Reservoir	Dolores River	R					2,300	2,050,000
Hovenweep	Dolores River	I,R	3,300				8,400	8,600,000
Municipal water	Dolores River	M			[2]1,500		900	1,500,000
Paradox Salinity Control	Dolores River	Q					3,000	16,000,000
Hatch Wash	Hatch Wash	I,R	NA	NA			NA	NA
Hop Creek Reservoir	Hop Creek	R					NA	NA
Indian Creek	Indian Creek	R,S					800	4,040,000
McElmo Creek	McElmo Creek	I,R,F,P	NA	NA			NA	NA
Mexican Hat								
Mexican Hat Reservoir plan	San Juan River	M,R,P,S			50,000	60,000	48,000	45,810,000
Halgaitoh Reservoir plan	San Juan River	M,R			50,000		40,000	12,030,000
Combination plan	San Juan River	M,R,P,S			50,000	60,000	48,000	55,420,000
Montezuma Creek	Montezuma Creek	I,R,S	NA	NA			NA	NA
Navajo Pumping	San Juan River	I	19,610				NA	NA
Pack Creek	Mill and Pack Creeks	I,M,F,R	1,200	1,820	2,700		4,300	10,920,000
Vega Reservoir	Vega Creek	R					NA	155,000
West Bluff	San Juan River	I	1,070				2,700	980,000
West Paradox	Buckeye, Deep, and Geyser Creeks	I,R		2,500			NA	246,000

NA = not available.

1/ Symbols used: I = irrigation; R = recreation and fishing; F = flood control; S = sediment control; P = power; M = municipal and industrial; Q = water quality improvement; H = highway improvement.

2/ Includes water that will be furnished to Dove Creek in authorized plan of Dolores Project.

Reservoir sites for potential projects

Project	Reservoir site	Water source	Reservoir capacity (acre-feet)	Dam structure	
				Height (feet)	Volume (cu. yds.)
Blanding	Recapture	Indian, Johnson, Recapture Creeks	6,500	140	1,300,000
Colorado River Storage					
Moab	Moab	Colorado River	183,000	NA	NA
Dewey	Dewey	Colorado River	8,200,000	NA	NA
New Dewey	New Dewey	Colorado River	NA	NA	NA
Slick Horn Canyon	Slick Horn Canyon	San Juan River	300,000	NA	NA
Bluff	Bluff	San Juan River	3,000,000	NA	NA
Lime Ridge	Lime Ridge	San Juan River	250,000	204	NA
Cottonwood	Cottonwood	Cottonwood Wash	1/9,500	100	420,000
Cross Canyon	Cross Canyon	Cross Canyon (return flows)	36,000	112	1,025,000
Dolores Extension	Bear Trap	Dolores River	110,000	118	396,000
Dolores Extension	Chico Creek	Dolores River	6,400	110	555,000
Dolores Extension	Coal Bed Canyon	Dolores River	7,500	90	320,000
Dolores Extension	Belmear	Dolores River	28,000	120	NA
Dolores Salinity Control	Bedrock	Dolores River	48,000	135	NA
Paradox Salinity Control	Paradox	Dolores River	12,200	45	NA
Hatch Wash	Rattlesnake	West Coyote Creek	8,500	NA	NA
Hatch Wash	East Canyon	East Canyon Creek	2,500	NA	NA
Hatch Wash	Hatch Rock	Hatch Rock	NA	NA	NA
Hop Creek	Hop Creek	Hop Creek	NA	NA	NA
Indian Creek	Indian Creek	Indian Creek	20,000	114	831,000
McElmo Creek	McElmo	McElmo Creek	112,000	175	3,521,000
Mexican Hat	Mexican Hat	San Juan River	658,100	267	4,330,000
Mexican Hat	Halgaitoh	San Juan River	51,300	120	2,540,000
Montezuma Creek	Montezuma Creek	Montezuma Creek	25,000	85	NA
Pack Creek	Plainfield	Mill Creek	9,100	217	2/
Pack Creek	Spanish Valley	Pack and Mill Creeks	5,500	97	1,100,000
Vega Reservoir	Vega	Vega Creek	2,338	70	3/139,000
West Paradox	Buckeye Enlargement	Buckeye, Deep, Geyser Creeks	4/4,217	54	100,000

NA = Not available.

1/ Initial capacity; subject to later enlargement.

2/ Planned as concrete arch dam.

3/ Site A.

4/ Capacity before enlargement 1,600 acre-feet.

and Wildlife. The Federal Water Pollution Control Administration made salinity studies of the Dolores River as a basis for the Bureau of Reclamation's plan for the Paradox Salinity Control Project.

It is not intended in this report to suggest the agency or the program by which any project should be further investigated or constructed. Cost estimates prepared by the Bureau of Reclamation, however, are based on Federal construction to Bureau of Reclamation standards and with allowances for contingencies, engineering, and overhead. Costs of electrical power required for pumping were estimated at commercial rates of the Colorado River Storage Project with an allowance of 1 mill per kilowatt-hour for transmission costs. These rates include a charge of $1.275 per kilowatt of demand per month and an energy charge of 3 mills per kilowatt-hour.

An interest rate of 4 5/8 percent was used in computing costs of interest during construction. This rate was also used in estimating annual equivalent project costs and benefits used as a basis for the general economic appraisals made in this report.

Irrigation benefits and payment of irrigation costs

Benefits that would result from increased irrigation in the San Juan Area were estimated in Bureau of Reclamation studies by general analyses. The estimates were based on data developed in earlier studies of areas of similar climate. Annual benefits per acre were estimated for a typical composite land class and for a full irrigation water supply. Areas with growing seasons of similar lengths were grouped for separate analyses. Since benefits per acre added by irrigation are less on lands where the climate is suitable for dryland crops than on lands where agricultural production is almost wholly dependent on irrigation, separate benefit estimates were made for these two types of land. Benefits per acre-foot of water in any area can be computed by dividing the per acre benefit by the annual water requirement.

Benefits were estimated for conditions of an adequate water supply being fully available over a 100-year period. Adjustments were then made for accrual of only partial benefits over development periods of either 5 or 10 years. The estimates were based on agricultural conditions anticipated about 25 years after first delivery of the increased water supply and reflect a trend toward improved farm production as a result of continuously improving farm techniques. Direct, indirect, and public benefits were estimated. Direct benefits are equal to the increase in net farm income. Indirect benefits include increased profits from retail and wholesale trade and processing and marketing of farm products that result from the increased irrigation. Public benefits are claimed for economic growth and are estimated at 5 percent of the direct benefits.

The capacity to pay for increased irrigation water is the portion of the increased farm income remaining after the farmer pays his increased operating expense and is compensated for his increased labor, management, and capital investment. The recommended water charge is usually a little less than the payment capacity to allow for contingencies. Specific recommended water charges are not suggested for each of the potential projects discussed in this chapter but a general estimate is made of the degree to which the irrigators could pay costs allocated to irrigation. Should any of the developments be authorized as participating projects with the Colorado River Storage Project, assistance in the repayment of the irrigation investment may be obtained from revenues of the Upper Colorado Basin Fund assigned to Utah or Colorado, depending on the project location.

Sediment retention benefits

New reservoirs at most locations in the San Juan Area would retain substantial amounts of sediment. This would be beneficial at points downstream, particularly at Lake Powell where the reduced sediment inflow would extend the useful life of the reservoir and its value for river regulation, power generation, recreation, and as a habitat for fish and wildlife. These benefits would not be realized for many years, however, since Lake Powell has sufficient storage space for approximately 200 years. Consequently no benefits for sediment retention were claimed for new reservoirs in project analyses.

Project Economic Appraisals

The reconnaissance-type data presently available does not justify more than general economic appraisals of potential projects. Even with more detailed data precise determinations, including the computation of benefit-cost ratios and payment capacities of the irrigators, would be hazardous under today's rapidly changing economic conditions. Estimates of project costs have increased substantially of late because of higher prices and interest rates without compensating increases in estimates of project benefits. Recognizing this, the Water Resources Council is actively seeking a broader and more realistic approach in determining the economic feasibility of a project. A special task force of the Council has prepared a report which suggests the establishment of four accounts to reflect the widespread benefits resulting from water and related land resource development. The suggested accounts are (1) national income, (2) regional development, (3) environmental impact and worth, and (4) well-being of people.

A number of the projects described in this chapter have physical and engineering feasibility and would fill present or estimated future needs. The economic merit of the projects can be better determined when policies and procedures for the evaluations have been formalized.

Blanding Project

Through construction of the Recapture Reservoir on Recapture Creek and a pumping plant at the reservoir, the Blanding Project would provide about 2,600 acre-feet of additional water annually within the pattern of seasonal irrigation need as a supplemental supply for 2,300 acres of presently irrigated land on White Mesa near Blanding. The reservoir would also provide recreation and fish and wildlife benefits and its dam would provide a potential improved crossing of Recapture Creek Canyon for Utah Highway 47. The location of the potential reservoir and pumping plant is shown on the map on the following page.

Project setting

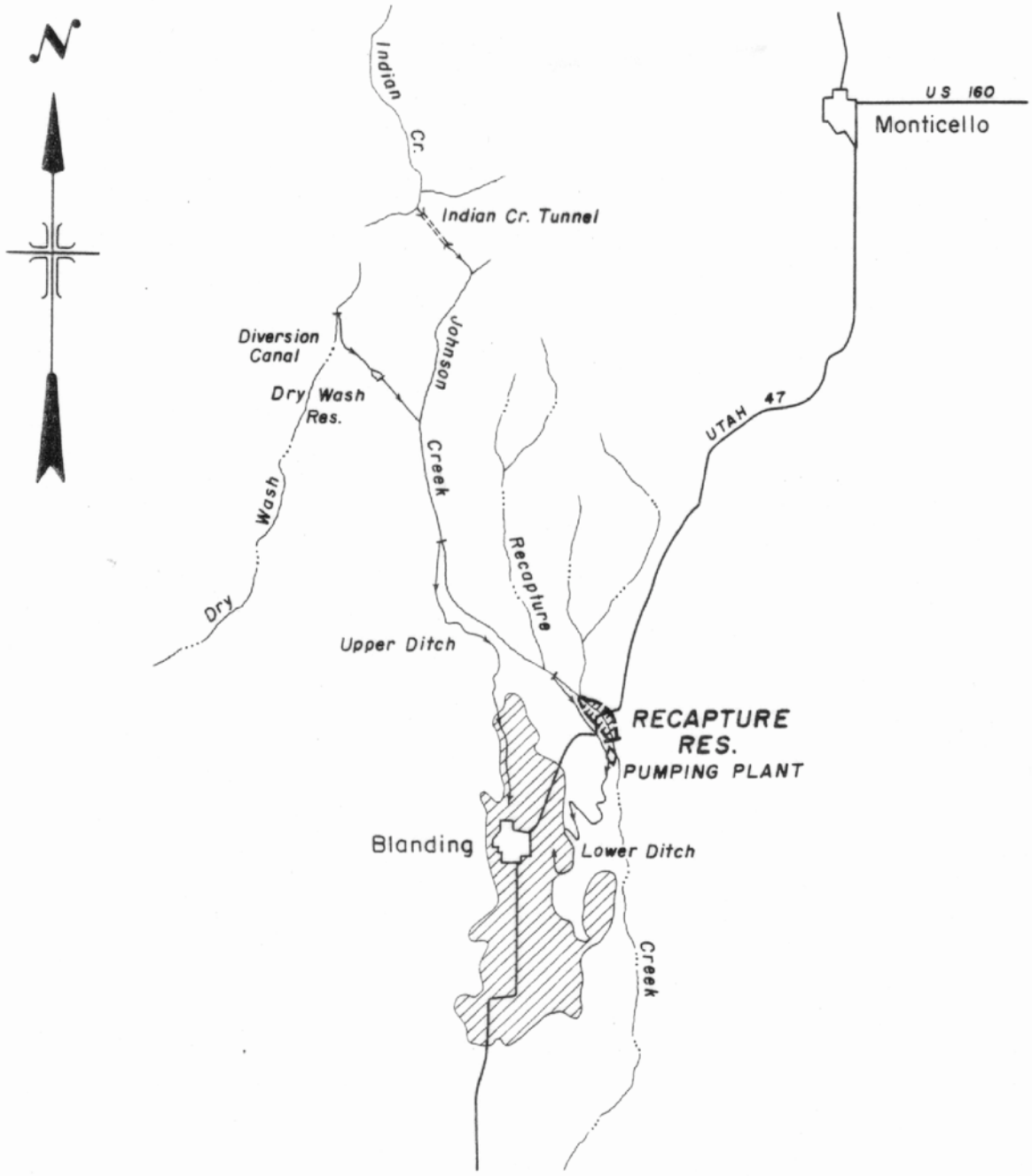
Recapture Creek and Johnson Creek, its principal tributary, flow southward from the Abajo Mountains to a junction at a point about 4 miles north of Blanding, Utah. From this junction Recapture Creek continues southward, entering the San Juan River about 5 miles east of Bluff, Utah. Flows of Johnson Creek are augmented by a tunnel diversion from the headwaters of Indian Creek, which flows northward from the Abajo Mountains, and by a diversion from the head of Dry Wash, which flows southward to join Cottonwood Wash about 31 miles above the wash's confluence with the San Juan River. Diversions from Dry Wash to Johnson Creek are regulated in the 184-acre-foot capacity Dry Wash Reservoir located on the diversion canal.

The 20-second-foot capacity Upper Ditch of the Blanding Irrigation Company diverts from Johnson Creek about 5 miles above the creek's junction with Recapture Creek but below the diverted inflows from Indian Creek and Dry Wash. The company's Lower Ditch, with a capacity of 40 second-feet, heads on Recapture Creek just below the creek's junction with Johnson Creek.

About 2,350 acres of arable land are under the Upper Ditch and 6,650 acres under the Lower Ditch. Because of limited water supply, however, the total area served from the two ditches varies from about 2,000 to 3,000 acres, depending on the amount of water available. During project studies made in 1967, a year of below-normal spring runoff, about 2,300 acres were irrigated.

Project plan

Recapture Reservoir would be formed by a dam located about a half mile downstream from the point where Recapture Creek is crossed by Utah Highway 47 and 2 miles below the mouth of Johnson Creek. Creek flows that are not now usable within the seasonal pattern of irrigation need would be stored in the reservoir and pumped as needed to the Lower Ditch.



LEGEND

Supplemental Irrigation Service Land

4 0 4

SCALE OF MILES

BLANDING PROJECT

Three other storage sites were considered and found less desirable than the Recapture site for project development. One was a higher site on Recapture Creek at its confluence with Johnson Creek. Another was on Johnson Creek at the point where the stream emerges from the Manti-La Sal National Forest near the head of the Upper Ditch. A third was on Indian Creek just below Newspaper Rock where storage would provide replacement water for downstream irrigation rights, thus permitting an increase in diversions from Indian Creek to Johnson Creek through the existing Indian Creek Tunnel.

Blanding, Utah, on White Mesa. Supplemental water is needed for the irrigated lands on the mesa. Local water supplies flow from Abajo Mountains in background.

Project works

The Recapture Dam would be a rolled earth structure 140 feet high above streambed. The crest would be 34 feet wide and 2,700 feet long at elevation 6,090. The crest width and elevation and the alinement of the dam axis were planned in cooperation with the Utah State Department of Highways to provide a favorable crossing for Utah Highway 47. The dam would include 1,300,000 cubic yards of embankment material.

A single reservoir outlet works with two branches would be provided on the left abutment of the dam. One branch, infrequently utilized, would discharge into Recapture Creek and the other would supply project water under pressure to the pumping plant. A spillway, located on the left abutment of the dam, would have a capacity of 1,000 second-feet at maximum water surface elevation (6,065.5 feet).

The pumping plant located immediately downstream from the dam's right abutment would pump reservoir water to the Lower Ditch. It would have 30 second-feet of capacity and would operate under a head, including friction losses, of 52 to 89 feet, depending on the water surface elevation of the reservoir.

The reservoir would have a capacity of 6,500 acre-feet below the top of its active conservation pool. This would include 5,050 acre-feet of active capacity and 1,450 acre-feet of inactive and dead capacity. In addition it would have a surcharge capacity of 5,150 acre-feet. The surcharge capacity, in combination with the spillway, would provide protection against a flood inflow having a peak of 12,000 second-feet and a 24-hour volume of 5,900 acre-feet. The reservoir would have adequate capacity to accommodate silt accumulations, estimated at 20 acre-feet annually.

Utah Highway 47 now passes through the reservoir site. A relocation across the crest of the dam would provide an improved alinement. Other necessary relocations from the reservoir basin include a sawmill owned by the San Juan Lumber Company, the 69-kilovolt wood pole transmission line of the Utah Power & Light Company, some telephone lines, and the county road leading to Bulldog Canyon and the Upper Recapture Creek drainage area. Approximately 660 acres of land would be required for the dam and reservoir, including 580 acres of Federal land and 80 acres privately owned.

Recreation facilities recommended by the Bureau of Outdoor Recreation to be provided at Recapture Reservoir include camp units, picnic units, parking areas, sanitary and water systems, paved roads, boat ramps, beach developments, landscaping, and administrative facilities. The existing Utah Highway 47 with some modification could be used as a boat-launching ramp.

A 2-year period would be required for construction of the dam, reservoir, and pumping plant. Recreation facilities would be added progressively as justified by recreation use.

Project costs

The investment cost of the Blanding Project is estimated at $2,888,000. This includes $2,300,000 for project construction of Recapture

Dam and Reservoir, $184,000 for construction of the pumping plant, and $276,000 as the present worth of the recreation facilities that would be provided from time to time. It also includes $128,000 in interest during construction computed for a 2-year period at 4 5/8 percent. About $400,000 of the cost of Recapture Dam is associated with building the dam to a higher elevation and wider crest width for an improved routing of Highway 47.

Annual operation, maintenance, and replacement costs are estimated at $32,400. This cost includes $6,300 for the dam, reservoir, and pumping plant (including $2,060 for pumping energy) and $26,100 for recreation facilities. The recreation figure is comprised of $18,700 for operation and maintenance and $7,400 for replacement of facilities.

Irrigation

The aeolian soils of the Blanding Area are moderately deep over creviced Dakota sandstone, moderately permeable, inherently fertile, and easy to till. The soils absorb moisture readily and have a high moisture-holding capacity. No problems from salts or alkali occur on the irrigated lands. Elevations range from 5,700 feet to 6,600 feet. The frost-free period averages about 149 days.

Livestock feeds, particularly alfalfa, hay, and pasture, are the principal crops grown on the irrigated lands. Some other types of hay and small grains are also grown.

The annual requirement for irrigation water delivered at the farm headgate is estimated at 3.38 acre-feet per acre. Allowing for conveyance losses of 10 percent between Recapture Reservoir and the farm, the annual requirement at the reservoir would be 3.76 acre-feet per acre distributed by months as shown in the following tabulation.

Irrigation requirement at Recapture Reservoir

	Acre-feet per acre
May	0.27
June	1.06
July	1.06
August	.82
September	.44
October	.11
Total	3.76

The existing Upper and Lower Ditches have capacity to divert about 90 percent of the flow of Recapture Creek during the spring runoff

season. About 50 percent of the water diverted is either outside the irrigation season or is in excess of normal irrigation requirements in the early irrigation season, however, so that without storage it has limited value. A minor part of the surplus water is stored in numerous small on-farm ponds constructed by individual farmers. Through storage in Recapture Reservoir, creek flows in excess of need and flows outside the irrigation season would be made usable when needed. Inflows to the creek from the 27 square miles of drainage area between the Lower Ditch and the reservoir would also be controlled and utilized. The reservoir would normally reach its highest level toward the end of April or in May and then would be gradually lowered over the next 2 or 3 months.

Water supply studies were based on the precipitation and runoff conditions for the 1958-66 period with 1960 eliminated because of inadequate records. Flows were estimated from altitude-runoff relationships and with allowance for diversions under preproject water rights. Flow or diversion records on Recapture and Johnson Creeks were not available. The studies indicated that an average of about 3,100 acre-feet annually is now diverted to the land by the two ditches, of which only about 1,200 acre-feet is available within the monthly pattern of need. Under project operation the average diversions to the land would be 3,900 acre-feet annually, of which 3,800 acre-feet would be within the pattern of need and the remaining 100 acre-feet would be diverted to the land outside the need pattern to avoid its spilling from a full reservoir. Thus the project would increase the water supply within the need pattern of lands by an average of 2,600 acre-feet annually. Under project operation the water supply would still be far short of meeting the full irrigation requirement of the land. The existing condition would be much improved, however, by the additional water and by regulation of much of the water now being diverted in excess of the immediate need. The modified use would increase the depletion to the Colorado River by about 750 acre-feet annually.

The water is of satisfactory quality for irrigation as is evidenced by its use for that purpose for more than 60 years.

Irrigation benefits from fully irrigated land in the Blanding Area, estimated for a 100-year period with adjustments for a 5-year project development period, would be $95 per acre annually, including $64 in direct benefits and $31 in indirect and public benefits. This is equivalent to $25 per acre-foot of water measured at Recapture Reservoir. The project irrigation benefit from 2,600 acre-feet of project water would be $65,800 annually, including $44,200 in direct benefits and $21,600 in indirect and public benefits.

Other project purposes

The Recapture Reservoir would have Statewide recreation significance according to a preliminary reconnaissance appraisal made by the Bureau of

Outdoor Recreation. Recreation activities would include fishing, camping, picnicking, boating, and swimming. Initial recreation use is estimated at 20,000 days annually, increasing to 107,000 days by year 2010. Recreation use was evaluated at $0.95 per recreation day.

Project effects on fish and wildlife were appraised by the Bureau of Sport Fisheries and Wildlife. Fishing benefits of Recapture Reservoir were estimated at $13,800 annually based on an expected 9,200 angling days. The project would not make an appreciable change in wildlife habitat, populations, or hunting.

The Bureau of Reclamation adjusted the recreation and fishing estimates of the cooperating agencies in order to eliminate overlapping fishery benefits in the two estimates and place the estimates on an average annual equivalent basis over a 100-year period for compatibility with other estimates used in the project economic and financial analyses. The estimates as adjusted are shown in the following table.

Adjusted recreation and fishing benefits

Item	Recreation	Fishing	Total
Annual use (days)	53,000	9,200	62,200
Annual benefits	$50,400	$13,800	$64,200

Since the location of Utah Highway 47 would be improved by rerouting across the Recapture Dam a transportation benefit would result. The benefit would be measured by the difference in cost of the highway with and without the dam and by the improvement in the highway location resulting from the rerouting. The benefit is expected to be substantial although its monetary value has not been determined.

Economic and financial appraisal

The Blanding Project, though operated with a limited water supply, would provide important multiple-purpose benefits in the Blanding Area. The project would have engineering feasibility. Its economic justification at this time would require an increase in the previously estimated benefits to irrigation, recreation, and fish and wildlife or a considerable benefit from an improved highway location across the Recapture Dam.

Cost allocations to project purposes, necessary for a sound project repayment analysis, have not been made because of insufficient data. Obviously the more costs that could be allocated to partly nonreimbursable purposes, such as recreation and fish and wildlife, or to other purposes such as transportation, the smaller would be the allocation to irrigation and the repayment obligation of the irrigators. The repayment ability of the irrigators would probably be sufficient to pay any operation, maintenance, and replacement costs that could logically be assigned to irrigation.

Cottonwood Project

Project purposes and plan

The Cottonwood Project would store flows of Cottonwood Wash in a reservoir that would be constructed on the wash to provide irrigation water for 1,200 acres of land located on lower White Mesa south of Blanding, Utah, between Cottonwood Wash and Recapture Creek. The project reservoir would also provide fishing and flood control benefits.

The dam on Cottonwood Wash would be located about 1 mile downstream from the point where the wash is crossed by Utah Highway 95. Water would be pumped from the reservoir through a lift of 560 feet to the land. It would be delivered to farm units under sufficient pressure for spinkler irrigation. Land drains would be provided as needed. Project works and lands are shown on the map on the following page.

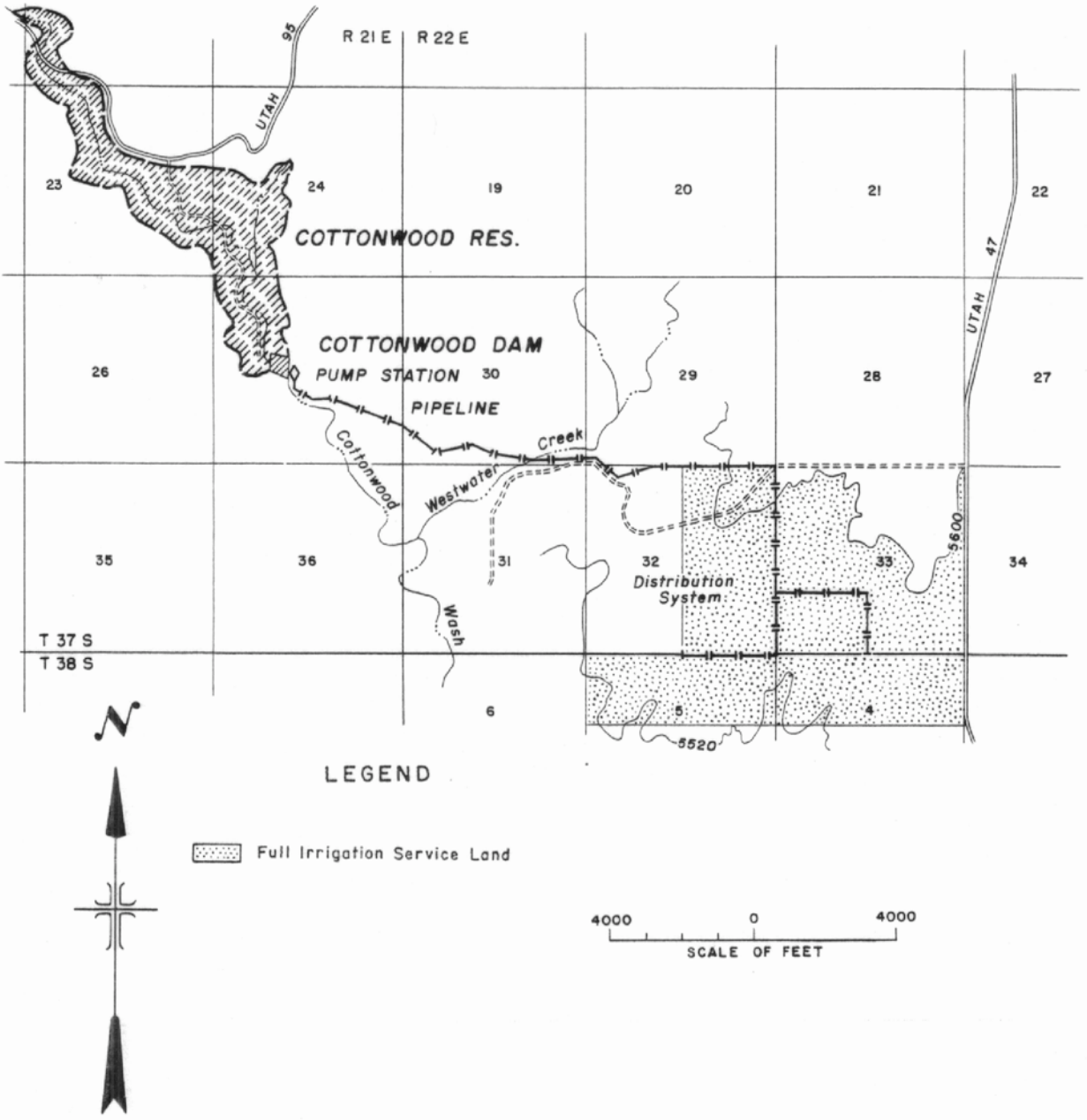
The project is being investigated by the San Juan County Water Conservancy District. Much of the data in this discussion was developed by the district or its consultants. Data on project costs and benefits have been adjusted by the Bureau of Reclamation to be comparable with those of other projects discussed in this report.

Project works

Cottonwood Dam, as initially constructed, would be 100 feet high, 560 feet long, and would contain 420,000 cubic yards of earth embankment. The reservoir would have a total capacity of 9,500 acre-feet, of which 7,600 would be active. A reservoir of this capacity would extend upstream to Highway 95 but would not require highway relocation. The dam would be raised 50 feet in 25 to 30 years after initial construction to compensate for sediment accumulation in the reservoir, estimated at 280 acre-feet annually. The increase in dam height would add 22,500 acre-feet to the reservoir capacity and would require relocation of the highway. Preliminary operation studies indicate that 4,300 acre-feet of active capacity should be maintained in the reservoir to meet project irrigation requirements.

A 13.3-second-foot capacity pumping plant would lift water 560 feet from the initial reservoir to the land. The supply pipeline would be 24 inches in diameter and 15,300 feet long.

Recreation facilities at Cottonwood Reservoir recommended by the Bureau of Outdoor Recreation include camp units, picnic units, parking areas, sanitary and water systems, paved roads, a boat ramp, beach development, landscaping, and administrative facilities.



COTTONWOOD PROJECT

A 2-year construction program would be required for initial features of the project. Recreation facilities would be installed initially and extended progressively as justified by recreational use.

Project costs

The investment cost of the Cottonwood Project is estimated at $4,140,000. This cost includes $2,779,000 for the initial dam, pumping plant, supply pipeline, distribution system, and land drains; $721,000 as the present worth of the cost of future enlargement of the dam and reservoir; and $460,000 as the present worth of the cost of recreation facilities that would be provided initially and extended from time to time. It also includes $180,000 in interest during construction computed for a 2-year construction period at 4 5/8 percent.

Operation, maintenance, and replacement costs are estimated at $57,300 annually. This includes $3,600 for the dam, reservoir, pipelines, and drains and $23,300 for the pumping plant with energy costs computed at rates applicable to Colorado River Storage Project power. It also includes $30,400 for recreation facilities to be provided initially and extended from time to time.

Irrigation

Lands that would be irrigated by the Cottonwood Project have not been classified. The soils are moderately deep over creviced Dakota sandstone, are moderately permeable, have good inherent fertility, and are easy to till. They absorb moisture readily and have a high moisture-holding capacity. No salinity or alkali problems would occur with irrigation. The lands are expected to have a light to moderate drainage requirement.

Irrigation water requirements are estimated at 3 acre-feet per acre annually with sprinkler irrigation. Requirements for the 1,200 acres would be 3,600 acre-feet.

Runoff records on Cottonwood Wash do not cover a sufficient period of time for reliable projections of future flows. The streamflow is erratic since much of the runoff results from thunderstorms during the summer and fall. The stream carries a high sediment load, especially during periods of storm runoff.

Water from Cottonwood Wash would be of satisfactory chemical quality for irrigation. The high sediment load would require reservoir capacity for its control as provided in the project plan.

Irrigation benefits were estimated for a 100-year period with adjustment for a 5-year development period. Benefits are estimated at

$114,000 annually, including $76,800 in direct benefits and $37,200 in indirect and public benefits.

Other project purposes

The recreation potential of Cottonwood Reservoir was appraised by the Bureau of Outdoor Recreation. The reservoir would provide a convenient en route camp area or wayside rest area for the highway traveler as well as afford recreation opportunity for local residents. The principal recreation activities at Cottonwood Reservoir would be camping, picnicking, swimming, fishing, and boating. An initial recreation use of 10,000 recreation days annually including fishing is expected, increasing to an optimum use of 120,000 recreation days 35 to 45 years after initial development. Recreation benefits were evaluated at $0.95 per recreation day. These use and benefit estimates, adjusted for a 100-year period of analysis, would be equivalent to an average annual recreation and fishing use of 59,000 days and an average annual benefit of $56,100.

Cottonwood Reservoir would reduce the sediment load carried by Cottonwood Wash to the San Juan River and downstream to existing reservoirs. It would also reduce flooding and silt deposition at the town of Bluff, located 20 miles downstream at the point where Cottonwood Wash joins the San Juan River.

Economic and financial appraisal

About $26,900 of the annual operation, maintenance, and replacement cost, including $19,800 for electrical energy, would be allocable to irrigation. The payment capacity of the irrigators would be considerably less than this cost.

The Cottonwood Project, although providing needed benefits to the area, would face problems of erratic streamflow, heavy sediment load, and high costs for operation and maintenance. It does not appear to be economically justified at this time.

Bluff Bench Project

Project purpose and plan

The Bluff Bench Project would consist of pumping water from the San Juan River for irrigation of 2,600 acres of presently undeveloped land. The lands are located on a bench 250 to 500 feet above the river north of Bluff, Utah, between Recapture Creek and Cottonwood Wash, two south-flowing tributaries of the San Juan River. The project is shown on the map on the following page.

The river water would flow by gravity to a desilting pond that would be excavated in the flood plain near the river channel. Two pumping plants would lift water from the desilting pond to the farm units. Additional pumps would be provided by the irrigators as needed to provide the pressure required for sprinkler irrigation. Drains would be constructed for lands having a drainage deficiency. Storage on the San Juan River was not considered to be necessary to assure a firm water supply.

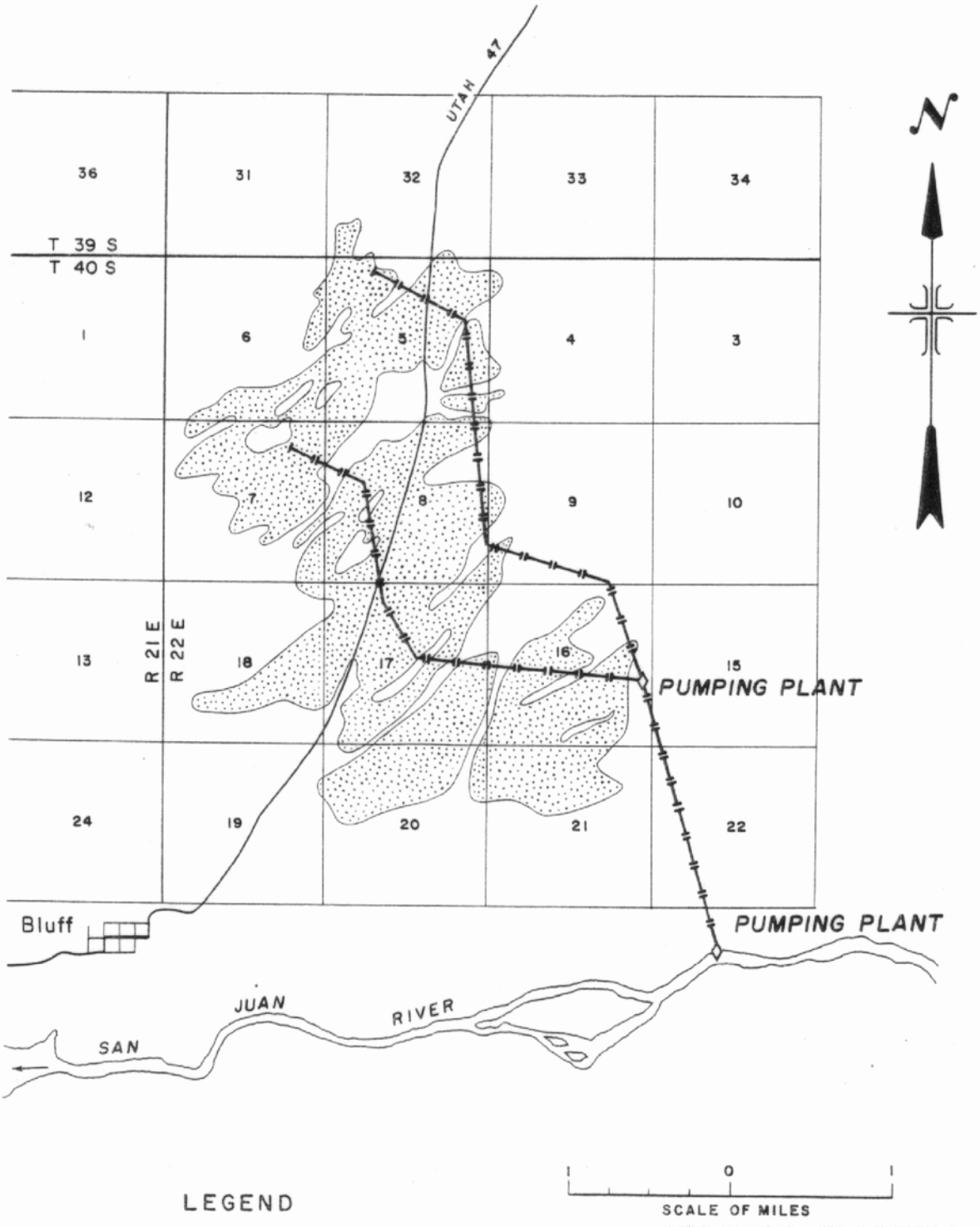
Project works

The pumping capacity and head at each of the pumping plants and the irrigated acreage that could be served from each are shown in the following tabulation.

	Pumping plants	
	First lift	Second lift
Capacity (second-feet)	54	26
Pump lift (feet)	390	120
Highest elevation served (feet)	4,700	4,810
Land area served (acres)	1,610	990

A 42-inch-diameter discharge line would extend 9,300 feet from the first pump to the second pump and would deliver water to pipe laterals serving lands below elevation 4,700. A 30-inch discharge line from the second pump would convey water to lands between elevations 4,700 and 4,810. The lateral distribution system would consist of 28,800 feet of pipe ranging from 36 inches to 18 inches in diameter. A drainage layout was not made but drainage costs were estimated on a per acre basis for drainage-deficient areas.

A 2-year construction program would be required to complete the pumping and lateral system. Drains would be constructed after initial project operation when needs could be more accurately determined.



BLUFF BENCH PROJECT

Project costs

The investment cost of the Bluff Bench Project is estimated at $3,327,000. This includes $784,000 for pumping facilities and the desilting pond, $1,616,000 for pump discharge lines, laterals, and miscellaneous valves and fittings, and $780,000 for drains. It also includes $147,000 in interest during construction computed at 4 5/8 percent interest.

Annual operation, maintenance, and replacement costs are estimated at $60,300. These costs include $10,000 for the lateral and drainage system and $50,300 for pumping facilities. The pumping cost includes $1,100 for operation, $6,500 for maintenance and replacement, and $42,700 for electric energy.

Irrigation

A reconnaissance land classification and drainage survey was made on Bluff Bench in March 1968. The survey covered 8,320 acres, of which 2,600 acres were found to meet class 2 standards for sprinkler irrigation. Soils of the area are principally aeolian. Wind action has shifted and reformed the soil material into roughly parallel strips of low-lying dunes, which are now stabilized by native vegetation. The soils most favorable for irrigation development lie in broad flats or shallow valleys between the dunes. These soils are principally sandy loams and loamy sands which overlie the massive white Bluff Sandstone at depths ranging from 5 feet to more than 14 feet. The sandy soils have a high water infiltration rate, a low available moisture capacity, and are relatively free of salt and alkali.

The massive sandstone formation underlying the soils would be a barrier to ground water movement. Drainage requirements would vary from low to high depending on irrigation methods, amount of water applied, depth of permeable material, and size of upslope irrigated areas which would contribute to the drainage deficiency.

Alfalfa is the principal crop grown on presently irrigated lands and is expected to be the principal crop on newly developed lands. The climate and good air drainage on the bench are suitable for orchards.

Water requirements of the project would average 10,000 acre-feet annually and depletion of the Colorado River would be about 6,500 acre-feet annually. The chemical quality of water is satisfactory for irrigation.

Irrigation benefits estimated for a 100-year period with adjustment for a 5-year development period would average $309,400 annually, including $213,200 in direct benefits and $96,200 in indirect and public benefits.

Economic and financial appraisal

The single-purpose Bluff Bench Project would be dependent solely upon irrigation for its economic justification. Annual irrigation benefits based on the production of alfalfa and other livestock feeds would likely approximate the annual equivalent project costs. Operation and maintenance costs, high because of the necessity of pumping all project water from the San Juan River, would likely exceed the payment capacity of the irrigators. More extensive-type farming, including the growing of fruits and vegetables, would be practical on the project if market conditions were favorable and would improve the economy of the project and the payment capacity of the farmers.

Bluff Project

The Bluff Project would involve pumping of San Juan River water for sprinkler irrigation of 442 acres of land. The land is located just east of Bluff, Utah, along the north side of the river. It lies between the river and Bluff Bench to the north, extending along the river approximately 3 miles.

An application to construct the project under the Small Reclamation Projects Act of 1956 was prepared for the San Juan County Water Conservancy District in 1967 by the engineering firm of Henningson, Durham & Richardson but has not yet been formally filed with the Bureau of Reclamation. The application is the source of much of the project data and the estimates in this discussion.

Bluff Project site from the air.

CHAPTER IX

POTENTIAL RECLAMATION PROJECTS
(Bluff Project)

Part of the land in the project area has previously been irrigated by a gravity diversion from the San Juan River. Alfalfa and some fruits and vegetables have been grown under irrigation. Several years ago the headworks of the irrigation canal were washed out by a flood and the banks of the river were so badly eroded that a new diversion structure could not be constructed in the same location. It was impractical to move the diversion point either upstream or downstream, so the canal was abandoned. Approximately 80 percent of the land within the project boundaries now lies dormant. However, two property owners pump water from the San Juan River for the irrigation of about 90 acres. One uses a sprinkler system and the other pumps to a gravity distribution system. Both have indicated that they would abandon their existing systems and participate in the Bluff Project.

The land is all privately owned except about 150 acres which are owned by the Navajo Indian Tribe. A dike has been constructed on the north bank of the river to prevent flooding of the agricultural lands.

Project works would consist of a 20-inch pipe inlet through the existing dike to a settling basin and a sump. The pumping plant would consist of two pumps with capacities of 3 1/3 and 5 1/3 second-feet, respectively, under total heads of 250 feet. The system would provide a minimum static pressure of 50 pounds per square inch at the highest point in the pipe distribution system to provide pressure for sprinkler irrigation. The project would provide 2,210 acre-feet of water annually for irrigation, resulting in a depletion of 1,440 acre-feet to the Colorado River.

Construction costs of the system are estimated at $208,750. Annual operation, maintenance, and replacement costs, including power for pumping at rates established for the Colorado River Storage Project, are estimated at $8,600. The operation and maintenance cost includes costs of cleaning the settling basin and sump.

Project irrigation benefits are estimated at $52,600 annually, including direct benefits of $36,200 and indirect and public benefits of $16,400. Although the Bluff Project is similar in plan to the Bluff Bench Project, its pump lift would be lower and consequently it would have a higher ratio of benefits to costs. The capacity of project farmers to pay project operation, maintenance, and replacement costs is demonstrated by the two farmers who are operating successfully in the project area. The San Juan County Water Conservancy District would operate the project and repay the project loan obligation to the United States. The conservancy district would have authority to utilize ad valorem tax revenues to assist the irrigators in the payment of project costs, if necessary.

West Bluff Project

Project purpose and plan

The West Bluff Project would involve pumping from the San Juan River for full irrigation service of 1,070 acres of lower bench lands located north of the river and west of Bluff, Utah, between Cottonwood Wash and Butler Wash.

A low head pumping plant on the San Juan River would discharge into a desilting pond near the river channel. The pond would be about 300 feet long, 50 feet wide, and 10 feet deep. From the pond water would be raised through a series of pump lifts to bench lands located 10 to 220 feet above the river. Water would be distributed to each farm unit by a low-pressure pipe lateral system. The irrigators would supply additional pressure required for sprinkler irrigation. A drainage system would be provided for lands having a drainage deficiency. A sketch map of the project appears on the following page.

Project works

Four pumping plants would be required, including the one on the river bank. The pumping capacity, head, and installed power capacity of each plant and the irrigated acreage that could be served from each pumping plant are shown in the following tabulation.

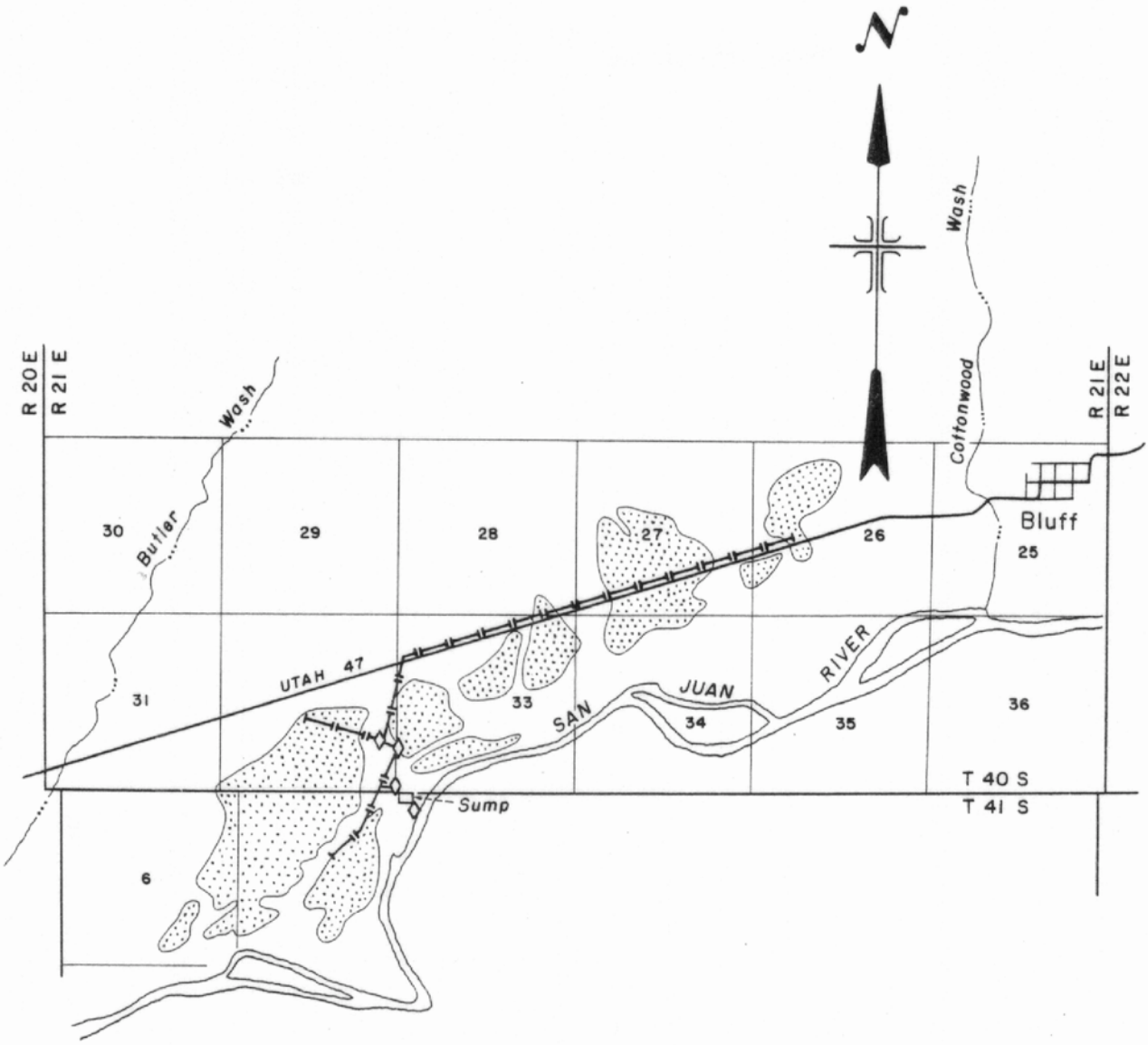
	Pumping plants			
	River unit	First lift	Second lift	Third lift
Capacity (second-feet)	28	28	24	14
Total pump head (feet)	10	122	55	54
Installed horsepower	50	540	220	130
Highest elevation served		1/4,400	4,450	4,500
Land area served (acres)		180	420	470

1/ First lift would serve lands between elevations 4,290 and 4,400 feet.

A pipe distribution system consisting of about 21,200 feet of concrete pressure pipe ranging from 30 to 18 inches in diameter would deliver water to each farm unit. A drainage layout was not prepared but drainage costs per acre were estimated for drainage-deficient areas. A 1-year construction period would be required for construction of all facilities except drains which would be added as their need and location are determined from project operation.

Project costs

The investment cost of the West Bluff Project is estimated at $980,000. This includes $268,000 for pumping facilities; $598,000 for



LEGEND

Full Irrigation Service Land

0

SCALE OF MILES

WEST BLUFF PROJECT

pump discharge lines, laterals, valves, and miscellaneous fittings; $110,000 for drains; and $4,000 for the sump.

Annual operation, maintenance, and replacement costs are estimated at $18,800. This estimate includes $4,100 for the distribution and drainage system and $14,700 for the pumping facilities, including $1,100 for operation, $4,000 for maintenance and replacement, and $9,600 for pumping energy.

Irrigation

A semidetailed land classification and drainage survey of the West Bluff Area was made in March 1968. The survey covered 4,800 acres, of which 1,403 acres were found to be arable if sprinkler irrigation methods were used and 1,005 acres were found to be arable under gravity irrigation methods. Sprinkler irrigation would permit irrigation of some of the sandier soils and steeper slopes where gravity methods would be infeasible.

Soils of the West Bluff Area are alluvial, having been deposited on fans by intermittent side streams and on terraces by the river. The soils are medium to coarse textured, composed largely of sandy loam, loam, and loamy sand. The sandy soils have a high infiltration rate and a low available moisture capacity. The sandy soils overlie gravel and cobble on the terraces and massive Entrada sandstone on the upper fans at depths ranging from surface outcroppings on nonarable lands to more than 14 feet (maximum depth augered) on arable lands. Most of the soils of the West Bluff Area are low in soluble salts and alkali. Some soils with excessive salt and exchangeable sodium content, indicated by "slick spots" and verified by soil tests, occur on the old flood plain of Cottonwood Wash near Bluff and on some terraced lands along the highway west of Bluff. These alkali lands were determined to be nonarable because of low productivity and high costs of reclamation.

The 1,070 acres of land that would be irrigated in the West Bluff Project plan include 400 acres of class 1 land, 596 acres of class 2 land, and 74 acres of class 3 land.

Project lands would have excellent surface drainage because of their topography and elevated position above natural drainageways. Terrace lands underlain by gravel and cobbles would have a low drainage requirement. Lands located upslope are underlain by a massive sandstone layer which would be a barrier to water movement. These higher lands can be expected to require a moderate drainage system to maintain a suitable water table depth.

Alfalfa is the principal crop presently grown on irrigated land at Bluff. A similar crop pattern would be expected in the West Bluff Area

although the soils and climate are suitable for a wide variety of crops, including fruit, melons, and vegetables. The local need for livestock feed and marketing problems with other crops tend to favor alfalfa and forage crops.

Water requirements are estimated at 4,100 acre-feet annually under sprinkler irrigation, based on a diversion rate of 3.85 acre-feet per acre. Depletions to the Colorado River would be about 2,700 acre-feet annually. The project plan is based on the assumption that additional storage regulation of the San Juan River would not be required. The chemical quality of San Juan River water is satisfactory for irrigation purposes, but the heavy silt load would require special attention as is provided in the project plan.

Annual irrigation benefits estimated for a 100-year period with adjustment for a 5-year development period would be $127,300, including $87,700 in direct benefits and $39,600 in indirect and public benefits.

Economic and financial appraisal

The West Bluff Project would be similar to the Bluff Project. It would likely be justified by a favorable ratio of benefits to costs. Operation, maintenance, and replacement costs would be high because of the pumping requirement and would approach or possibly exceed the farmers' payment capacity.

The San Juan County Water Conservancy District is reported to be studying the possibility of including the West Bluff Project with the Bluff Project in an application for construction under the Small Reclamation Projects Act of 1956.

Mexican Hat Project

Project purposes and plan

Mexican Hat Reservoir, with a capacity of 658,100 acre-feet, would be formed by a dam on the San Juan River about 1 mile downstream from Mexican Hat, Utah. The reservoir would provide water for municipal and industrial use at a large-scale, coal-fired, electric-generating plant. Power would also be generated by a hydroelectric powerplant at the dam. Recreational, fish and wildlife, and sediment-retention benefits would be provided by the reservoir.

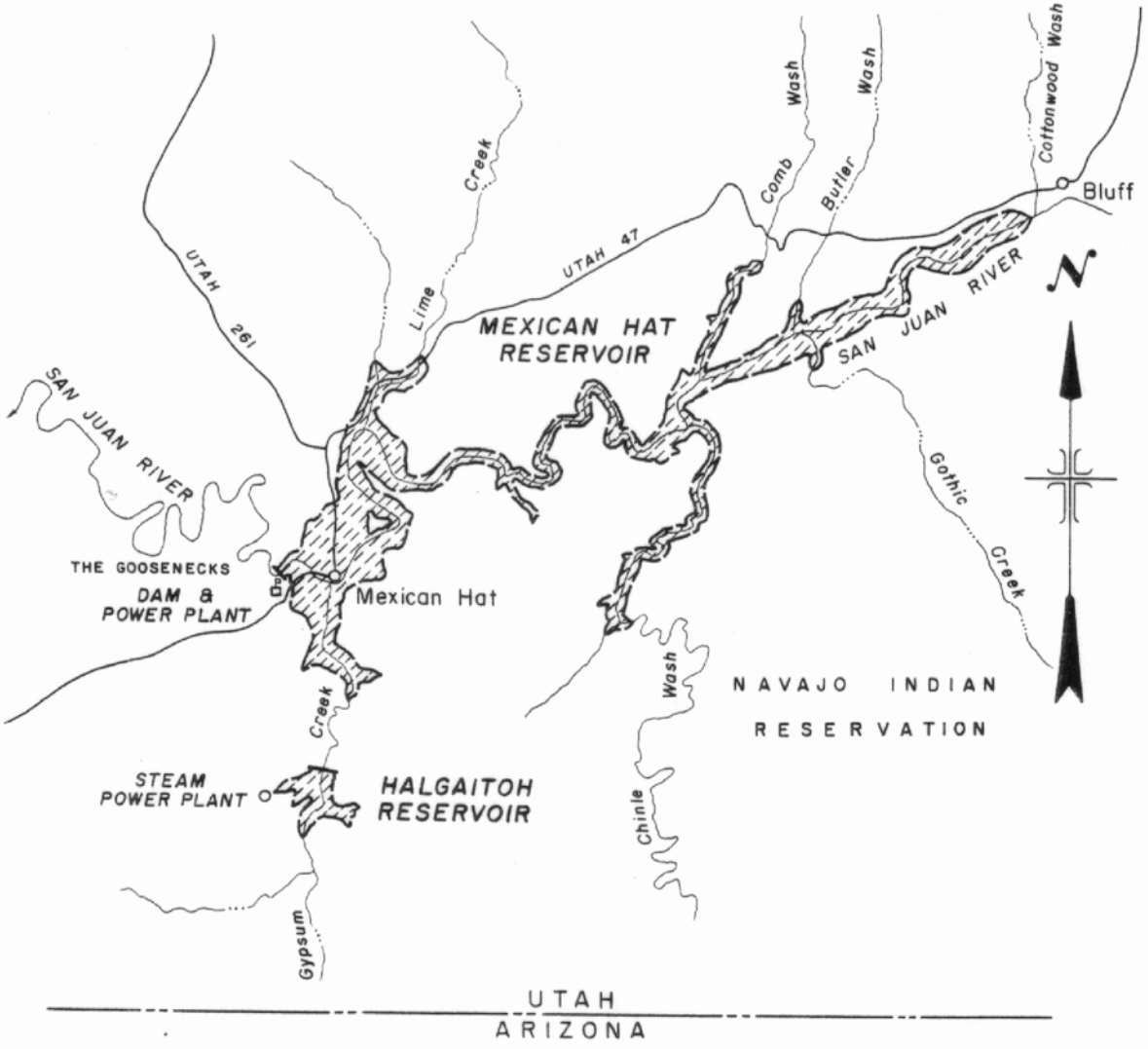
As an addition to the Mexican Hat Reservoir plan, or as an alternative storage development, the offstream Halgaitoh Reservoir supplied by pumping from the San Juan River would furnish municipal and industrial water for the fuel-electric power development and would benefit recreation and fish and wildlife. Following a discussion of the Mexican Hat Reservoir, the Halgaitoh Reservoir is discussed. Locations of the two reservoirs are shown on the map on the following page.

Water provided for uses associated with steam-electric power generation would be obtained at the Mexican Hat Reservoir by the operators who would provide their own conveyance facilities. The project would provide transmission lines, switchyard, and substations required to connect the hydroelectric powerplant to the transmission system of the Colorado River Storage Project. Debris basins would be constructed on Chinle Wash and Chaco River, tributaries of San Juan River, to reduce sediment inflow at Mexican Hat Reservoir and thus extend the useful life of the project. Recreation facilities would be provided at the reservoir as recommended by the Bureau of Outdoor Recreation.

The reservoir would normally reach its highest permissible elevation late in May and hold it until the latter part of July. Drawdown for hydroelectric power generation would be minimized during the recreation season.

Sedimentation

Operating plans for the Mexican Hat Reservoir would be influenced by the sediment load of the San Juan River which though heavy has shown a decreasing trend in recent years. Improved range management and conservation programs resulting in reestablishment of vegetative cover on land denuded during the drought of the 1930's may be a factor in the reduction. Impending upstream storage and diversion developments, such as the Navajo Indian Irrigation, San Juan-Chama, and Animas-La Plata reclamation projects and a number of Public Law 566 projects planned by the Soil Conservation Service, may further reduce the sediment load. Although the sediment inflow to the Mexican Hat Reservoir cannot be accurately forecast under these changing



MEXICAN HAT PROJECT

conditions, the annual deposition is expected to range between 10,000 and 19,000 acre-feet. Debris basins on Chinle Wash and the Chaco River, which drain 37 percent of the most erosive part of the drainage area above the Mexican Hat site, may further reduce the deposition by up to 50 percent.

Because of the sediment problem, it is not planned to utilize the full capacity of the reservoir. The upper 25 feet of reservoir capacity would not be used initially in normal operation. Then as sediment is deposited into the active pool, the operating level would be raised to compensate for the loss of capacity and to cover unsightly sediment deposits at the head of the reservoir near Bluff, Utah. By repeatedly raising the operating level of the reservoir in this manner and limiting the operational capacity to about 300,000 acre-feet, the recreational attractiveness of the reservoir would be prolonged for many years.

Project works

Mexican Hat Dam would be a rolled earth, sand, gravel, and rockfill structure 267 feet high above streambed and 1,270 feet long at its crest. It would contain 4,330,000 cubic yards of material. Utah Highway 47 would be relocated across the dam. The outlet would be located on the right abutment. It would consist of two parallel 24-foot-diameter tunnels constructed to handle diversion of the river during construction. One tunnel would later be used for the hydroelectric powerplant and the other for a separate river outlet works. Each would consist of an intake structure, trashrack, guard gate, gate chamber, and steel penstock inside the tunnel.

A service spillway would be constructed on the right abutment. The spillway would be controlled by four 25x38-foot radial gates set at spillway crest elevation 4,265 feet. The spillway would have a capacity of 88,500 second-feet at a maximum water surface elevation of 4,302.2 feet. A 100-foot-wide concrete chute would cut through the right abutment, extend down the canyon wall, and terminate in a flip bucket near river level. An auxiliary spillway on the ridge leading from the left abutment would be used only in control of the maximum design flood. It would consist of a 1,000-foot-long concrete control section set at elevation 4,295 feet. Its capacity would be 70,000 second-feet at maximum water surface elevation.

Of the 658,100 acre-feet of capacity in the Mexican Hat Reservoir, 521,400 acre-feet would be active and 136,700 acre-feet would be inactive and dead. A surcharge capacity of 78,000 acre-feet in combination with a service spillway capacity of 88,500 second-feet and an auxiliary spillway capacity of 70,000 second-feet would provide protection against an inflow design flood having a peak of 250,000 second-feet and a 5-day volume of 1 million acre-feet.

The Mexican Hat hydroelectric powerplant would have an installed capacity of 60,000 kilowatts and would be designed for operating heads

varying from 160 to 255 feet, depending on the water surface elevation in the reservoir.

The Chinle Wash debris basin would have a capacity of 300,000 acre-feet. It would control an area of 4,100 square miles that drains directly into the Mexican Hat Reservoir Basin. A dam 235 feet high and 1,500 feet long containing 3,300,000 cubic yards of material would be required.

The Chaco River debris basin would have a capacity of 320,000 acre-feet. It would control an area of 4,550 square miles that drains into the San Juan River near Shiprock, N. Mex., 75 miles above the head of Mexican Hat Reservoir. A dam 140 feet high, 2,500 feet long, and containing 4,050,000 cubic yards of material would be required.

Both debris basins would be of earthfill construction. The outlets and service spillways would consist of restricted flow risers and pipe outlet conduits. Auxiliary spillways cut in rock abutments with concrete control sections would also be provided to protect both dams.

The project transmission line would connect with the 230-kilovolt transmission line of the Colorado River Storage Project that extends from the Glen Canyon Powerplant to the Shiprock Substation. As an alternative a connection could be with the 138-kilovolt line of the Utah Power and Light Company at La Sal, Utah. Recreation facilities at Mexican Hat Reservoir would include camp units, picnic units, parking areas, sanitary and water systems, paved roads, boat ramps, beach developments, landscaping, and administrative facilities.

A 5-year program would be required for construction of the dams, reservoir, powerplant, and transmission facilities. Recreation facilities would be provided for initial use and added progressively as justified by increased use.

Project costs

Investment costs are estimated at $51,100,000. This estimate includes $45,800,000 for construction and $5,300,000 in interest during construction computed at 4 5/8 percent. Project operation, maintenance, and replacement costs are estimated at $268,000 annually. Costs by features are listed on the following page.

Feature	Estimated costs: Construction	Estimated costs: Annual operation, maintenance, and replacement
Mexican Hat Dam and Reservoir	$25,000,000	$20,000
Mexican Hat Powerplant	10,400,000	120,000
Transmission lines, switchyard, substation	2,000,000	20,000
Chinle Wash debris basin	3,300,000	5,000
Chaco River debris basin	4,000,000	5,000
Recreation facilities	1/ 1,100,000	98,000
Total	45,800,000	268,000

1/ Present worth of initial facilities and those added progressively to meet increased recreation use.

Municipal and industrial water

A water supply of 50,000 acre-feet annually would be made available at Mexican Hat Reservoir for municipal and industrial uses. The water would be intended for use at a large thermal-electric generating plant to be located near Mexican Hat. Coal could be supplied from the Black Mesa deposits about 40 to 50 miles southwest of Mexican Hat on the Navajo Reservation in Arizona. The increased stream depletion that would result from this use is estimated at 40,000 acre-feet annually.

The annual benefit from water used for municipal and industrial purposes is estimated at $300,000. The benefit was determined as equivalent to the cost of a single-purpose project that would supply the same quantity and quality of water at the same delivery elevation. The single-purpose project was considered to consist of a desilting works and pumping plant on the San Juan River to lift water 160 feet to elevation 4,200 feet. The annual cost of the alternative would include $175,000 for amortization of $2,400,000 in construction costs in 35 years at 6 1/2 percent interest and $125,000 in operation, maintenance, and replacement costs.

Hydroelectric power

Operation of Mexican Hat Reservoir and the 60,000-kilowatt powerplant would be coordinated with other storage reservoirs and powerplants of the Colorado River Storage Project. An electronic computer program, which takes into account water supply, reservoir storage, power market, and other factors affecting optimum operation of the Colorado River Storage Project power system, was used to study the effect of the addition of Mexican Hat Powerplant to the system. The study was based on water supply conditions for the 60-year period 1906 through 1965 adjusted for stream depletions resulting from all present upstream developments.

Results of the study were modified to reflect anticipated future flows of the San Juan River after development of projects now under construction or authorized, including the San Juan-Chama, Navajo Indian Irrigation, Animas-La Plata, and Dolores Projects. With these future modified flows it is estimated that the Mexican Hat Powerplant could produce from 200 million to 250 million kilowatt-hours of energy annually.

Benefits from power production at the Mexican Hat Powerplant are estimated at $1,380,000 annually. Since Colorado River Storage Project's interconnected power system serves an extensive area, a weighted average value of power for the entire area was used in estimating benefits. The value of power was assumed equal to the cost of obtaining equivalent power from the most economical alternative source likely to be developed in the absence of the power-producing units of the storage project. Steam-electric plants constructed and operated by private utilities are considered the most likely alternative source.

Recreation and fishing

The Bureau of Outdoor Recreation found from preliminary studies that the Mexican Hat Reservoir would help meet existing and future needs for water-associated recreation facilities in the San Juan Area. Because of the sparse population, nonresident tourists figured heavily in the anticipated recreation demand.

Although the reservoir would have well over 100 miles of shoreline, much of it would be confined to steep-walled canyons so that less than 10 miles would be readily accessible for recreation use. Access could be attained only near Bluff and at two or three places near Mexican Hat. Principal recreation activities at the reservoir would be fishing, sightseeing, camping, boating, swimming, and picnicking.

Annual recreation use of the reservoir, including fishing, is estimated by the Bureau of Outdoor Recreation at 50,000 days initially, increasing to 450,000 days within 35 to 40 years.

Project effects on fishing were appraised by the Bureau of Sport Fisheries and Wildlife. That agency found that operation of Mexican Hat Reservoir would be suitable for the development of a good cold water-warm water fishery. With comprehensive development of public use facilities and access for the reservoir area, 90,000 man-days of fishing would be provided by the reservoir annually.

Recreation and fishing estimates of the Bureau of Outdoor Recreation and Bureau of Sport Fisheries and Wildlife were adjusted to eliminate overlapping fishing benefits and place the estimates on an average annual equivalent basis over a 100-year period at 4 5/8 percent interest for

compatibility with other estimates used in the project economic and financial analyses. The adjusted estimates are shown below.

Adjusted recreation and fishing benefits

Item	Recreation	Fishing	Total
Annual use (days)	138,700	90,000	228,700
Annual benefits	$117,900	$135,000	$252,900

A potential also exists for the development of an attractive float fishery on the San Juan River below Mexican Hat Dam. Experience on river reaches below Glen Canyon, Flaming Gorge, and Navajo Dams indicates that with adequate minimum flows and clear, cool water excellent fishing can be provided. Below Mexican Hat Dam the use of this fishery would be dependent upon a downstream access takeout point as a terminus for float fishing parties. No estimate of use for this potential fishery was made.

Other project purposes

Construction of Mexican Hat Project would provide sediment-retention and water quality benefits on the San Juan River below Mexican Hat. The useful life of Lake Powell and Glen Canyon Dam would be extended and the recreation and fishing values of the San Juan arm of Lake Powell would be enhanced. The clear, cool water released at Mexican Hat Dam would enhance recreation and scenic values through the scenic Goosenecks of the San Juan River. The benefits from these potentials have not been evaluated in monetary terms.

Economic and financial appraisal

The heavy sediment load carried by the San Juan River is an important factor in the high cost of a storage development on the river. The estimated cost of the project, if reduced to annual equivalents, would exceed the presently estimated annual benefits as reported above. Another appraisal made under future conditions may be more favorable.

Halgaitoh Reservoir

An offstream reservoir with a nearly stable water surface elevation and adjacent land suitable for construction of a steam-electric powerplant and appurtenant facilities would have some advantages for cooling purposes over the Mexican Hat Reservoir. Reservoir water used for cooling could be returned to the reservoir and recooled by evaporation from the reservoir surface. Most favorable of a number of offstream reservoir sites in the vicinity of Mexican Hat appears to be one located on Gypsum Creek, an intermittent-flowing tributary of the San Juan River. This site, located about 5 miles south of Mexican Hat, is appropriately called "Halgaitoh" from a Navajo word meaning water in an open prairie. The reservoir would be supplied largely by pumping from the San Juan River.

The Halgaitoh Reservoir could be developed as a multiple-purpose facility to provide municipal and industrial water as well as recreation and fishing benefits. It could be constructed either as a supplement to the Mexican Hat Reservoir or as an alternative to the reservoir. In either event it would replace the Mexican Hat Reservoir as a source of cooling water for the steam-electric powerplant.

A Supplement to Mexican Hat Reservoir

The Halgaitoh Dam on Gypsum Creek would be an earthfill structure 120 feet high and 3,550 feet long at the crest. It would contain 2,540,000 cubic yards of material. The outlet, intended only for occasional use, and the service spillway would both be located in the right abutment. An auxiliary spillway discharging into a side channel of Gypsum Creek would be located at a saddle on a ridge beyond the left abutment.

Halgaitoh Reservoir would have 51,300 acre-feet of capacity and a surface area of 1,625 acres. An active capacity of 7,300 acre-feet would be provided in the upper 5 feet of the reservoir below which would be 44,000 acre-feet of inactive and dead storage capacity. A surcharge capacity of 17,300 acre-feet in combination with a service spillway capacity of 990 second-feet and an auxiliary spillway capacity of 1,620 second-feet would provide protection against an inflow design flood having a peak of 29,000 second-feet and a 2-day volume of 19,000 acre-feet.

Most of the reservoir water supply would be pumped from Mexican Hat Reservoir. Intermittent and erratic inflows would enter from Gypsum Creek. The pumping plant at Mexican Hat Reservoir would have a capacity of 100 second-feet against a maximum head of 330 feet. About 3.2 miles of 48-inch-diameter pipe would convey the water to Halgaitoh Reservoir. An annual water supply of about 50,000 acre-feet would be required at Halgaitoh Reservoir for consumptive uses and to offset evaporation losses at the reservoir.

Benefits from municipal and industrial uses of Halgaitoh Reservoir water are estimated at $1,100,000 annually. This amount is the estimated average annual equivalent cost of the Halgaitoh Reservoir development if constructed and operated for municipal and industrial purposes only and with private financing and repayment of costs in 35 years at 6.5 percent interest. In this single-purpose alternative a desilting works would be constructed on the San Juan River as a substitute for the Mexican Hat Reservoir to provide water of suitable quality for pumping.

The Halgaitoh Reservoir with a near-constant water level, located near scenic areas and easily accessible from Utah Highway 47, would have a good recreational potential, according to a Bureau of Outdoor Recreation appraisal. Recommended recreational facilities include camp and picnic units, parking areas, water and sanitary systems, paved roads, boat

ramps, beach developments, landscaping, and administrative facilities. As a supplement to Mexican Hat Reservoir, the Halgaitoh Reservoir would initially provide 20,000 days of recreation use annually, including fishing, and would reach an optimum use of 275,000 recreation days in about the 50th year of development. With Halgaitoh Reservoir attracting some recreationists who would otherwise visit Mexican Hat Reservoir, the initial visitation at Mexican Hat would be reduced to 30,000 days annually (from 50,000 days), but the maximum use of 450,000 days annually at Mexican Hat would still be anticipated in about 40 years. Average annual fishing use at Halgaitoh Reservoir was independently estimated by the Bureau of Sport Fisheries and Wildlife at 44,000 days annually, representing a benefit of $66,000.

Recreation and fishing estimates of the cooperating agencies were adjusted to eliminate duplicated fishing benefits and to place the evaluations on an average annual equivalent basis over a 100-year period at 4 5/8 percent interest, the same as other estimates used in the project economic analyses. The adjusted estimates for the two reservoirs combined are shown below.

Adjusted recreation and fishing benefits

Item	Recreation	Fishing	Total
Annual use (days)	75,200	44,000	119,200
Annual benefits	$71,700	$66,000	$137,700

With the Halgaitoh Reservoir and appurtenant facilities added to the Mexican Hat Project, the project investment cost would be increased to $64,400,000, including $55,420,000 for construction and $8,980,000 in interest during construction at 4 5/8 percent. Operation, maintenance, and replacement costs are estimated at $444,000.

Annual benefits of the Mexican Hat Project with the Halgaitoh Reservoir would be $2,870,600. This represents an increase of $937,700 over the benefits without the Halgaitoh Reservoir. The increased benefits result from the greater value of municipal and industrial water supplied at Halgaitoh Reservoir plus added recreation and fishing benefits at that reservoir. Municipal and industrial benefits would increase from $300,000 annually to $1,100,000 annually. The added recreation benefits would be $71,700 and the added fishing benefits would be $66,000.

Project construction costs would be increased by $9,610,000 and annual operation and maintenance costs by $174,000.

If constructed as a supplement to the Mexican Hat Reservoir, the Halgaitoh Reservoir would provide additional benefits approximating its annual cost. The overall project, including both reservoirs, would not be economically justified under the present estimate of benefits and costs.

An Alternative to Mexican Hat Reservoir

The Halgaitoh Reservoir would be the same whether constructed to operate with or without the Mexican Hat Reservoir. Without Mexican Hat, however, greater costs would be involved in constructing and operating the water supply facilities. A desilting works would be required on the San Juan River, the maximum pumping head would be increased to 480 feet, and the length of the 48-inch-diameter supply line would be increased to 4.9 miles.

Investment costs of the Halgaitoh development would be $12,860,000, including $12,030,000 in construction costs and $830,000 in interest during construction at 4 5/8 percent. Operation and maintenance costs are estimated at $280,000 annually.

Municipal and industrial water uses and benefits of the Halgaitoh Reservoir would be the same under either plan. Recreation and fishing uses and benefits would also be the same except that without Mexican Hat Reservoir initial recreation use at Halgaitoh would be greater (30,000 days annually vs. 20,000 days) and optimum recreation use at Halgaitoh would occur in the 25th year rather than in the 50th year. The average annual recreation use at Halgaitoh Reservoir, adjusted for a 100-year period, would be 128,400 recreation days and the average annual recreation benefit $122,000. Halgaitoh Reservoir as an alternative to the Mexican Hat Reservoir would produce total benefits of $1,288,000 annually.

Dolores Project Extensions

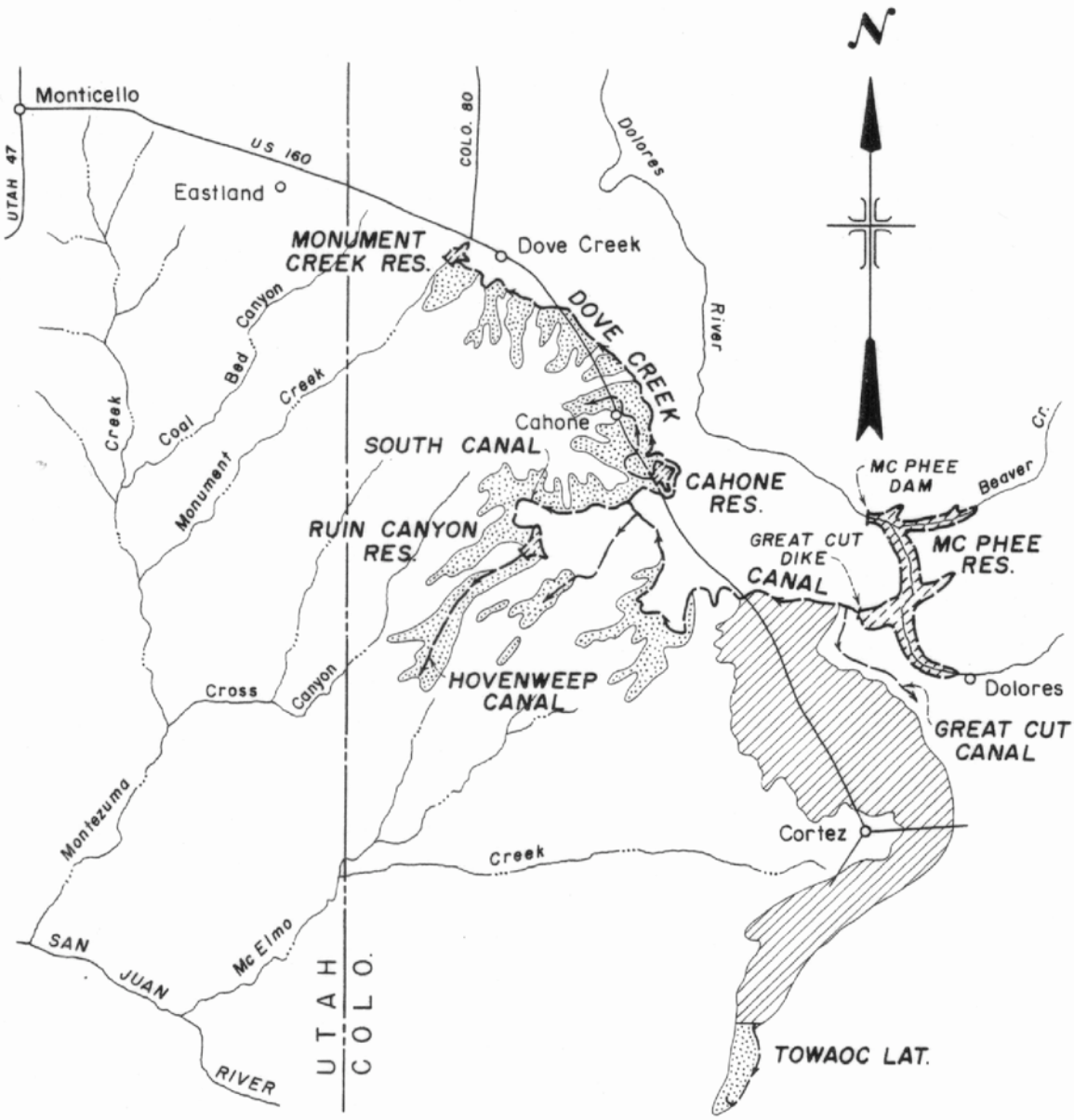
Introduction

Five potentialities for expanding the presently authorized Dolores Project are discussed in this chapter. Principal features of the Dolores Project are described below as a basis for understanding the extension plans.

Dolores Project features

Under the Dolores Project, authorized for construction by the Colorado River Basin Project Act of September 30, 1968, the McPhee Reservoir will be constructed on the Dolores River immediately downstream from Dolores, Colo. Except for surplus water and a small amount for existing downstream rights, all water entering the McPhee Reservoir will be released through the Great Cut Dike into the 68-mile-long Dove Creek Canal. The Dove Creek Canal and its major branch, the South Canal, will deliver water to three offstream reservoirs. The Dove Creek Canal will supply the Cahone Reservoir along its route and the Monument Creek Reservoir at its terminus. The South Canal will convey water to Ruin Canyon Reservoir. In the nonirrigation season water will be stored in the reservoirs for subsequent use. In the irrigation season releases from the canals will be bypassed through the reservoirs and will be supplemented as desired by reservoir releases. The Monument Creek Reservoir water will be distributed to lands south of the reservoir through the Monument Creek Lateral. The Hovenweep Canal, heading at Ruin Canyon Reservoir, will distribute part of the reservoir water to lands on Cajon Mesa between Hovenweep and Ruin Canyons. The Cross Canyon Lateral will head at a separate outlet on Ruin Canyon Reservoir and will serve lands north of Cajon Mesa between Ruin and Cow Canyons. The project will make available in the Monument Creek Reservoir 1,200 acre-feet of water annually for the town of Dove Creek. The plan was made in anticipation that the town would construct at its own expense a treatment and pumping plant at the reservoir and a pipeline to connect with existing storage and distribution facilities in the town. The plan of the authorized project is shown on the map on the following page.

The Dolores Municipal Water Extension would add facilities to the plan of the authorized project to pump water from Monument Creek Reservoir and convey it for municipal use in Dove Creek and other points from Cahone, Colo., to Monticello, Utah. Two of the project extensions would add the Bear Trap and Chico Creek Reservoirs to the plan. The reservoirs would be supplied from the Dove Creek Canal and would be used principally for irrigation. The Hovenweep Extension would involve construction of Belmear Reservoir on a tributary of the Dolores River above the McPhee Reservoir to provide water to be used for irrigation under an extension of the authorized Hovenweep Canal. The fifth extension would consist of the Coal



LEGEND

Supplemental Irrigation Service Land

Full Irrigation Service Land

5 0 5
SCALE OF MILES

DOLORES PROJECT

(AUTHORIZED SEPT. 30, 1968)

Bed Canyon Reservoir below the irrigable lands of the Dolores Project for fish and wildlife purposes. Coal Bed Canyon Reservoir would be supplied largely by return flows from irrigation and by spills and releases of water from project works that are not usable for irrigation.

Cost estimates for the potential extensions were based on plan modifications prior to construction of Dolores Project works rather than modification of the works after construction.

from construction of the Dolores Project and other influences, an annual requirement of 1,200 acre-feet is estimated by 2020.

Residents of Eastland presently haul their domestic water from outside sources, as do most of the people living along U.S. Highway 160 between Monticello and Cahone that could be served by the project extension.

Monticello obtains a satisfactory water supply for present municipal needs from streams heading on the Abajo Mountains but will need additional supplies for future growth. The Monticello system reservoirs are high enough that water from them could be fed back into the project extension pipeline, if desirable, during periods of high streamflows.

Cahone receives an adequate municipal water supply from a rural water system recently constructed by the Montezuma Valley Rural Water Users Association to serve the area between Cahone and Cortez. An interconnection between this system and the Dolores Project Extension pipeline at Cahone may be found desirable.

Since Dove Creek can obtain municipal water from the authorized Dolores Project and supplies now available at Cahone and Monticello are sufficient for present needs, only the residents of Eastland and those living along U.S. Highway 160 have an urgent need for the Dolores Municipal Water Extension. The extension will be required eventually, however, for the entire area, so an early feasibility study, followed by project authorization, if justified, would be desirable for an orderly development that would include the Dove Creek facilities in the larger system and possible construction of the system in stages to meet water needs as they arise.

Extension Costs and Repayment

The pumping plants and pipelines outlined above for the Dolores Project Municipal Water Extension would cost about $1.5 million. The annual operation, maintenance, and replacement costs, including the cost of pumping energy, are estimated at $18,000.

In addition to these extension project costs the municipal water users would be required to pay an allocated share of the costs of the Dolores Project. In order to repay all investment costs in a 50-year period with interest at 4 5/8 percent and pay operation, maintenance, and replacement costs, a water charge of about 25 cents per 1,000 gallons would be required.

Municipal water extension

Purpose of Extension

Facilities would be added to the plan of the authorized Dolores Project to pump water from the project's Monument Creek Reservoir and convey it for municipal and industrial purposes in nearby Dove Creek, Colo., and in areas extending south from Dove Creek to Cahone, Colo., and westward to Eastland and Monticello, Utah.

The pump lift to Dove Creek would be 225 to 244 feet, compared with a lift of 925 feet in the existing system which supplies the community from two wells in the gravel stratum adjacent to the Dolores River. The conveyance distance to Dove Creek from the Monument Creek Reservoir would be a little less than 3 miles compared with a distance of 4½ miles from the wells.

Extension Plan

A pumping plant would be constructed at Monument Creek Reservoir and a pipeline provided to convey pumped water to Dove Creek and thence northwest 24 miles to Monticello and also 11 miles southeast of Dove Creek serving potential users along U.S. Highway 160 between Dove Creek and Cahone. A 3-mile branch would extend southward from the Monticello line to Eastland. The pumping plant at the reservoir would operate against a head of 320 feet which is adequate to deliver water to Dove Creek, Eastland, and Cahone. A second pump would be provided to lift water an additional 365 feet into Monticello's storage reservoirs.

A system capable of supplying 1,500 acre-feet of water annually was used in analyses of the project extension. This would include the 1,200 acre-feet planned for Dove Creek in the Dolores Project plus an additional 300 acre-feet. While this amount of water would not meet system needs until year 2020 as was planned for the Dolores Project, it is expected to meet the needs until major replacements would be required at which time additional capacity could be provided. Final decisions as to the size and capacity of the system would be made in the course of detailed feasibility studies. Costs of water treatment facilities are not included in estimates for the project extension.

Water Requirements

It was found in the course of studies made for the Dolores Project that the present municipal water supply for Dove Creek averages about 110 acre-feet annually, equivalent to a per capita use of about 100 gallons per day. A higher per capita rate of about 275 gallons per day is anticipated with project development since the supply would be less expensive than the present supply. With population increases resulting

CHAPTER IX

POTENTIAL RECLAMATION PROJECTS
(Dolores Extension--Bear Trap Reservoir)

Bear Trap Reservoir extension

Extension Purposes

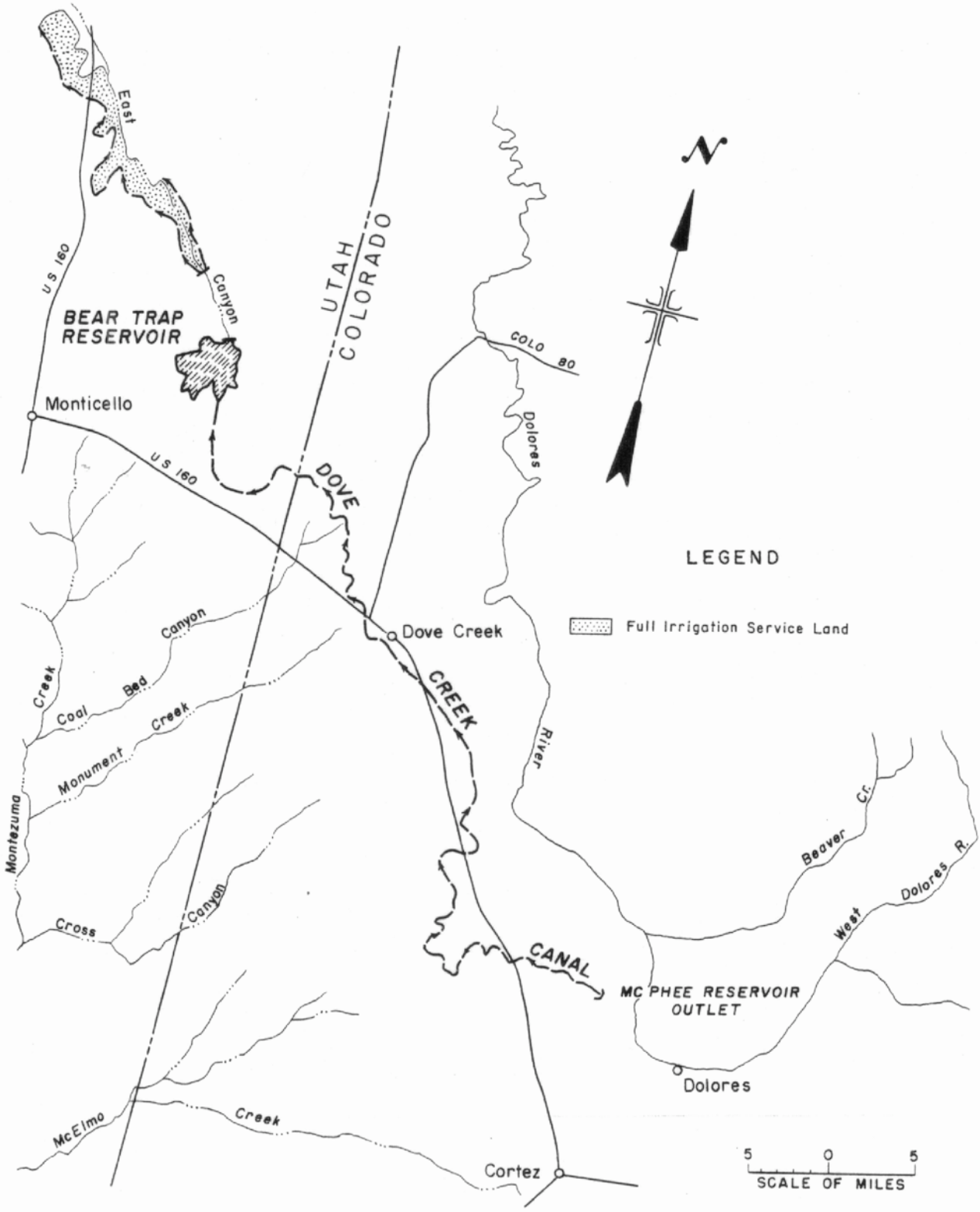
The Bear Trap Reservoir Extension of the Dolores Project would provide an irrigation water supply for 3,750 acres of presently undeveloped land in Dry Valley located about 16 miles north of Monticello, Utah. The reservoir would also provide recreation and fish and wildlife benefits.

Extension Plan

The extension plan would require the Dove Creek Canal to be enlarged and extended 29 miles to the Bear Trap Reservoir site. The canal would also be realined at a flatter grade to obtain a terminal elevation of 6,800 feet required to supply the Bear Trap Reservoir and to reduce the cut through the divide between the San Juan and Colorado River drainage areas. The planned capacity of the canal would be increased from 1,200 to 1,400 second-feet at the canal head and from 40 to 450 second-feet at the terminal.

The Bear Trap Reservoir with a total capacity of 110,000 acre-feet and an active capacity of 95,000 acre-feet would be formed by a dam 118 feet high on East Canyon Wash. A surcharge capacity of 5,900 acre-feet would be provided to control an inflow design flood having a peak of 18,500 second-feet and an 18-hour volume of 5,900 acre-feet. The reservoir surface area would be 5,950 acres. The average annual sediment inflow is estimated at 37 acre-feet. The outlet works at the dam would discharge into East Canyon Wash. An uncontrolled orifice, constructed as part of the outlet works, would serve as a spillway and would prevent storage encroachment on the reservoir surcharge capacity. A map of the Bear Trap Reservoir Extension is on the following page.

Runoff forecasts would permit Dolores River water, which would otherwise spill from McPhee Reservoir, to be released into the Dove Creek Canal for storage in Bear Trap Reservoir. Since the supply would not be available every year, Bear Trap Reservoir would be operated for long-term holdover storage. Water would be released from the reservoir into East Canyon Wash and rediverted by a dam at the head of Dry Valley. Irrigation laterals would extend both east and west from the diversion dam. The East Lateral, with an initial capacity of 20 second-feet, would extend 9.3 miles to serve 600 acres on the east side of Dry Valley. The West Lateral, with an initial capacity of 70 second-feet, would extend 32 miles to serve 3,150 acres on the west side of the valley. Drains would be provided to meet the high drainage requirement anticipated because of the flat terrain and underlying impermeable barrier.



BEAR TRAP RESERVOIR
EXTENSION

Irrigation

Dry Valley lands, discussed in Chapter II, have not been classified. Project analyses are based on the assumption that the lands, if classified, would on the average be the equivalent of class 2 land.

The annual requirement for irrigation water, based on sprinkler irrigation, is estimated at 3.2 acre-feet per acre at the farm headgate or 4 acre-feet per acre at Bear Trap Reservoir. The requirement at the reservoir for 3,750 acres would be 15,000 acre-feet. In order to provide this amount of water and meet the increased losses in the 97-mile-long Dove Creek Canal and the Bear Trap Reservoir, releases at the McPhee Reservoir would need to be increased by an average of 32,600 acre-feet annually.

Water operation studies were made based on runoff for the critically dry period 1948 through 1957. The studies were governed by forecasts of inflow to McPhee Reservoir and regulations for drawdown of McPhee and Bear Trap Reservoirs during consecutive years of below normal runoff to prevent extreme water shortages in any year. Water deliveries at farm headgates would have averaged 13,300 acre-feet annually during the 1948-57 period. A projection of the 10-year studies indicates that deliveries would have averaged 14,000 acre-feet annually for the 30-year period 1928 through 1957. A summary of the 10-year Bear Trap Reservoir operation is is shown in the following table.

Bear Trap Reservoir operation summary
(Unit--1,000 acre-feet)

	McPhee Reservoir			Bear Trap Reservoir							
							Shortage			Reservoir content	
Year	Spills without Bear Trap Extension	Releases to Bear Trap Reservoir	Conveyance losses in Dove Creek Canal 1/	Inflow	Irrigation requirement	Reservoir releases	Unit (1,000 acre-feet)	Per cent of requirement	Evaporation	Maximum	Minimum
1948	104.9	104.9	28.3	76.6	15.0	15.0	0	0	8.2	67.0	53.4
1949	120.3	95.6	25.8	69.8	15.0	15.0	0	0	14.0	110.0	94.2
1950	0	0	0	0	15.0	15.0	0	0	12.2	94.2	67.0
1951	0	0	0	0	15.0	15.0	0	0	9.0	67.0	43.0
1952	201.2	91.4	24.6	66.8	15.0	15.0	0	0	12.0	97.8	82.8
1953	0	0	0	0	15.0	15.0	0	0	10.8	82.8	57.0
1954	0	0	0	0	15.0	15.0	0	0	7.4	57.0	34.6
1955	0	0	0	0	15.0	9.0	6.0	40	4.4	34.6	21.2
1956	0	0	0	0	15.0	4.2	10.8	72	2.6	21.2	14.4
1957	132.1	109.3	29.4	79.9	15.0	15.0	0	0	9.4	78.1	69.9
Total	558.5	401.2	108.1	293.1	150.0	133.2	16.8	112	90.0		
Average	55.8	40.1	10.8	29.3	15.0	13.3	1.7	11	9.0		

1/ Losses attributable to Bear Trap Reservoir Extension, equivalent to 27 percent of releases in preceding column.

Depletions to the Colorado River from the Bear Trap Reservoir Extension are estimated at 22,600 acre-feet annually. This includes consumptive use of 9,200 acre-feet on the irrigated land, 4,400 acre-feet in conveyance losses, and 9,000 acre-feet in increased reservoir evaporation.

Irrigation benefits were estimated at $95 per acre annually, including $64 per acre in direct benefits and $31 per acre in indirect and public benefits. For the project extension these would amount to a total of $356,200 annually, including $240,000 in direct benefits and $116,200 in indirect and public benefits.

Other Extension Purposes

Recreation use at Bear Trap Reservoir would be of local significance according to a reconnaissance appraisal by the Bureau of Outdoor Recreation. Recreation activity would include fishing, camping, picnicking, swimming, and boating. Recreation facilities at the reservoir would include camp units, picnic units, parking areas, sanitary and water systems, paved roads, boat ramps, beach developments, landscaping, and administrative facilities.

Annual recreation use, including angling, is estimated at 5,000 recreation days initially and 90,000 days under optimum use expected about years 2020-25. Annual benefits from such use, computed on the basis of $0.90 per day, would be $4,500 initially and $81,000 ultimately.

Fish and wildlife benefits at Bear Trap Reservoir were estimated by the Bureau of Sport Fisheries and Wildlife at an average of $9,300 annually based on an expected use of 6,200 angling days.

The Bureau of Reclamation adjusted the recreation and fishing estimates of the cooperating agencies to eliminate overlapping fishing benefits and place the estimates on an average annual equivalent basis over a 100-year period, the same as other estimates used in project economic and financial analyses. The adjusted estimates are shown in the following table.

Adjusted recreation and fishing benefits

Item	Recreation	Fishing	Total
Annual use (days)	31,100	6,200	37,300
Annual benefits	$28,000	$9,300	$37,300

Extension Cost

The investment cost of the Bear Trap Reservoir Extension is estimated at $14,090,000. This includes $12,780,000 for construction of features itemized below, $400,000 as the present worth of recreation facilities that would be provided from time to time as the need develops,

and $910,000 in interest during construction computed for a 3-year period at 4 5/8 percent.

Feature	Construction cost
Dove Creek Canal Enlargement and Extension	$9,040,000
Bear Trap Dam and Reservoir	1,650,000
East Canyon Diversion Dam	50,000
East Lateral	250,000
West Lateral	1,040,000
Drains	750,000
Total	12,780,000

Annual operation, maintenance, and replacement costs are estimated at $54,500, including $32,700 for irrigation and joint use facilities and $21,800 for recreation facilities.

Economic and Financial Appraisal

With costs so high in relation to benefits the Bear Trap Reservoir Extension of the Dolores Project could not be justified economically. The annual payment capacity of the irrigators would probably be about equal to the operation, maintenance, and replacement cost assigned to irrigation, leaving little or nothing for repayment of construction costs.

Under the Federal Water Project Recreation Act of July 9, 1965 (Public Law 89-72), repayment would be required of a portion of the cost allocated to recreation and fish and wildlife enhancement, including separable operation, maintenance, and replacement costs and one-half of the separable cost of construction and interest during construction.

Chico Creek Reservoir Extension

Extension Purposes

The Chico Creek Reservoir Extension of the authorized plan of the Dolores Project would extend irrigation service to an additional 14,960 acres of land in Colorado and Utah west of Dove Creek, Colo. The Chico Creek Reservoir would replace the Monument Creek Reservoir in the authorized plan and would provide similar benefits in the form of municipal water, recreation, and fishing. The Forks Reservoir on the Dolores River in the extension plan would provide additional recreation, fishing, and flood control benefits.

Extension Plan

Additional storage of Dolores River water would be accomplished at the 200,000-acre-foot capacity Forks Reservoir, formed by a dam on the river about 13 miles upstream from Dolores, Colo., at a point just below the junction of the river's East and West Forks. Storage water released from the Forks Reservoir would flow via the Dolores River and the McPhee Reservoir to the Dove Creek Canal.

The planned capacity of the Dove Creek Canal would be increased to convey the additional water. The portion of the canal beyond the Cahone Reservoir would be constructed at a flatter grade and extended an additional 14 miles to the Chico Creek Reservoir. Chico Creek Reservoir, with a capacity of 6,400 acre-feet, would be formed by a dam on Chico Creek, a southwest-flowing tributary of Coal Bed Canyon. It would further regulate water conveyed by the Dove Creek Canal and would store minor inflows from Chico Creek.

Two laterals heading at the reservoir outlet would distribute irrigation water to lands on opposite sides of Chico Creek. The Northdale Lateral would serve lands southwest of the reservoir. The Cedar Point Lateral would deliver water to lands south of the reservoir. The Monument Creek Lateral, which would distribute Monument Creek Reservoir water in the authorized Dolores Project plan, would become a branch of the Cedar Point Lateral in the extension plan. A third lateral, designated as the Piute Lateral, would be an extension of the Dove Creek Canal. From the canal terminus the lateral would continue westward, crossing Chico Creek on the Chico Creek Dam. The lateral would run generally parallel to and higher than the Northdale Lateral, providing water to lands between the two laterals. From its higher alinement and extended length in the extension plan, the Dove Creek Canal could directly serve a larger land area. Drains would be provided as needed on lands served by the extension facilities.

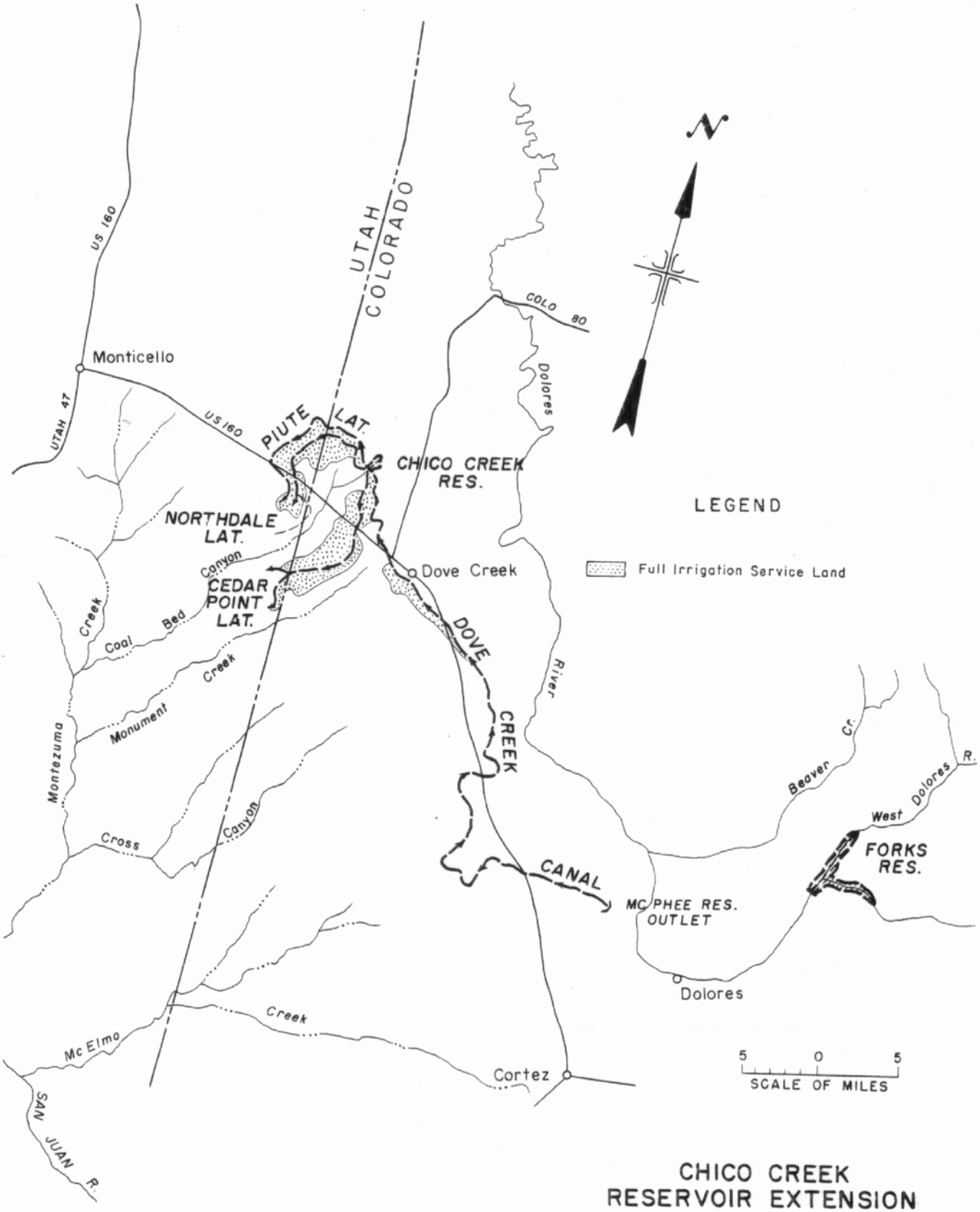
Dry-farmed lands that would be irrigated from Chico Creek Reservoir Extension of Dolores Project. Snow-capped Abajo Mountains are in background.

In the extension plan municipal water for Dove Creek, Colo., would be provided at the Chico Creek Reservoir rather than at the Monument Creek Reservoir in the authorized plan. Recreation facilities would be provided at the Forks and Chico Creek Reservoirs.

Project facilities and lands of the Chico Creek Reservoir Extension are shown on the map on the following page.

Project Works

The Forks Dam on the Dolores River would be constructed to a height of 250 feet in order to provide 200,000 acre-feet of storage capacity. Construction of this reservoir would be more economical than increasing



CHICO CREEK
RESERVOIR EXTENSION

the capacity of the authorized McPhee Reservoir, which would require moving the town of Dolores.

The planned capacity of the Dove Creek Canal would be increased from 1,200 to 1,430 second-feet at the canal head and from 40 to 170 second-feet at the terminal. The canal grade beyond the Cahone Reservoir would be reduced enough to provide a terminal canal water surface elevation of 6,812 feet at the Chico Reservoir. The higher and longer canal could provide irrigation water directly to an additional 3,130 acres of land.

The Chico Creek Reservoir capacity of 6,400 acre-feet would include 5,400 acre-feet of active capacity and 1,000 acre-feet of inactive and dead capacity. The Chico Creek Dam would be an earthfill structure 110 feet high and 1,980 feet long, containing 550,000 cubic yards of embankment material. A service spillway would be constructed as part of the outlet works. The service spillway plus an auxiliary spillway and 3,600 acre-feet of reservoir surcharge capacity would protect the reservoir against flood damage.

Data on irrigation laterals in the project extension are tabulated below.

Name of lateral	Initial capacity (second-feet)	Length (miles)	Acres served
Northdale	75	18	3,400
Cedar Point	160	19	1/7,920
Piute	50	24	2,080
Total	285	61	1/13,400

1/ Includes 1,570 acres that would be served from the Monument Creek Lateral in the authorized Dolores Project plan.

Recreation facilities at Chico Creek Reservoir recommended by the Bureau of Outdoor Recreation include camp and picnic units, parking areas, sanitary and water systems, paved roads, a boat ramp, beach developments, landscaping, and administrative facilities. No appraisal has been made of recreation use at the Forks Reservoir.

Advance planning and major construction of the Dolores Project are expected to require about 10 years. Some of the last facilities constructed during this period under the extension plan would be the Chico Creek Reservoir and its distribution laterals since these are all at the end of the long Dove Creek Canal. Construction of the Forks Reservoir could follow by a few years the construction of other extension facilities as the long-term holdover storage provided by the reservoir would not be needed until a substantial part of the extension lands is being

irrigated. Recreation facilities would be provided progressively as the need for them develops.

Project Costs

The investment cost of the Dolores Project would be increased $27,640,000 by the Chico Creek Reservoir Extension. This would include $24,780,000 in construction costs and $2,860,000 in interest during construction computed at 4 5/8 percent. Annual operation, maintenance, and replacement costs would be increased $58,000, including $50,300 for added reclamation and joint use facilities and $7,700 for recreation facilities. In estimating these cost increases, allowance was made for savings resulting from the extension, such as the cost of Monument Creek Reservoir which would be eliminated.

Irrigation

Most of the lands that would be irrigated under the extension plan have been classified to reconnaissance standards. Although the extension lands are similar to those of the Dove Creek Area of the Dolores Project, they will have more extensive drainage deficiencies because of shallower soils and the presence of Mancos shale under a portion of the area. Irrigable land acreages in the extension plan are tabulated below. The acreages might be reduced if a detailed land classification were made, depending on soil depths.

Irrigable lands in Chico Creek Reservoir Extension Plan

Location	Land area (acres)		
	Colorado	Utah	Total
Between Cahone Reservoir and Monument Creek			
Lands under higher alinement of Dove Creek Canal	1,350	0	1,350
Between Monument and Chico Creeks			
Under Dove Creek Canal	1,780	0	1,780
Under Cedar Point Lateral	1/5,950	400	1/6,350
West of Chico Creek			
Under Northdale Lateral	1,600	1,800	3,400
Under Piute Lateral	400	1,680	2,080
Total	11,080	3,880	14,960

1/ Exclusive of 1,570 acres that would be served under either the authorized Dolores Project or Chico Creek Reservoir Extension.

Water requirements of the 14,960 acres in the extension area are estimated at 47,100 acre-feet annually measured at the reservoir from which the land area would be served. Stream depletions of the Colorado River would be increased by about 29,000 acre-feet annually.

Irrigation benefits would be increased about $1,137,000 annually by the project extension. This figure includes $792,900 in direct irrigation benefits and $344,100 in indirect and public benefits.

Other Project Purposes

The 1,200 acre-feet of municipal and industrial water for the town of Dove Creek would be supplied from Chico Creek Reservoir in the extension plan rather than from Monument Creek Reservoir as in the authorized Dolores Project Plan. The Chico Creek Reservoir would be about 64 feet higher but nearly 5 miles farther from Dove Creek than the Monument Creek Reservoir. These differences in the municipal and industrial water sources for Dove Creek were not analyzed in evaluating the extension.

The recreation potential of Chico Creek Reservoir was found by the Bureau of Outdoor Recreation to be comparable to that of Monument Creek Reservoir, which it would replace. Recreation activities anticipated at Chico Creek Reservoir would include fishing, camping, picnicking, swimming, and boating. Initial recreation use was estimated at 8,000 days annually, including fishing, and was estimated to increase to an optimum annual use of 50,000 days in about 45 years. The Bureau of Sport Fisheries and Wildlife estimated the fishing benefits of Chico Creek Reservoir at $8,600 annually based on an expected use of 5,700 angling days.

The recreation and fishing estimates of the cooperating agencies were adjusted to eliminate duplicated fishing benefits and to place the evaluations on an average annual equivalent basis over a 100-year period, the same as other estimates used in the project economic and financial analyses. The adjusted estimates are tabulated below.

Adjusted recreation and fishing benefits

Item	Recreation	Fishing	Total
Annual use (days)	19,600	5,700	25,300
Annual benefits	$17,600	$8,600	$26,200

The annual recreation and fishing benefits at Chico Creek Reservoir would amount to about $14,600 more than those at Monument Creek Reservoir which would be eliminated from the project. The recreation and fishing potentials of the Forks Reservoir were not appraised. The reservoir would also provide some flood control benefit, as yet unevaluated, in the 13 miles of river channel extending downstream to McPhee Reservoir.

Economic and Financial Appraisal

The estimated increase in annual benefits resulting from the Chico Creek Reservoir Extension would be less than the estimated annual equivalent cost of the extension, indicating that the extension would not be justified economically. The increase in the irrigator's payment capacity

would exceed the cost of operating, maintaining, and replacing the irrigation and joint use facilities of the extension.

Alternative Extension Plan

A Chico Creek Reservoir Extension plan that would serve a smaller irrigable land area was also analyzed. The plan would be the same as the larger extension plan except that the Northdale and Piute Laterals would be eliminated and Forks Reservoir and Dove Creek Canal would have smaller capacities. Elimination of these laterals would limit the increased service area of the extension to 9,480 acres, all of which would be east of Chico Creek and Coal Bed Canyon. All land served would be in Colorado, except 400 acres in Utah. Water requirements for the smaller extension area, measured at the reservoir from which the land would be served, would average 29,700 acre-feet annually. Extension-caused depletions to the Colorado River would be 18,400 acre-feet annually.

The alternative extension plan would increase costs of the authorized Dolores Project plan by $18,430,000. This cost includes $16,520,000 for construction and $1,910,000 in interest during construction computed at 4 5/8 percent. The annual operation, maintenance, and replacement costs would be increased by $39,000. The alternative appears to be slightly less favorable economically than the larger Chico Creek Reservoir Extension plan.

N

109°00'

38°30'

108°50'

38°20'

Grand Co., Utah
San Juan Co., Utah

Mesa Co., Colorado
Montrose Co. Colorado

San Juan Co., Utah

T26S
T27S

T27S
T28S

T49N
T48N

T48N
T47N

R24E
R25E

R25E
R26E

R20W
R19W

R19W
R18W

R18W
R17W

Manti-La Sal National Forest

Deep Creek

Deep Creek Diversion

Geyser Creek

Geyser Creek Diversion

Bulkhead

Rattlesnake Creek

Willow Basin Creek

West Paradox Creek

Manti-La Sal National Forest

BLM

PARADOX

BLM

BEDROCK

RIVER

Hwy 90

LOCATION MAP

UTAH

COLORADO

West Paradox Watershed

Grand County

San Juan County

Montrose County

LEGEND

- Watershed Boundary
- State Line
- County Line
- National Forest Boundary
- Irrigated Land
- Bureau of Land Management Boundary

Montrose County	38,029 Acres
Total in Colorado	38,029 Acres
San Juan County	20,064 Acres
Grand County	2,157 Acres
Total in Utah	22,221 Acres
Total Watershed Area	60,250 Acres

WATERSHED MAP
WEST PARADOX WATERSHED

Grand and San Juan Co. Utah and Montrose Co. Colo.

CHAPTER IX

POTENTIAL RECLAMATION PROJECTS
(Dolores Extension--Hovenweep)

Hovenweep Extension

Extension Purposes

The Hovenweep Extension of the Dolores Project would provide irrigation water to 3,300 acres of presently undeveloped land in the Hovenweep Area in Utah near the Utah-Colorado State line. Recreation and fish and wildlife benefits would be provided at the extension's Belmear Reservoir.

Extension Plan

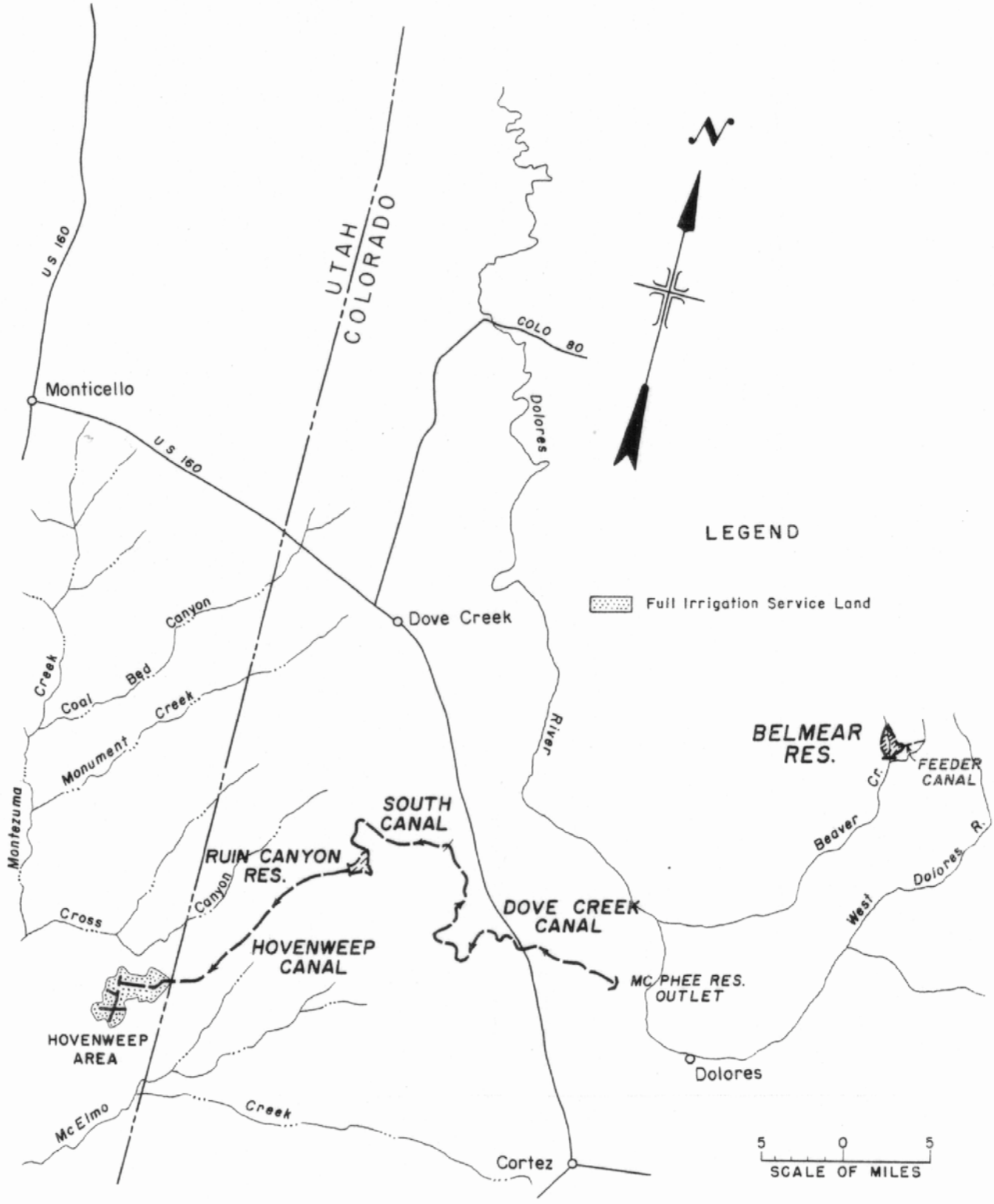
Belmear Reservoir would be constructed on a tributary of Beaver Creek. Beaver Creek flows southwest, joining the Dolores River in the McPhee Reservoir Basin. A 1.5-mile-long inlet canal would convey water to the Belmear Reservoir from Beaver Creek. Recreational facilities would be provided at the reservoir as needed.

Water stored in the Belmear Reservoir would be released for irrigation, flowing in natural channels to McPhee Reservoir and thence through the Dove Creek and South Canals to Ruin Canyon Reservoir. The planned capacities of these canals would be increased to convey the extension water. The water would be released from the Ruin Canyon Reservoir to the Hovenweep Canal, which would be enlarged and extended, and conveyed to a forebay reservoir at the canal terminus. From the forebay reservoir a pressure pipe distribution system suitable for sprinkler irrigation without pumping would convey the water to the land. Land drains would be provided where needed. Works that would be modified or constructed and lands that would be irrigated under the extension are shown on the map on the following page.

The Belmear Dam would be a rolled earthfill structure 120 feet high and 615 feet long at the crest. The reservoir capacity would be 28,000 acre-feet, including 26,000 acre-feet of active capacity and 2,000 acre-feet of inactive and dead capacity. The 1.5-mile-long reservoir inlet canal would have a capacity of 180 second-feet.

Planned capacities of the Dove Creek and South Canals for the Dolores Project would be increased by 30 second-feet to accommodate the project extension. The Hovenweep Canal would be extended 3.8 miles and its planned capacity increased from 90 to 125 second-feet at the canal head and from 10 to 50 second-feet at the terminus. The forebay reservoir with a capacity of about 400 acre-feet would be located near the head of the irrigable land area.

The pipe distribution system would have an initial capacity of 60 second-feet. It would require 11.2 miles of pipe with diameters ranging from 36 to 12 inches.



HOVENWEEP EXTENSION

Extension Costs

The investment cost of the Hovenweep Extension is estimated at $9,200,000. This includes $8,600,000 in construction costs as itemized below and $600,000 in interest during a 3-year construction period computed at 4 5/8 percent.

Feature	Construction cost
Belmear Dam and Reservoir	$3,000,000
Belmear Diversion Dam	160,000
Belmear Inlet Canal	315,000
Dove Creek Canal (added capacity)	720,000
South Canal (added capacity)	85,000
Hovenweep Canal (added capacity and extension)	640,000
Hovenweep Forebay Dam and Reservoir	600,000
Pipe distribution system	2,000,000
Drains	1,050,000
Recreation facilities	30,000
Total	8,600,000

Annual operation, maintenance, and replacement costs are estimated at $15,000, including $12,900 for reclamation and joint use facilities and $2,100 for recreation facilities.

Irrigation

The lands that would be irrigated are on a part of Cajon Mesa that is near the Hovenweep National Monument. A small part of the land area is in the Navajo Indian Reservation. Cajon Mesa is a part of the Montezuma Creek land area described in Chapter II. (An alternative means of irrigating the Hovenweep lands under the Cross Canyon Project is described later in this report.)

In estimating the arable land acreage, consideration was given to the depth of the medium-textured soils over massive sandstone, the gently undulating topography, and the general lack of deep, natural drainage channels. It was concluded that at least 6 feet of soil depth would be required with sprinkler irrigation to maintain the water table at a suitable depth to provide a proper salt balance and support full crop production. The drainage requirement would be high because of the shallow depth to sandstone, high infiltration rates, and low water-holding capacity of the soil. The 3,300 acres that would be irrigated appear from preliminary studies to be comparable to class 2 lands on the Dolores Project.

Irrigation water requirements were estimated for a cropping pattern consisting of 30 percent alfalfa, 35 percent irrigated pasture, 30 percent small grains and beans, and 5 percent corn. The annual water

requirement per acre with sprinkler irrigation was estimated at 2.65 acre-feet at the farm headgate, 3.27 acre-feet at Ruin Canyon Reservoir, and 3.92 acre-feet at McPhee Reservoir. The total annual requirement for the extension would be 10,800 acre-feet at Ruin Canyon Reservoir or 12,900 acre-feet at McPhee Reservoir.

Annual irrigation benefits were estimated for a 100-year period with adjustments for reduced benefits during a 5-year development period. The benefits would be $95 per acre, including $64 in direct benefits and $31 in indirect and public benefits. For the entire extension acreage the annual benefits would be $313,500, including $211,200 in direct benefits and $102,300 in indirect and public benefits.

Recreation, Fish, and Wildlife

Recreation and fish and wildlife appraisals were made of the existing Ground Hog Reservoir by the National Park Service and the Bureau of Sport Fisheries and Wildlife in connection with studies made for the Dolores Project. Since the Ground Hog Reservoir is in the general vicinity of the Belmear Reservoir site and the two reservoirs would be of similar size, the Ground Hog appraisals were assumed to apply to the Belmear Reservoir. On this basis recreation use would average 5,000 days annually and recreation benefits would be $5,000 annually. Fishing use would be 3,000 days annually, resulting in a benefit of $4,500.

Economic and Financial Appraisal

Benefit-cost relationships as presently estimated indicate that the Hovenweep Extension could not be economically justified. The payment capacity of the irrigators induced by the extension, however, would substantially exceed the estimated cost of operation, maintenance, and replacement of extension works, thus permitting some repayment of the investment costs.

CHAPTER IX

POTENTIAL RECLAMATION PROJECTS
(Dolores Extension--Coal Bed Canyon Reservoir)

Coal Bed Canyon Reservoir Extension

Purpose and Plan

The Coal Bed Canyon Reservoir would be constructed for recreation and fish and wildlife purposes. Located below arable land areas, it would not be useful for irrigation. Its water supply would consist largely of operational wastes from the Dolores Project conveyed to the reservoir through a short extension of a project lateral. The reservoir would not require other modifications of the Dolores Project facilities although unused capacity in project canals in offpeak periods would be utilized to convey surplus water to the reservoir from the Dolores River. In the event the Chico Creek Reservoir Extension is constructed, the Coal Bed Canyon Reservoir would receive return flows from much of the land area that would be irrigated. U.S. Highway 160 which now crosses the Coal Bed Canyon Reservoir basin would be relocated across the dam. The location of the reservoir site at the intersection of the highway with Coal Bed Canyon may be seen on the map on page 85. Readily accessible from U.S. 160, the reservoir would afford an excellent rest area and recreation and fishing spot for the many vacationers and others who travel this highway. A near-constant release of about 5 second-feet would be made from the reservoir to provide a stream fishery in Coal Bed Canyon. A water supply averaging 4,800 acre-feet annually would be needed to offset reservoir evaporation and provide fishery releases. Depletions to the Colorado River from the project extension would average 2,300 acre-feet annually, including 1,200 acre-feet of reservoir evaporation and 1,100 acre-feet associated with stream fishery releases.

Extension Works

Coal Bed Canyon Reservoir would be formed by an earthfill dam 90 feet high and 820 feet long across Coal Bed Canyon, a normally dry streambed that is in the drainage area of Montezuma Creek, a tributary of San Juan River. The dam and reservoir would be in Colorado just east of the Colorado-Utah line. The dam site is about a mile east of the State line and a half mile south of Highway 160.

The crest of the dam would be 50 feet wide to accommodate the relocated highway. The embankment would contain 320,000 cubic yards of material. The reservoir capacity would be 7,500 acre-feet, of which 4,500 acre-feet would be active and 3,000 acre-feet inactive or dead. In addition 8,100 acre-feet of surcharge capacity would be provided as the most economical means of controlling the inflow design flood estimated to have a peak inflow of 15,500 second-feet and a 24-hour volume of 8,100 acre-feet. An ungated spillway constructed in combination with the reservoir outlet would evacuate surcharge storage and prevent encroachment of surcharge capacity during normal operations.

Recreation facilities recommended at the Coal Bed Canyon Reservoir by the Bureau of Outdoor Recreation include camp units, picnic units, parking areas, sanitary and water systems, paved roads, boat ramps, beach developments, landscaping, and administrative facilities. The recreation facilities would be added from time to time as justified by increased recreation use.

Extension Costs

The investment cost of the Coal Bed Canyon Reservoir Extension is estimated at $2,050,000. This includes $1,300,000 for construction of Coal Bed Canyon Dam and $750,000 as the present worth of recreation facilities that would be provided initially and added periodically.

Annual operation, maintenance, and replacement costs are estimated at $51,500, including $4,000 for the dam and reservoir and $47,500 for recreation facilities.

Recreation, Fish, and Wildlife

Coal Bed Canyon Reservoir was found by the Bureau of Outdoor Recreation to be of State-wide significance for recreation. Recreation activities would include fishing, camping, picnicking, swimming, and boating. Initial recreation use, including fishing, was predicted at 20,000 days. Optimum recreation use of 210,000 days annually is anticipated by year 2025. Recreation values were computed at $1 per day, resulting in benefits of $20,000 initially and $210,000 by time of optimum use.

The Bureau of Sport Fisheries and Wildlife, in cooperation with the Colorado Game, Fish, and Parks Department, supplied preliminary appraisals of the reservoir and downstream fishery. Average annual fishing use at the reservoir was estimated at 26,600 days, representing a benefit of $39,900. The downstream fishery was estimated to provide 7,100 days use annually and a benefit of $21,300.

The Bureau of Reclamation adjusted the recreation and fishing estimates of the cooperating agencies to eliminate overlapping fishing benefits and place the estimates on an average annual equivalent basis over a 100-year period at 4 5/8 percent interest for compatibility with other estimates used in the project economic and financial analyses. The estimates as adjusted are shown in the following table.

Adjusted recreation and fishing benefits

Item	Recreation	Fishing	Total
Annual use (days)	65,700	33,700	99,400
Annual benefits	$65,700	$61,200	$126,000

Economic Appraisal

Economically the recreation and fishing benefits of the Coal Bed Canyon Reservoir as estimated above would not justify the cost of the development. The Bureau of Outdoor Recreation found that although the reservoir would provide increased opportunities for participation in water-oriented recreation, it would reduce estimated recreation use at companion terminal reservoirs of the Dolores Project. The Coal Bed Canyon site is about 21 miles from Cahone Reservoir site and 5 miles from Monument Creek Reservoir site, both included in the authorized plan for the Dolores Project. It is also only 6 miles from the Chico Creek Reservoir site being considered as an alternative to Monument Creek Reservoir. Because of these factors, the Bureau of Outdoor Recreation recommended that Coal Bed Canyon Reservoir not be constructed as an addition to the Dolores Project.

Cross Canyon Project

Project purposes

Cross Canyon flows, consisting mostly of return flows from lands that will be irrigated by the authorized Dolores Project, would be developed for irrigation of lands in eastern San Juan County, Utah. Recreation, fish and wildlife, and sediment control benefits would also be provided.

Project plans

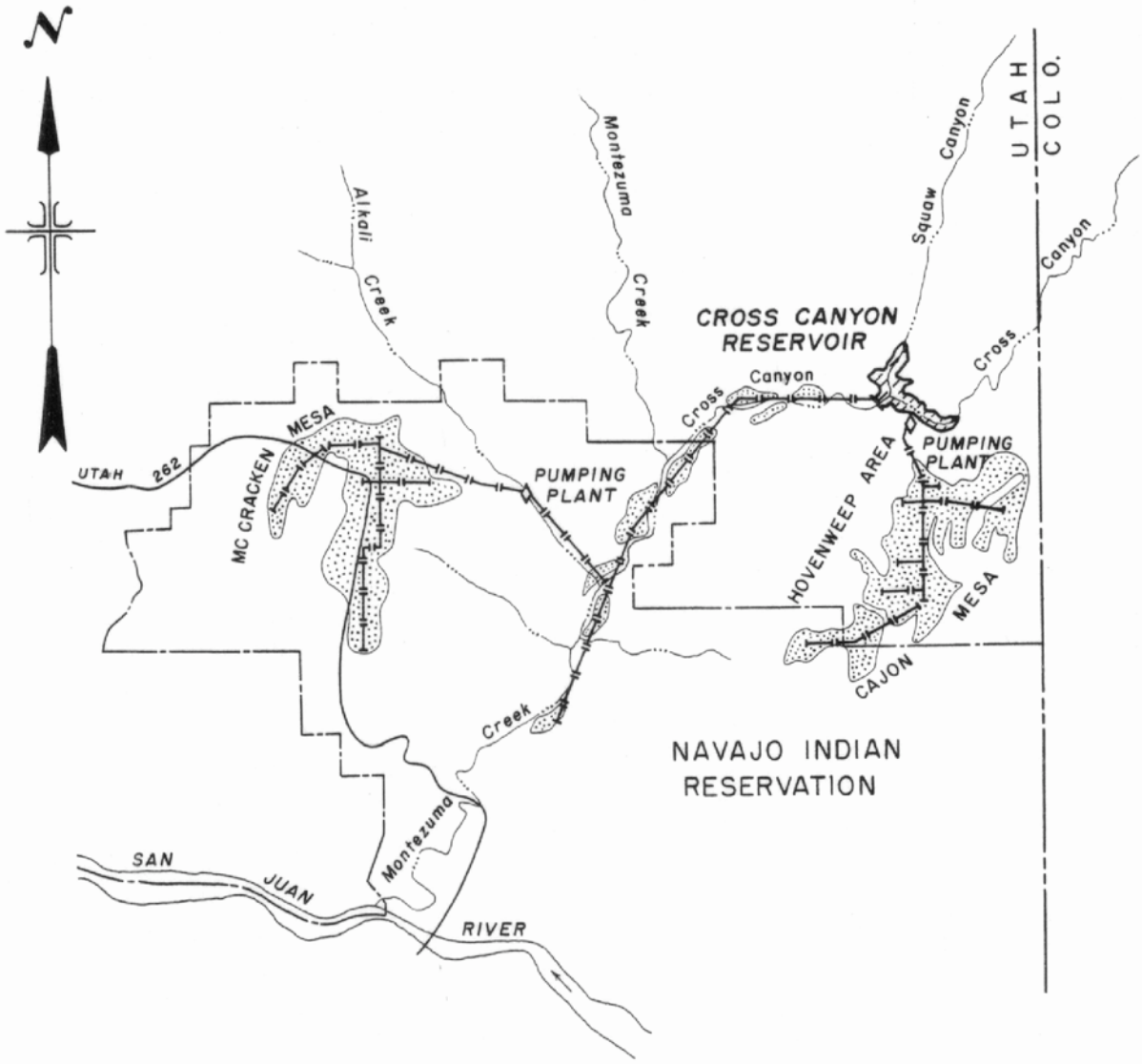
Project plans are necessarily tentative pending development of the Dolores Project and a determination of its return flow characteristics. It is estimated that return flows from about 18,800 acres of Dolores Project land in the Cross Canyon drainage area will average 23,300 acre-feet annually and that the widely fluctuating natural flows of Cross Canyon will average 1,000 acre-feet annually. Present plans are based on these estimates. The plans are shown on the map on the following page.

Cross Canyon Reservoir with a capacity of 36,000 acre-feet would be formed by a dam on Cross Canyon about 5 miles above its junction with Montezuma Creek. The dam would be about 4 miles west of the Utah-Colorado line and 8 miles northeast of the Hatch Trading Post. Reservoir water would be conveyed by separate works for irrigation in three different land areas. Part of the water would be released by gravity flow to 1,000 acres of valley lands in scattered tracts downstream along Cross Canyon and Montezuma Creeks. About three-fourths of the valley land area is in the Navajo Indian Reservation. The remaining water would be pumped from the reservoir to 3,000 acres of Indian land on McCracken Mesa west of the reservoir and to 3,000 acres partly within the reservation in the Hovenweep Area on Cajon Mesa south of the reservoir. The Hovenweep lands are essentially the same lands that could also be irrigated by the potential Hovenweep Extension of the Dolores Project previously discussed. Land drains would be provided for all mesa lands. Cost data and economic appraisals are presented later for project service to different land combinations--one with all lands included, one with Hovenweep lands eliminated, and one with McCracken Mesa lands eliminated.

Recreation facilities would be provided at Cross Canyon Reservoir as recommended by the Bureau of Outdoor Recreation. These would include camp units, parking areas, sanitary and water systems, paved roads, boat ramps, beach developments, landscaping, and administrative facilities.

Project works

Cross Canyon Dam would be an earthfill structure 112 feet high and 1,240 feet long, containing 1,025,000 cubic yards of material. The outlet works would be in the left abutment. The spillway would consist of an



LEGEND

Full Irrigation Service Land

4 0 4

SCALE OF MILES

CROSS CANYON PROJECT

uncontrolled open trapezoidal channel 150 feet wide in a saddle beyond the right abutment. A concrete-lined control section at the spillway crest would lead to a natural draw that joins Cross Canyon below the dam site.

Of the 36,000 acre-feet of capacity in the Cross Canyon Reservoir 17,000 acre-feet would be active and 19,000 acre-feet inactive and dead capacity. The large inactive and dead capacity is provided primarily to retain sediment accretions, estimated at 200 acre-feet annually. A smaller capacity reservoir would suffice if part of the mesa lands were excluded from the irrigation plan, but in view of the heavy sediment load and the spillway location, the 36,000-acre-foot capacity reservoir was assumed in all plans.

A pipe system required to convey reservoir water to the valley lands would include about 64,000 feet of pipe varying from 30 to 15 inches in diameter. Once on the land, the water would be distributed by open laterals and ditches. In order to also provide water to lands on McCracken Mesa the first 47,000 feet of the pipeline below the reservoir, extending to the mouth of Alkali Canyon, would be 48 inches in diameter. A branch 15,000 feet long would then extend up Alkali Canyon to a pumping plant that could lift 60 second-feet of water 523 feet. The McCracken Mesa distribution lateral system, designed for sprinkler irrigation, would consist of 57,500 feet of concrete pipe with diameters ranging from 45 to 15 inches.

Facilities required for sprinkler irrigation of the Hovenweep Area would include a 60-second-foot capacity pumping plant at Cross Canyon Reservoir to lift water against a total head of 443 feet. The pipe distribution system would consist of about 52,800 feet of concrete pipe ranging from 36 to 12 inches in diameter.

Project costs

Estimated investment and operation, maintenance, and replacement costs of the Cross Canyon Dam and Reservoir and of facilities to distribute the water under each of three different irrigation plans are summarized in the table on the following page.

Irrigation

Arable lands along Cross Canyon and Montezuma Creeks consist of small, discontinuous tracts of alluvium in the broader portions of the narrow valley, being confined between canyon walls and the vertical banks of the stream channels. The soils are predominantly coarse to medium textured and contain moderate amounts of salt and alkali as indicated by a predominance of greasewood cover and slick (sodic) spots. These lands could be readily leached and reclaimed if developed for irrigation.

Project costs

	Plan 1 (Valley and Hovenweep lands)	Plan 2 (Valley and McCracken lands)	Plan 3 (Valley, Hovenweep, and McCracken lands)
Irrigable area (acres)	4,000	4,000	7,000
Construction costs ($1,000)			
Cross Canyon Dam and Reservoir	2,600	2,600	2,600
Valley pipeline	1,950	1/	1/
Hovenweep Pumping Plant	1,390		1,390
Hovenweep pipeline and laterals	2,000		2,000
Hovenweep drains	950		950
McCracken Pumping Plant		1,470	1,470
McCracken pipeline and laterals		7,400	7,400
McCracken drains		950	950
Present worth recreation facilities	210	210	210
Total construction cost	9,100	12,630	16,970
Interest during construction2/	630	870	1,180
Total investment cost	9,730	13,500	18,150
Annual operation, maintenance, and replacement cost ($1,000)			
Irrigation and joint use facilities except pumping	14.2	14.2	24.0
Pumping			
Operation and maintenance	5.8	6.3	12.1
Energy	41.6	49.5	91.1
Recreation, specific facilities	13.1	13.1	13.1
Total	74.7	83.1	140.3

1/ Included in cost of McCracken pipeline and laterals.
2/ Three-year construction period with interest at 4 5/8 percent.

Mesa lands in the McCracken and Hovenweep Areas lie at about the same elevation and have similar characteristics. The soils are yellowish-red loams and clay loams overlying massive sandstone. The soils are particularly shallow in the swales and drainageways and slightly deeper on the intervening gently rolling ridges.

Drainage characteristics of the valley lands are favorable because of the fairly deep soils of moderate permeability and favorable topography. These lands would have moderate or low drainage requirements with irrigation. Mesa lands have generally unfavorable drainage characteristics because of limited soil depths over a massive sandstone layer which would act as a barrier to water movement. The drainage requirement of these lands would be high with irrigation.

Practically the entire Cross Canyon drainage from which the project water would be derived lies in the Dakota sandstone formation with typical reddish-brown aeolian soils. Normally irrigation return flows from such an area would be entirely suitable for reuse for irrigation. The quality of return flow water should be determined, however, following development of the Dolores Project.

The annual irrigation water requirement at Cross Canyon Reservoir would average 4,440 acre-feet for the valley lands, 9,800 acre-feet for Hovenweep lands, and 9,800 acre-feet for McCracken Mesa lands. Requirements were estimated on the basis of gravity irrigation of the valley lands and sprinkler irrigation of the mesa lands.

Project-caused depletions of the Colorado River would amount to about 18,200 acre-feet annually including 2,600 acre-feet from reservoir evaporation, 2,800 acre-feet from irrigation of valley lands, 6,400 acre-feet from irrigation of Hovenweep lands, and 6,400 acre-feet from irrigation of McCracken Mesa lands.

Irrigation benefits were estimated for a 100-year period with adjustment for a 5-year development period. Annual benefits would average $95 per acre, including $64 per acre in direct benefits and $31 per acre in indirect and public benefits. Estimated annual benefits are shown below for each project land area.

	Annual irrigation benefits		
Land area	Direct	Indirect and public	Total
Valley lands	$64,000	$31,000	$95,000
McCracken Mesa lands	192,000	93,000	285,000
Hovenweep lands	192,000	93,000	285,000
Total	448,000	217,000	665,000

Other project purposes

Cross Canyon Reservoir was found by the Bureau of Outdoor Recreation to have limited recreational potential because of its location off main traveled roads. The principal recreation uses would be fishing, camping, picnicking, swimming, and boating. Initial recreation use including fishing was estimated at 5,000 recreation days annually and the optimum use at 42,000 recreation days annually. Optimum use would occur about 25 to 35 years following construction.

The fishing potential of the reservoir was appraised by the Bureau of Sport Fisheries and Wildlife. Average annual fishing use was estimated at 10,600 fisherman days, having an annual benefit of $15,900.

Recreation and fishing estimates of the two cooperating agencies were adjusted by the Bureau of Reclamation to eliminate duplicated fishing benefits and to place the estimates on an average annual equivalent basis for compatibility with other estimates used in the project economic and financial analyses. The adjusted estimates are shown below.

Adjusted recreation and fishing benefits

Item	Recreation	Fishing	Total
Annual use (days)	14,000	10,600	24,600
Annual benefits	$11,200	$15,900	$27,100

Cross Canyon Reservoir would provide sediment retention benefits by reducing sediment deposition in downstream reservoirs, reducing stream bank erosion and loss of land resources. The value of these benefits has not been estimated.

Economic and financial appraisal

The annual equivalent cost of the Cross Canyon Project under any of the three irrigation plans discussed would be considerably higher than the annual benefits. Primarily because of high costs required for pumping, the irrigators could pay only about half of their operation, maintenance, and replacement cost obligation. Lands in the Hovenweep Area on Cajon Mesa could be irrigated at a lower cost under an extension of the Dolores Project, previously discussed, than from the Cross Canyon Project. Valley lands along Cross Canyon and Montezuma Creeks could likely be irrigated with return flows from the Dolores Project without storage regulation. Private irrigation development of these small, scattered tracts would be expected.

Montezuma Creek Project

Construction of a dam and reservoir on Montezuma Creek as a means of storing water for the irrigation of 2,500 acres of land in scattered tracts downstream along the creek channel has been considered by the San Juan County Water Conservancy District. Montezuma Creek Dam would be located about 8 miles north of the Hatch Trading Post and 3 miles upstream from the junction of Montezuma Creek and Cross Canyon. It would be 80 feet high and would form a 25,000-acre-foot capacity reservoir.

A reservoir at this location would be required to accommodate high flood peaks and heavy sediment depositions. More than 25,000 acre-feet of capacity would be desirable to meet these requirements and to store water for irrigation. A larger reservoir at the site, however, would inundate presently irrigated lands at the upper end of the reservoir basin. Much of the land area that could be irrigated from the Montezuma Creek Reservoir could also be served by return flows to Cross Canyon from the authorized Dolores Project, with or without storage regulation in Cross Canyon as previously discussed in connection with the potential Cross Canyon Project.

The San Juan County Water Conservancy District has filed with the Utah State Engineer an application to appropriate water for the Montezuma Creek Project. In recognition of the adverse conditions related to this development, however, the Conservancy District in 1968 applied to change its water right from Montezuma Creek to the San Juan River.

Several potential reservoir sites have been noted on Montezuma Creek upstream from the site discussed above. These have not been investigated, but it is possible that one might be found that could be developed economically to provide supplemental water for lands now irrigated from the creek.

West Paradox Project

Consideration has long been given to a plan to increase the irrigation water supply for lands in West Paradox Valley near Paradox and Bedrock, Colo., through enlargement of the Buckeye Reservoir which was constructed in 1913 by the Paradox Valley Canal and Reservoir Company. A proposal to construct the project under Public Law 566, 83rd Congress, was investigated by the Soil Conservation Service. Essentials of the project plan as reported by that agency are described below and are shown on the map on the following page.

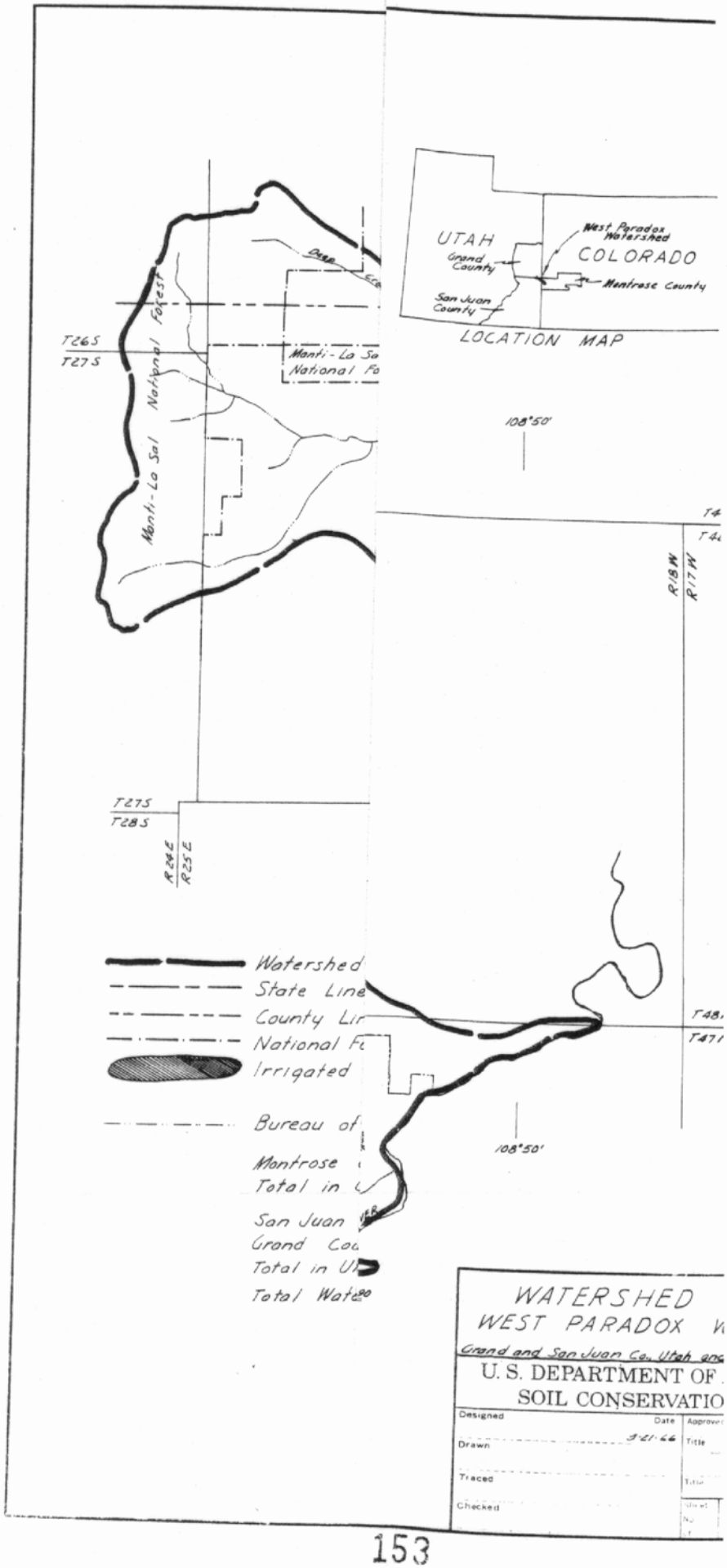
Existing development

The Buckeye Reservoir on Buckeye Creek, a tributary of West Paradox Creek, intercepts natural runoff from a drainage area of 3.3 square miles. Runoff from an additional 22 square miles in the Geyser Creek and Deep Creek drainage areas is diverted to Buckeye Creek above the reservoir. The reservoir, located in the La Sal Division of the Manti-La Sal National Forest, is the only storage facility serving lands in the West Paradox Area. The Buckeye Dam is a hydraulic fill structure about 40 feet high with a crest length of 450 feet. For safety reasons, apparently to prevent overtopping, the Colorado State Engineer limits storage to about 1,600 acre-feet. The width of the dam, 450 feet at the base and 250 feet at the top, indicates that a higher structure was originally planned but was not completed.

The reservoir company stock is held by most of the valley farmers but is not distributed in proportion to irrigated land ownerships. The storage water is used to supplement water available under direct flow rights that have priority over the reservoir storage rights. The irrigated area is said to average about 2,500 acres but to vary from 2,000 to 3,500 acres, depending on the available water supply in any year. Under average conditions about 1,500 acres have a full water supply and 1,000 acres a partial water supply. Streamflows are augmented by a few low-producing wells, and some land receives water pumped from the Dolores River. The approximate portion of the irrigated land used for each type of crop is: alfalfa, 41 percent; small grain, 25 percent; corn, 20 percent; and pasture, 14 percent. No significant change in crops grown would be expected with a more stable water supply. A typical irrigated ranch includes 250 acres, but several are much larger.

Reservoir enlargement plan

The Soil Conservation Service plan provided for raising the Buckeye Dam about 14 feet to provide a total storage capacity of 4,217 acre-feet. In order to prevent seepage through the existing embankment, a cutoff trench would be excavated to bedrock upstream from the centerline of the dam. The trench would be backfilled with about 70,000 cubic yards of suitable core material, and an additional 30,000 cubic yards of material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West Paradox Watershed
Grand County
San Juan County
Montrose County
LOCATION MAP
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would be added to raise the embankment. A new gate would be added at the existing spillway conduit, and a concrete chute would be built for an emergency spillway. Riprap would be placed on the face of the dam, and drains would be installed in the downstream section of the dam.

Buckeye Reservoir in foreground provides water for irrigation of lands in the sunken West Paradox Valley at top center of photo.

The enlarged Buckeye Reservoir would increase the irrigation storage capacity by 1,800 acre-feet to a total of 3,400 acre-feet. The full reservoir capacity would be allocated by purposes as shown below.

	Reservoir capacity (acre-feet)
Irrigation	3,400
Recreation pool	600
Flood control	184
Sediment retention	33
Total	4,217

On the assumption that any streamflows beyond the direct flow rights for 2,000 acres would be available for storage, the Soil Conservation Service estimated that the enlarged reservoir capacity allocated to irrigation would be filled in 55 percent of the years and that, on an average, 72 percent of the irrigation capacity would be utilized annually. With the reservoir enlargement the irrigation water supply would justify continued irrigation of 2,500 acres as at present, but the portion of the land receiving a full water supply would be increased from 1,500 to 2,200 acres.

The enlarged reservoir with its minimum pool of 600 acre-feet is expected to attract an average of 5,000 recreation visitors annually for full or partial day stays.

The reservoir would continue to be operated and maintained by the Paradox Valley Canal and Reservoir Company. The recreation features would be operated and maintained by the Forest Service and the Colorado Game, Fish, and Parks Department. Enlargement of Buckeye Reservoir may justify the Forest Service in undertaking a water stabilization program above the reservoir financed from its own appropriations.

Economic and financial appraisal

The cost of the reservoir enlargement is estimated at $246,000 and the increased cost of operation and maintenance at $900 annually based on 1967 prices.

Average annual direct primary benefits were estimated at $16,500, including $9,000 from the increased irrigation water, $5,000 from recreation, and $2,500 from redevelopment. The redevelopment benefits were claimed because the project is located in the Four Corners Economic Development Region. Secondary benefits were computed at $1,800 annually. These include 10 percent of the sum of the direct primary benefits, annual operation and maintenance costs, and increased costs of farm production. Nominal project benefits in flood control and sediment retention were not evaluated.

Construction costs were allocated to irrigation and recreation in proportion to the new storage capacity provided for each purpose by the reservoir enlargement. On the basis of 1,800 acre-feet for irrigation and 600 acre-feet for recreation, the allocation would be 75 percent and 25 percent, respectively. Approximately 50 percent of the costs could have been paid by funds available under Public Law 566. The Colorado Game, Fish, and Parks Department and the Forest Service agreed to participate in development of the recreational potential of the project. Planned sources of project repayment revenues are shown on the following page.

Federal funds under P.L. 566	$148,415
Colorado Game, Fish, and Parks Department	24,386
Irrigators	73,155
Total	245,956

Required payments by the irrigators per share of stock in the canal company, based on amortization of costs at 4 5/8 percent interest, would vary according to the repayment period as shown below.

Repayment period	Payment per share of stock
20 years	$0.74
40 years	.55
50 years	.52

A report on the West Paradox Project has been made to the affected water users by the Soil Conservation Service. Any further action toward development of the project will require the support and sponsorship of the people in the project area.

Paradox Salinity Control Project

Project purpose

The Dolores River, in traversing a 4-mile reach through Paradox Valley in Colorado, is estimated to pick up about 230,000 tons of dissolved solids annually. This is one of the major sources of salts in the Colorado River which inflict heavy damage to downstream water users. The object of the Paradox Salinity Control Project would be to prevent these salts from entering the river.

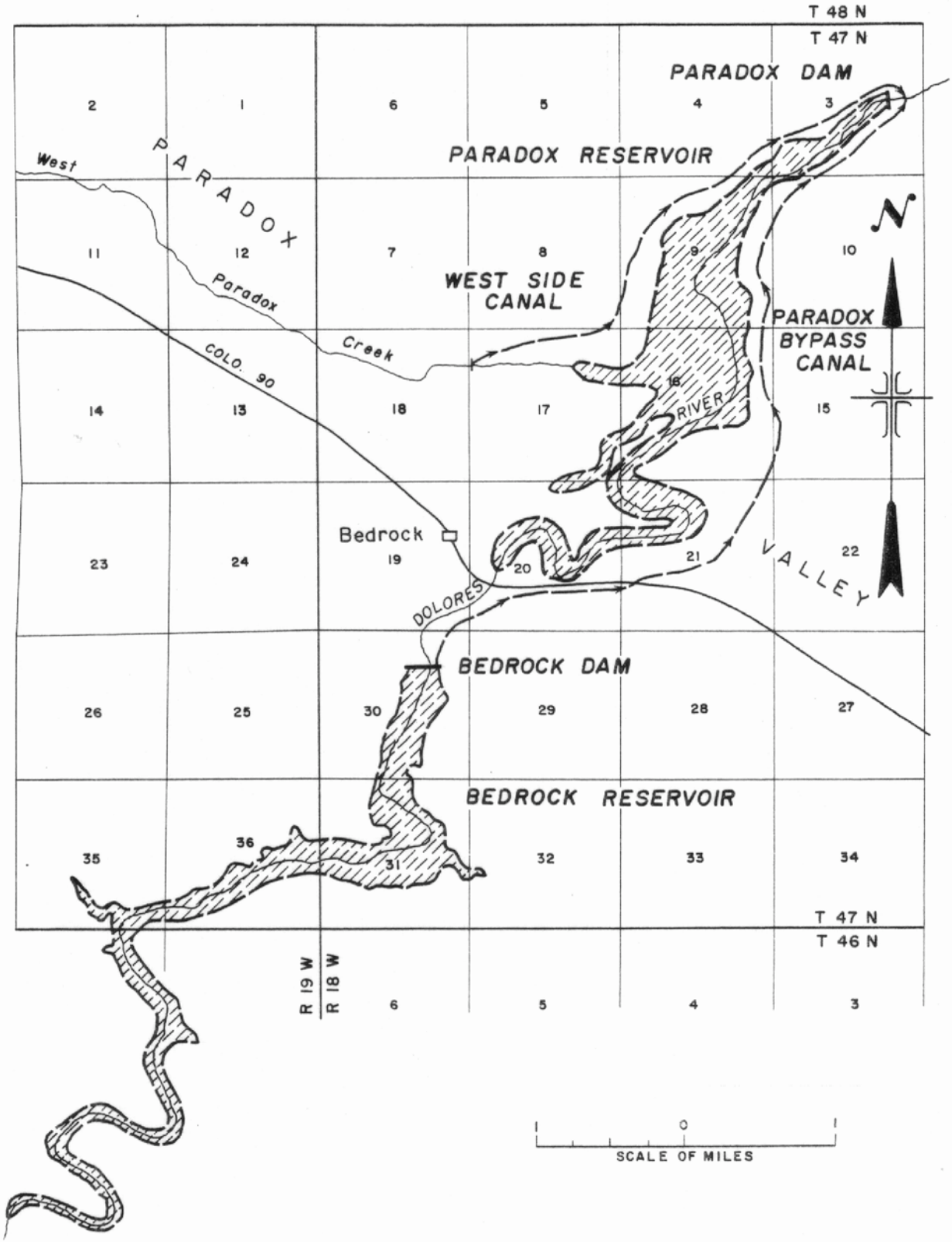
Project setting

Paradox Valley is about 22 miles long and 3 miles wide. It is rimmed by a nearly vertical escarpment 1,000 to 1,800 feet high. The Dolores River, flowing northeast, cuts across the center of the valley in its narrow dimension. The river both enters and leaves the valley in cuts through the highest portions of the valley rim--a circumstance that leads to the name Paradox Valley.

The valley was formed as an anticlinal structure by plastic flowage of salts in the underlying Paradox formation. Data from exploratory oil wells indicate that the Paradox formation is more than 10,000 feet thick and is composed of about 75 percent salt and gypsum. Erosion has exposed the salt and gypsum beds. Ground water adjacent to the Dolores River has a salinity concentration of about 25,000 parts per million. Wells have encountered a deeper brine with a concentration of 270,000 parts per million.

Preliminary project plan and works

Bedrock Reservoir with a capacity of 48,000 acre-feet would be formed by a dam on the Dolores River immediately upstream from Paradox Valley. The reservoir would control river flows, permitting the water to be released at a regulated rate and conveyed through the valley in the Paradox Bypass Canal. The 5.7-mile-long concrete-lined canal with a capacity of 1,500 second-feet would also extend around the east side of the Paradox Reservoir that would be formed on the river by a dam immediately below Paradox Valley. Paradox Reservoir, with a capacity of 12,200 acre-feet and a surface area of 1,000 acres, would serve as an evaporating pond for inflows to the Dolores River below Bedrock Reservoir. The uncontaminated flows of West Paradox Creek which normally enter the Dolores River in Paradox Valley would be diverted around the west side of the Paradox Reservoir to the river by an unlined canal of 100-second-foot capacity. The Paradox Reservoir would inundate some of the land that would be irrigated by the West Paradox Project previously described. Project facilities are shown on the map on the following page.



PARADOX SALINITY
CONTROL PROJECT

Bedrock Dam would be an earth, sand, gravel, and cobble fill structure 135 feet high and 1,300 feet long at its crest. The outlet works on the right abutment with a capacity of 1,500 second-feet would discharge directly into the Paradox Bypass Canal. The reservoir capacity of 48,000 acre-feet in combination with the outlet works would control river flows including floods of 100-year frequency. An ungated ogee spillway with a concrete chute and stilling basin would be provided to protect the dam against greater flood flows.

Paradox Dam would be about 45 feet high and 600 feet long. It would have a concrete overflow section with a crest height 25 feet above streambed that would serve as a spillway. A small capacity outlet would be used only in emergencies.

Project cost and benefits

The investment cost of the Paradox Salinity Control Project is estimated at $17,100,000. This cost includes $16,000,000 for construction and $1,100,000 for interest during construction computed at 4 5/8 percent over a 3-year construction period. The annual operation, maintenance, and replacement cost of the project is estimated at $30,000.

Benefits from the project salinity control are estimated at $14,271,000 by the Federal Water Pollution Control Administration.

Alternative plans

The preliminary salinity control plan described above was formulated from reconnaissance information. It may be revised as a result of further studies based on better data on hydrology, ground water movement, and water quality. The studies would be aimed at reducing costs and eliminating the possibility of flushing salts from Paradox Reservoir into the Dolores River in the event a flood of more than 100-year frequency should occur, causing a discharge over the Bedrock Dam spillway. Construction of Bedrock Reservoir and the Paradox Bypass Canal to capacities sufficient to control the design flood does not appear to be economically justified by the salinity benefits.

Consideration should be given to a plan that would eliminate the storage reservoirs in favor of a lined bypass canal with a capacity of about 5,000 second-feet that would convey Dolores River flows through Paradox Valley in all but the wettest years. Routing the water through the canal would prevent most of the river flows from flooding the salty soil and rock formations adjacent to the river, dissolving the salt and carrying it into the river. The salt inflow from Paradox Valley to the Dolores River would be expected to be substantially reduced by this means.

Pack Creek Project

Project purposes

The Pack Creek Project would develop flows of Mill Creek and its tributary, Pack Creek, near Moab, Utah, to provide water for irrigation, municipal, and industrial use and to provide benefits to recreation, fish and wildlife, and flood control. Lower lands in Moab Valley would be reclaimed by drainage and irrigated with water pumped from the Colorado River.

Project setting

Mill Creek, with headwaters in the La Sal Mountains, enters Moab Valley through a narrow canyon near Moab, Utah, and flows westward across the valley to the Colorado River. Just before it enters Moab Valley, Mill Creek is joined by its North Fork. In Moab Valley it is joined by Pack Creek, a tributary from the southeast. Pack Creek heads in the La Sal Mountains and traverses Spanish Valley in its course toward Mill Creek. Pack Creek Springs issue near the creek channel in the lower portion of Spanish Valley near the Moab City Park about 5 miles southeast of Moab.

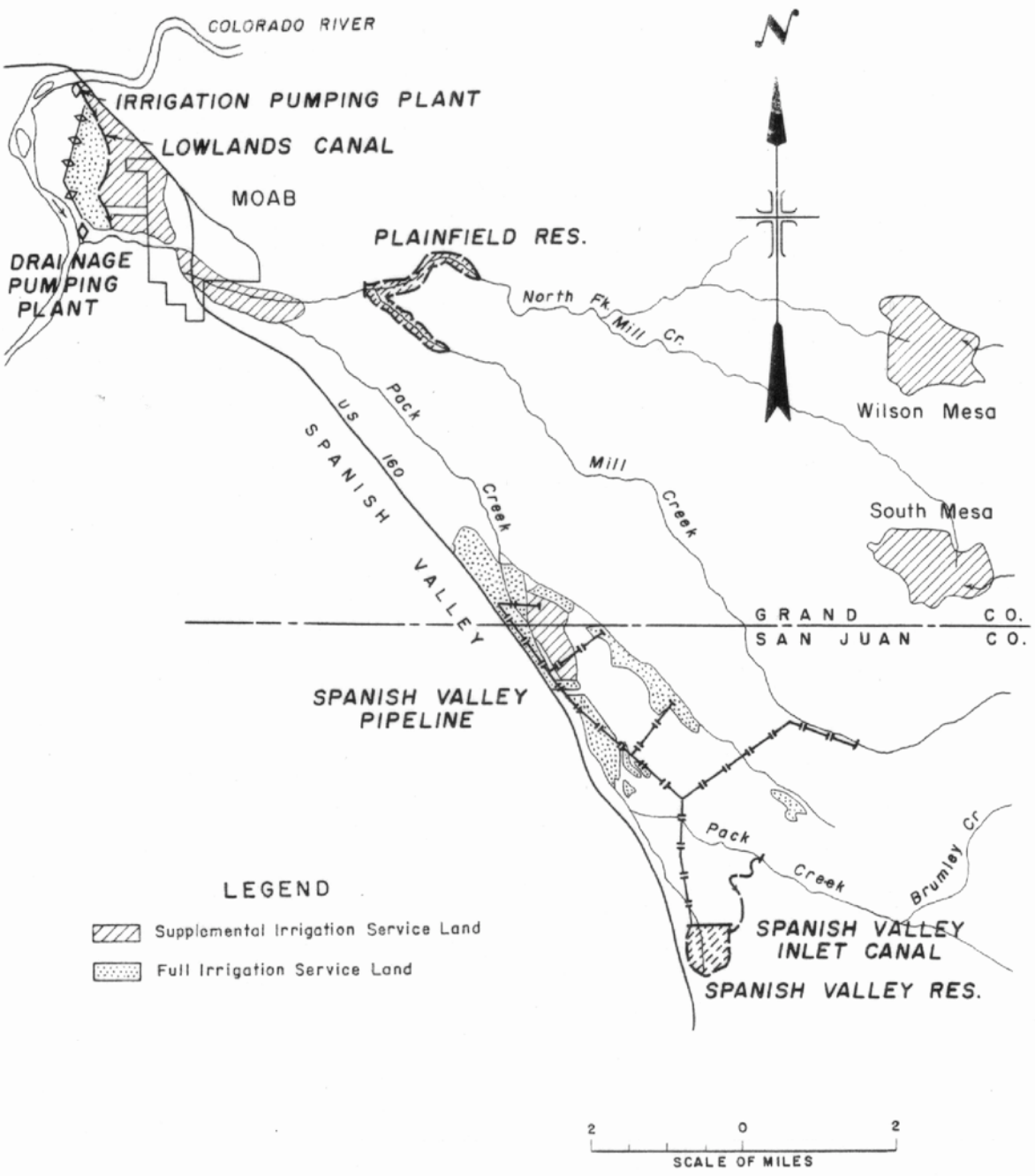
Irrigable lands in the project area are located in Moab and Spanish Valleys and on Wilson and South Mesas. Wilson Mesa is located high on the North Fork of Mill Creek at an elevation of about 7,000 feet. South Mesa is located between Mill Creek and the North Fork at an elevation of 7,200 feet. Valley lands range in elevation from 3,900 feet in Moab Valley to 5,000 feet in Spanish Valley.

The Moab Valley floor slopes slightly northward toward the Colorado River. A low, flat swamp area of about 1,000 acres adjacent to the Colorado River is subject to flooding by the river and collects waste water and return flow from irrigation.

Project plan

A sketch map of the project plan appears on the following page. The Plainfield Reservoir would be formed by a dam on Mill Creek just below the creek's junction with its North Fork. Surplus Mill Creek flows would be stored in the reservoir and released as needed for irrigation in Moab Valley and for municipal and industrial purposes in Moab and adjacent areas. Part of the water would replace existing irrigation supplies from Mill Creek and Pack Creek. This would permit the replaced water to be transferred to higher lands in Spanish Valley or on Wilson and South Mesas.

The Spanish Valley Reservoir would be located at the head of Spanish Valley about 11 miles southeast of Moab. It would be formed by a dam on an unnamed tributary of Pack Creek. The reservoir would be supplied mostly by diversions from Pack and Mill Creeks. The stored water would be



PACK CREEK PROJECT

released as needed for the irrigation of lands in Spanish Valley. It would be conveyed by the potential Spanish Valley Pipeline under sufficient pressure for sprinkler irrigation. Sprinkler irrigation is planned for the presently undeveloped lands in the upper portion of Spanish Valley. Some water would be released at the pipeline terminal into Pack Creek for supplemental gravity irrigation of lower lands in the valley.

Pack Creek water would be conveyed to the reservoir through the Spanish Valley Inlet Canal. Mill Creek water would be diverted into a branch of the Spanish Valley Pipeline under an arrangement that would permit either direct distribution to the irrigators or reverse flow through the pipeline and the reservoir outlet for storage in Spanish Valley Reservoir.

Recreation facilities would be provided at the Plainfield and Spanish Valley Reservoirs as recommended by the Bureau of Outdoor Recreation. These would include picnic units, parking areas, sanitary and water systems, paved roads, boat ramps, beach development, landscaping, and administrative facilities. Camping units would also be provided at the Spanish Valley Reservoir because of its location near a major highway and anticipated greater recreation use.

Development of the swamp area along the Colorado River near Moab would require diking the area to control inflows, land drainage, and development for irrigation farming. Irrigation water would be pumped from the Colorado River to the potential Lowlands Canal for distribution in the area.

Project irrigation water would be furnished to 3,020 acres of land as shown below.

	Irrigated area (acres)		
	Full service	Supplemental service	Total
Wilson and South Mesas	0	400	400
Spanish Valley	830	300	1,130
Moab Valley	1/ 370	1,120	1,490
Total	1,200	1,820	3,020

1/ Lower lands to be served by pumping from Colorado River.

Project water would average 7,780 acre-feet annually, including 5,120 acre-feet for irrigation and 2,660 acre-feet for municipal and industrial uses. The irrigation water would include 940 acre-feet to supplement supplies on land now irrigated and 4,180 acre-feet for full service irrigation of new land. These estimates of water supply are based on streamflows for the 17-year period 1950 through 1966.

Moab Valley showing irrigated lands along lower Mill Creek at right and center of photo and along Pack Creek at left. Town of Moab is nestled below bare rock slopes and escarpments on which flood flows frequently originate during storms.

Water pumped from the Colorado River would average 1,600 acre-feet annually. The remaining 6,180 acre-feet of the project supply would be developed by storage in the Plainfield and Spanish Valley Reservoirs, including 390 acre-feet used above the reservoirs by exchange. A summary of the reservoir operations is shown on the following page.

Summary of reservoir operations
(Unit--acre-feet annually)

	Plainfield	Spanish Valley	Total
Storable flows1/			
Mill Creek	3,270	2,240	5,510
Pack Creek	0	1,720	1,720
Total	3,270	3,960	7,230
Reservoir releases and losses			
Irrigation	150	2,980	3,130
Municipal and industrial use	2,660	0	2,660
Controlled flood release	340	0	340
Uncontrolled spills	30	400	430
Evaporation	310	470	780
Change in content2/	-220	+110	-110
Total	3,270	3,960	7,230

1/ Streamflows remaining after bypassing 4,360 acre-feet at Plainfield Reservoir and 1,110 acre-feet at Spanish Valley Reservoir for preproject irrigation rights and after allowing for a future upstream project diversion of 390 acre-feet from Mill Creek for irrigation on Wilson and South Mesas.

2/ Average annual change in reservoir content over the 17-year study period 1950-66.

The Pack Creek Project would deplete the flow of the Colorado River by an average of 4,300 acre-feet annually.

Project works

The Plainfield Dam is planned as a concrete arch structure 217 feet high with a crest length of 550 feet. The reservoir would have a capacity of 9,100 acre-feet, of which 7,900 acre-feet would be active. An additional surcharge capacity of 3,500 acre-feet would be provided which, together with the spillway capacity of 3,500 second-feet, would be adequate for an inflow design flood having a peak of 13,200 second-feet and a 24-hour volume of 6,600 acre-feet. With the spillway capacity limited to 3,500 second-feet to prevent downstream damage, this design flood proved more critical in flood routing than a thunderstorm having a peak inflow of 17,500 second-feet and a 12-hour volume of 3,500 acre-feet. The reservoir would have adequate capacity for sediment accumulation estimated at 10 acre-feet annually. Spillway discharges would cascade down the natural rock face of the left abutment and reenter Mill Creek about 800 feet downstream from the dam. The outlet would consist of three individually controlled 12-inch-diameter pipes extending through the dam about 90 feet above streambed. Discharges would fall in open air to a stilling basin about 15 feet deep formed by a rock dike about 200 feet downstream from the dam.

View looking upstream to Plainfield Dam site on Mill Creek near Moab, Utah.

Spanish Valley Dam would be 97 feet high and would have a crest length of 2,750 feet. It would contain about 1,100,000 cubic yards of embankment material. The single reservoir outlet located in the left abutment would connect directly with the Spanish Valley Pipeline. An uncontrolled shallow V-notch weir and a 100-foot-wide concrete apron located in a low point on the right abutment would serve as a spillway.

Spanish Valley Reservoir would have 5,500 acre-feet of capacity, of which 4,730 acre-feet would be active. In addition, it would have a surcharge capacity of 900 acre-feet that would be sufficient to store the inflow design flood. The reservoir would have adequate capacity to retain sediment inflow estimated at 0.8 acre-foot annually. U.S. Highway 160 would be relocated around the reservoir basin, as would four power lines, a telephone line, and a 30-inch-diameter high pressure gas line.

The Spanish Valley Inlet Canal would extend 1.8 miles from Pack Creek to the Spanish Valley Reservoir. A narrow section in the bottom of the canal would convey normal flows of 25 second-feet or less while a wider upper section would permit conveyance of 490 second-feet during periods of high runoff.

The Spanish Valley Pipeline would extend from the outlet of Spanish Valley Reservoir about 6 miles down Spanish Valley to serve irrigable lands. A feeder branch from Mill Creek would join the main branch about 1.7 miles below the reservoir outlet. A shutoff valve just below the junction would permit Mill Creek water to be fed back into the reservoir through the outlet at times when it was not needed for irrigation. The pipeline would have an initial capacity of 30 second-feet and the Mill Creek branch 20 second-feet. In all, 53,800 feet of pressure pipe would be required for the system, ranging in diameter from 12 to 27 inches.

The pumping plant on the Colorado River would be located near the Highway 160 bridge. It would have a capacity of 15 second-feet and would lift water about 20 feet to the Lowlands Canal. The canal would be 2.2 miles long and would serve lands near the river reclaimed by drainage. A dike along the Colorado River bank would protect the area from flooding by the river. An open drain along the upland side of the dike would be fed by about 3.2 miles of closed subsurface drains. A 12-second-foot pumping plant would discharge the drainage water over the dike to the river.

A 3-year construction program would be required for the project. Recreation facilities would be added progressively as justified by use.

Project costs

The investment cost of the Pack Creek Project is estimated at $11,680,000. This includes $9,900,000 for construction of features tabulated below and $1,020,000 as the present worth of the recreation facilities that would be provided progressively over a period of developing need. It also includes $760,000 in interest during construction computed for a 3-year period at 4 5/8 percent.

Feature	Construction cost
Plainfield Dam and Reservoir	$5,250,000
Spanish Valley Dam and Reservoir	2,700,000
Spanish Valley Inlet Canal	170,000
Spanish Valley Pipeline, including Mill Creek branch	1,300,000
Lowlands Canal, Laterals, and Colorado River pump	157,000
Lowlands dike, drains, and drain pump	323,000
Total	9,900,000

Annual operation, maintenance, and replacement costs are estimated at $91,400. This figure is made up of $8,100 for the dams, reservoirs, canals, and pipelines; $1,600 for pumping plants and electric energy; and $81,700 for recreation facilities.

Water quality

Water of Mill and Pack Creeks is of excellent quality for irrigation. Colorado River water is of satisfactory quality for irrigation during periods of normal or high flows. In low flow periods Colorado River water at the pump site is somewhat saline but could be used for irrigation with good management practices, proper cropping patterns, and the drainage system planned for the project.

Mill Creek water stored in the Plainfield Reservoir would be of good chemical quality for municipal and industrial use. Normal treatment would be required.

Irrigation

The character of all land areas that would be irrigated by the project is discussed under "Spanish Valley Area" in Chapter II.

A detailed classification was made in 1957 of lands in Moab and Spanish Valleys. Results of the classification are summarized below.

Land classification summary

	Presently irrigated land		Presently nonirrigated land		Total		
Land class	Spanish Valley	Moab Valley	Spanish Valley	Moab Valley	Spanish Valley	Moab Valley	Project
Class 2	347	693	349	6	696	699	1,395
Class 3	51	45	967	7	1,018	52	1,070
Class 4F			1,069	8	1,069	8	1,077
Class 4P		175				175	175
Class 5				384		384	384
Class 6W	39				39		39
Class 6			4,336	3,135	4,336	3,135	7,471
Subtotal	437	913	6,721	3,540	7,158	4,453	11,611
Right-of-way					344	126	470
Townsite and airport					195	784	979
Total	437	913	6,721	3,540	7,697	5,363	13,060

The 1957 classification was made to standards appropriate for gravity irrigation. A reclassification, if made to standards suitable for

sprinkler irrigation, would probably show a larger arable area and some upgrading of land classes, especially in the Spanish Valley Area. Lands on Wilson and South Mesas have not been classified.

Irrigation water requirements would vary among sections of the project area depending on elevation, land characteristics, crops grown, and method of irrigation. Annual diversion requirements per acre and in total are shown for each area in the following table. All requirements are estimated for gravity irrigation except those for full service lands in Spanish Valley which are based on sprinkler irrigation.

Area	Irrigated area (acres)		Annual diversion requirement		
			Acre-feet per acre		
	Full service land	Supplemental service land	Full service land	Supplemental service land	Total (acre-feet)
Wilson and South Mesas	0	400		3.00	1/400
Spanish Valley	830	300	2/3.37	5.12	4,360
Moab Valley	3/370	1,120	4.61	4.49	6,700
Total	1,200	1,820			11,460

1/ Diversion requirement considered to be limited by water supply on the mesas that would be usable by exchange.

2/ Rate based on sprinkler irrigation. All other rates shown are based on gravity irrigation.

3/ Lower lands to be served by pumping from Colorado River.

Irrigation benefits in Moab and Spanish Valleys were estimated at $119 per acre annually, including $82 in direct benefits and $37 in indirect and public benefits. Benefits on Wilson and South Mesas were estimated at $61 per acre annually, including $41 in direct benefits and $20 in indirect and public benefits. The 5,120 acre-feet of project water would provide irrigation benefits of $157,600 annually, including $108,400 in direct benefits and $49,200 in indirect and public benefits.

Municipal and industrial water

The Moab municipal water system is supplied from springs and wells as discussed in Chapter V. The Pack Creek Project would make an additional 2,660 acre-feet available annually to meet the growing municipal and industrial water needs in Moab and vicinity.

The long-term water needs of the Moab area are expected to require more water than would be provided by the project. It is estimated in a

University of Utah study[1] that municipal and industrial needs in Grand County will increase to 25,000 acre-feet annually by year 2020 from the 6,923 acre-feet used in 1960, representing an increase of 18,077 acre-feet. Much of the increase will likely occur in the Moab area, which now has a majority of the county's people and the greater part of its industrial development.

The Pack Creek Project could be extended to provide additional municipal and industrial water for the Moab area as the need arises. This could be accomplished by pumping from the Colorado River to lands in Moab Valley planned to be served from Plainfield Reservoir. This would permit the replaced reservoir water to be used for municipal and industrial purposes. About 4,500 acre-feet of water annually could be made available by this means. This additional pumping is not included in the present project plan but remains a potentiality for the future.

Benefits from the use of 2,660 acre-feet of project water for municipal and industrial purposes are estimated at $77,000 annually. The benefits were considered to be equal to the average annual equivalent cost of obtaining a like amount of water of comparable quality from the most likely alternative single-purpose means of development. The alternative means of providing 2,700 acre-feet of water for Moab and immediate area would be a 10-second-foot pumping plant on the Colorado River and water treatment facilities to provide water of comparable quality to that of the project.

Recreation, fish, and wildlife

Both the Plainfield and Spanish Valley Reservoirs would have recreational value, with the greatest potential being at the Spanish Valley site, according to appraisals made by the Bureau of Outdoor Recreation.

Recreation use at the Plainfield Reservoir would be limited by the steep shoreline, lack of land suitable for recreation development, difficult access, and unfavorable reservoir size and shape. The use would be only of local significance. The principal recreation activities would be picnicking, fishing, and boating. An initial use of 5,000 recreation days annually, increasing to 48,000 recreation days during the 2000-05 period, is estimated. The value of recreation at Plainfield Reservoir was computed to be $1 per recreation day. The recreation use and benefits are exclusive of fishing which was appraised by the Bureau of Sport Fisheries and Wildlife.

1/ "Municipal and Industrial Water Requirements--Utah Counties, 1960-2020," March 1966, by Bureau of Economic and Business Research, University of Utah, in cooperation with Bureau of Reclamation and Utah State Engineer.

The recreation potential of Spanish Valley Reservoir is favorable because of the size of the water body, its location on a major highway, and availability of adjacent land for recreation development. Principal activities would be camping, picnicking, swimming, and fishing. Boating should be permitted, but due to the limited size of the reservoir, high speed boating and water skiing should be curtailed or even prohibited. An initial use of 10,000 recreation days annually, including fishing, increasing to 278,000 recreation days by the year 2005, is estimated. The value of recreation at Spanish Valley Reservoir was computed to be $1 per recreation day.

Project effects on fish and wildlife were appraised by the Bureau of Sport Fisheries and Wildlife. Fishing benefits of Plainfield Reservoir were estimated at $12,000 annually based on an expected 8,000 fishing days, while those at Spanish Valley Reservoir were estimated at $5,100 annually based on 3,400 fishing days. The project would not have an appreciable effect on wildlife.

The Bureau of Reclamation adjusted the recreation and fishing estimates of the cooperating agencies to eliminate overlapping fishing benefits at the Spanish Valley Reservoir and place the estimates on an average annual equivalent basis over a 100-year period at 4 5/8 percent interest for compatibility with other estimates used in the project economic and financial analyses. The estimates as adjusted are shown in the following table.

Adjusted recreation and fishing benefits

Item	Recreation	Fishing	Total
	Plainfield Reservoir		
Annual use (days)	30,000	8,000	38,000
Annual benefits	$30,000	$12,000	$42,000
	Spanish Valley Reservoir		
Annual use (days)	148,600	3,400	152,000
Annual benefits	$148,600	$5,100	$153,700
	Project total (both reservoirs)		
Annual use (days)	178,600	11,400	190,000
Annual benefits	$178,600	$17,100	$195,700

The marsh area in lower Moab Valley that would be drained and irrigated by pumping from the Colorado River in the present project plan could, as an alternative, be developed as a waterfowl management area, according to a 1959 appraisal made by the Bureau of Sport Fisheries and Wildlife. Further consideration of this alternative should be given in future planning of the Pack Creek Project.

Flood control

By controlling flows of Mill Creek at its entrance into Moab Valley, the Plainfield Reservoir would provide flood control protection for the valley, including the town of Moab. Reservoir space would be reserved for flood control during spring periods when runoff forecasts indicate that the reservation would be desirable.

The Spanish Valley Reservoir would also provide flood control for Moab Valley and for irrigated lands in Spanish Valley. The inlet canal from Pack Creek to the reservoir would have sufficient capacity to convey peak flows of 50- to 100-year frequency on Pack Creek and its tributary, Brumley Creek.

Flood control benefits of $150,000 annually for Plainfield and Spanish Valley Reservoirs were adopted for project analyses. This benefit value is based on the cost of a single-purpose flood control project, consisting of channel improvements on Mill Creek, determined to be economically justified by studies concluded in 1965 by the Corps of Engineers. The cost of the single-purpose project was estimated at $3,180,000. The average annual equivalent cost over a 100-year period at 4 5/8 percent interest would be $150,000.

Economic and financial appraisal

Benefits from the Pack Creek Project would be $580,300 annually, including $531,100 in direct benefits and $49,200 in indirect and public benefits. Direct benefits include $108,400 from irrigation, $77,000 from municipal and industrial water, $178,600 from recreation, $17,100 from fish and wildlife, and $150,000 from flood control. The $49,200 in indirect and public benefits are attributed to irrigation.

A comparison of the benefits and costs as estimated for the Pack Creek Project shows the project to be marginal economically. A reappraisal under the more comprehensive criteria for benefit evaluations being considered by the Water Resources Council would be more favorable. The existing flood hazard in the Moab area makes urgent a flood control measure such as would be provided by the project.

The project-related increased payment capacity of the irrigators would likely substantially exceed the operation, maintenance, and replacement costs that would be allocated to irrigation, leaving a balance to apply on repayment of the irrigation investment costs which would be reimbursable. All costs allocated to municipal and industrial water, and part of the costs allocated to recreation and fish and wildlife would be reimbursable, while all costs allocated to flood control, and part of the costs allocated to fish and wildlife and recreation would be nonreimbursable.

Rock-slope Floods Near Moab

Apart from the flood problems that would be alleviated by the previously described Pack Creek Project is the flood runoff from the bare rock slopes and escarpments which overlook Moab on the northeast and southwest. Floods from these local sources are of yearly frequency and cause damages averaging about $43,500 annually. The damage ranges widely, affecting streets, homes, business property, farms, and irrigation structures. The flood occurrences are generally independent of floods on Mill and Pack Creeks.

From a recent reconnaissance inspection the Soil Conservation Service concluded that there are no sites suitable for debris basins nor similar flood control structures. The problem is also compounded by soluble gypsum deposits in the alluvial fans at the mouths of the canyons. Observation of the performance of the rock Gabian-type structures built by the Civilian Conservation Corps in 1939-41 lead the Soil Conservation Service to the conclusion that these structures are an effective substitute for one-structure control. This method of flood control on these drainages appears to be physically and economically feasible provided requirements for periodic cleanout and maintenance are satisfied. The program could be undertaken independently and need not be a part of the Pack Creek or other multiple-purpose project.

Hatch Wash Project

Hatch Wash is a tributary of Kane Springs Creek which flows northwest and enters the Colorado River 12 miles southwest of Moab. Reservoir sites were considered for development on Hatch Wash and on two of its tributaries--West Coyote Creek and East Canyon Creek--but all were found to be unsuitable because of insufficient water.

The Rattlesnake Reservoir site on West Coyote Creek could be developed to a capacity of 8,500 acre-feet, according to the 1946 basin-type report entitled "The Colorado River." Inflow to the reservoir could be increased by construction of a feeder canal that would intercept the flows of two other streams that enter West Coyote Creek below the reservoir site. Water from this development could be used to irrigate lands located south and east of La Sal Junction.

No runoff records are available on West Coyote Creek. Most of the usable creek flow, however, is already used for irrigation and livestock watering above the Rattlesnake site. A small impoundment at the site is now used mainly for livestock watering. An abandoned irrigation ditch extending from the reservoir to downstream lands is evidence of the inadequate water supply.

East Canyon Reservoir site on East Canyon Creek could have a capacity of about 2,500 acre-feet, according to the 1946 basin report. The water would be used on lands along the creek in Dry Valley. East Canyon Creek flows, however, are too meager to justify a project development. The Bear Trap Reservoir site several miles farther upstream on East Canyon Creek was previously discussed under the potential Bear Trap Reservoir Extension of the authorized Dolores Project. The extension plan involves a diversion of water to the reservoir from the Dolores River.

The Hatch Rock Reservoir site is on Hatch Wash at a point 2 miles east of Hatch Rock. Water stored at this site, below points of inflow from Coyote and East Canyon Creeks, would be below arable lands in Dry Valley. A reservoir at this site would be useful primarily for recreation and fish and wildlife propagation. A 16-year runoff record at a point immediately below the reservoir site showed annual flows averaging 1,190 acre-feet and varying from 100 acre-feet in 1955 to 3,310 acre-feet in the following year. This is not enough water to justify a storage development.

Indian Creek Project

Project purposes and plan

The Indian Creek Reservoir, formed by a dam on Indian Creek about 12 miles above the creek's confluence with the Colorado River, would have value as a fishery and recreational attraction and would provide sediment-retention benefits. The reservoir would be below all present diversions from the creek which include water for irrigation of about 600 acres in the creek basin and a tunnel diversion to Recapture Creek in the San Juan River Basin. Two debris basins would be constructed to retain part of the sediment that would otherwise be carried into the reservoir. Locations of the reservoir and debris basins are shown on the map on the following page.

Project works

A dam 114 feet high above streambed would form a reservoir with 20,000 acre-feet of capacity. The dam would be 850 feet long at the top and would contain 820,000 cubic yards of embankment material. The reservoir outlet would have a capacity of 132 second-feet at normal water surface elevation. The spillway, located on the left abutment away from the dam, would be an open trapezoidal channel 200 feet wide cut in sandstone with a concrete control section. A spillway capacity of 26,000 second-feet in combination with a reservoir surcharge capacity of 10,000 acre-feet would provide protection against an inflow design flood having a peak flow of 30,000 second-feet and a 24-hour volume of 40,000 acre-feet.

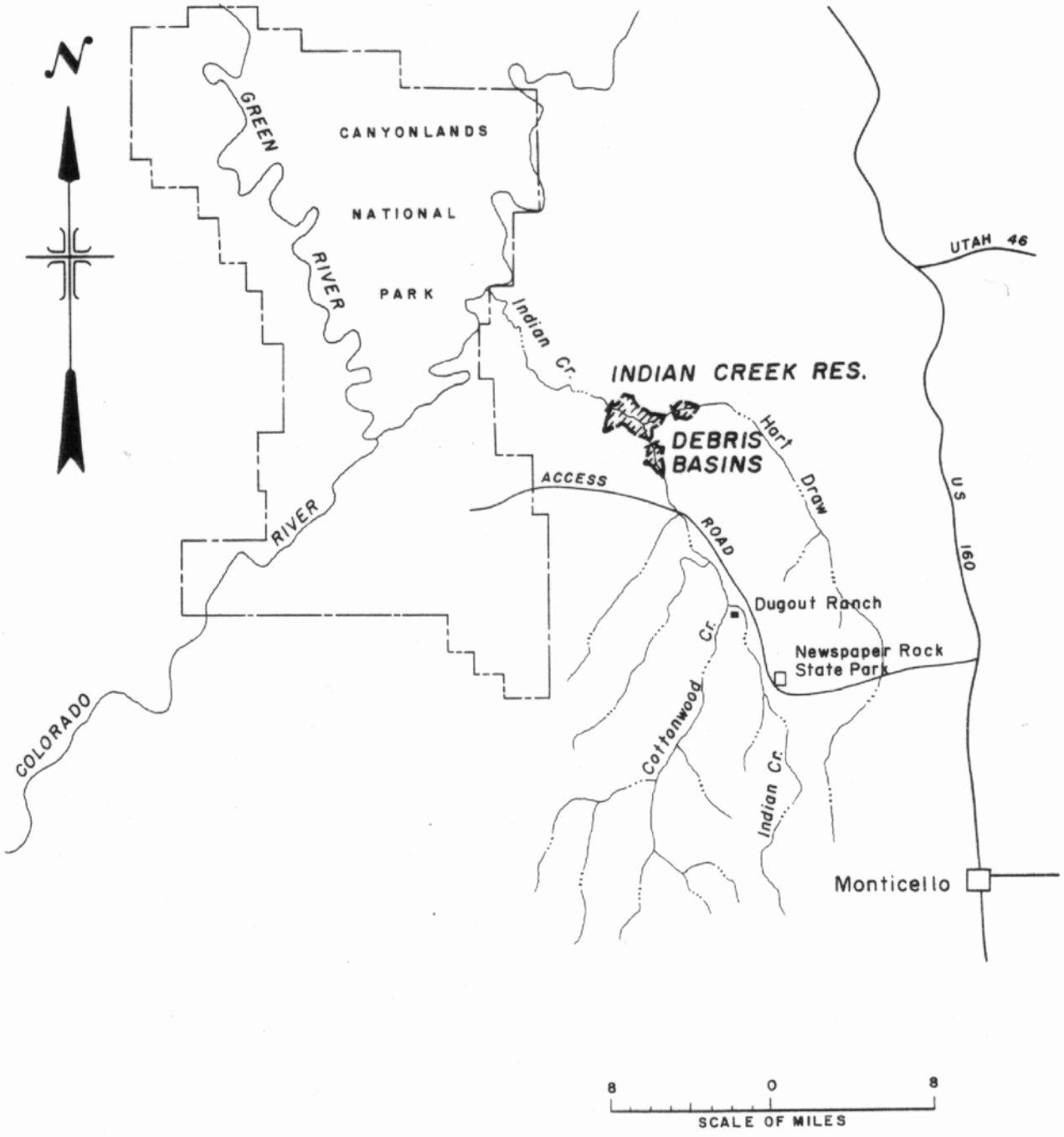
Sediment inflow to the reservoir from Indian Creek and Hart Draw, estimated at 380 acre-feet annually, would be partially controlled by debris basins constructed on these two stream channels above the reservoir. Evaporation losses at project facilities are estimated at 800 acre-feet annually.

Recreation facilities that would be provided at Indian Creek Reservoir, as recommended by the Bureau of Sport Fisheries and Wildlife, include camp units, picnic units, parking areas, sanitary and water systems, paved roads, beach developments, landscaping, a boat ramp, and administrative facilities.

A 2-year construction program would be required. Recreation facilities would be provided to meet initial demands and expanded as recreation use increases.

Project costs

The investment cost of the Indian Creek Project is estimated at $4,220,000. The cost includes $2,000,000 for Indian Creek Dam and Reservoir, $76,000 for access roads, $820,000 for the two debris basins,



INDIAN CREEK PROJECT

and $1,144,000 as the present worth of the cost of recreation facilities to be provided initially and added from time to time to meet increased use. It also includes $180,000 in interest during construction computed for a 2-year period at 4 5/8 percent interest.

Annual operation, maintenance, and replacement costs are estimated at $65,200, including $5,000 for the dams and reservoirs and $60,200 for recreation facilities and general administration.

Recreation and fishing

In order to prolong the attractiveness of Indian Creek Reservoir for recreation, the reservoir would be operated initially at near its minimum pool of 6,700 acre-feet with a surface area of 180 acres. As sediment encroaches into the storage pool, causing objectionable shallow water depths, the operating level would be raised enough to cover the flats that may have been built up and reestablish the natural beauty of the shoreline. This process could be repeated as desirable over a period of many years until operation at full reservoir capacity of 20,000 acre-feet with a surface area of 400 acres is reached.

The recreation potential of the reservoir was appraised as good to excellent by the Bureau of Outdoor Recreation. Located 3 miles off the east entrance road to Canyonlands National Park, the reservoir would be an important side attraction for visitors traveling to and from the park. The natural shoreline on the downstream portion of the reservoir would be colorful Navajo sandstone. The upstream shoreline would have gently sloping areas that are ideal for recreational facilities. Recreation activities at the reservoir would include camping, picnicking, fishing, swimming, and limited boating.

Initial recreation use at Indian Creek Reservoir, including angling, was estimated at 20,000 days annually. An optimum use of 200,000 days annually is expected about 40 years following initial development. The value of recreation was computed to be $1.05 per recreation day. Annual recreation benefits would be $21,000 initially and $210,000 under optimum development.

The Bureau of Sport Fisheries and Wildlife appraised the fishing potential of Indian Creek Reservoir. It was found to be suitable for development of a trout fishery with average annual angling use estimated at 12,500 fisherman days. The benefits would average $37,500 annually.

Preliminary appraisals of possibilities for development of a small stream fishery on Indian Creek below the reservoir were not encouraging. Although downstream releases of from 3 to 6 second-feet could probably be maintained, no appraisal of the value of such a release was made pending a determination of water temperatures and other factors that would affect the stream fishery.

Recreation and fishing estimates of the two cooperating agencies were adjusted to eliminate duplicated fishing evaluations and to place the estimates on average annual values over a 100-year period for compatibility with other evaluations used in the project analyses. The adjusted values are shown below.

Adjusted recreation and fishing values

Item	Recreation	Fishing	Total
Annual use (days)	87,800	12,500	100,300
Annual benefits	$92,200	$37,500	$129,700

Sediment retention

Indian Creek Reservoir and the two debris basins above the reservoir would provide sediment-retention benefits by improving the water quality in the 12 miles of creek channel below the reservoir and by reducing sediment deposition in Lake Powell on the Colorado River. The benefits have not been evaluated.

Economic appraisal

Benefit and cost estimates shown above indicate that the Indian Creek Project would not be economically justified at this time. A future reappraisal may show the reservoir development to be justified, however, as visitation to the recently created Canyonlands National Park increases and a need for water-oriented recreation becomes greater in this arid locality to supplement the park facilities.

Recreation and Fishing Reservoirs

Hop Creek Reservoir

The Hop Creek Reservoir site, as yet unevaluated, is reported to provide a good potential for a small recreation and fishing development. The site is on Hop Creek, a small tributary of Cottonwood Creek, which in turn is tributary to Indian Creek and the Colorado River. It is on the northwest slope of the Abajo Mountains in the Monticello Ranger District of the Manti-La Sal National Forest.

The Hop Creek site is not easily accessible at present. It will be made accessible, however, and its value for recreation will be increased when a road is constructed between the Natural Bridges National Monument on Highway U-95 and Canyonlands National Park. Such a road is tentatively scheduled for construction within 5 to 10 years. Further consideration should be given to Hop Creek Reservoir development as definite plans are made for the road construction.

Vega Reservoir

A potential recreation and fishing reservoir on Vega Creek about 3 miles east of Monticello is being investigated by the San Juan County Water Conservancy District in cooperation with State and County agencies. A report on a reservoir formed by dams at two alternative sites was prepared in September 1968 by engineering consultants for the district.

Dam site A is on Vega Creek about one-half mile north and upstream from the point where the creek is crossed by U.S. Highway 160. Dam heights of both 62 feet and 70 feet were considered at this location. Site B is at the highway crossing where the existing road fill would be utilized as a dam. The upstream face of fill would be covered with a concrete paving slab or a bituminous lining.

Summary data for dams and reservoirs at the two locations as determined by the engineering consultants are tabulated below.

Dam site	Dam height (feet)	Reservoir Capacity (acre-feet)	Reservoir Surface area (acres)	Construction cost
Vega Creek, site A	62	1,510	85	$129,000
Vega Creek, site A	70	2,338	146	155,000
Vega Creek, site B	47	1,420	75	1/98,000

1/ Site B cost shown includes a 6-inch thick concrete paving slab on face of embankment. The cost would be $92,000 with a 6-inch bituminous lining or $119,000 with a 12-inch bituminous lining.

The consultants' report shows that the Vega Reservoir could be constructed at relatively low cost in an area easily accessible to both local residents and travelers. The question of a water right for the project would need to be explored. Flows of Vega Creek and Montezuma Creek to which it is tributary are utilized by irrigators whose rights are prior to any water appropriation that could be made for the reservoir.

CHAPTER IX

POTENTIAL RECLAMATION PROJECTS
(Navajo Reservation Projects)

Projects on Navajo Indian Reservation

The Navajo Indian Irrigation Project is currently being constructed under plans that would provide irrigation water for 110,630 acres in the New Mexico portion of the Navajo Reservation. The water source is the San Juan River with storage provided in the Navajo Reservoir, constructed in the 1958-63 period as a unit of the Colorado River Storage Project. Development and settlement of this large project will be the major reclamation enterprise of the Navajo Tribe for the next several years. Potential water resource developments in other parts of the reservation, including the Utah portion that is within the area covered by this report, will continue to be of interest even if temporarily retarded by the larger project.

A current program to provide improved domestic water supplies and sanitary facilities for the Utah portion of the reservation is discussed in Chapter IV. The potential Bluff and Cross Canyon Projects would irrigate lands that are partly in Indian ownership, as previously discussed. The Mexican Hat Reservoir would be located partly on Navajo Indian Reservation lands and the Halgaitoh Reservoir would be entirely on the reservation. Other potential Indian projects--the McElmo Creek Project and possibilities of pumping from the San Juan River--are discussed below.

McElmo Creek Project

A study of a dam and reservoir site on McElmo Creek was made in 1964 by consulting engineers for the Utah Indian Affairs Commission. The reservoir would be in the Navajo Indian Reservation about 2 miles northeast and upstream from Aneth, Utah. Preliminary designs and estimates were made for a dam 175 feet high that would form a reservoir with a capacity of 112,000 acre-feet and a surface area of 1,728 acres. Operation of the reservoir and uses of its water were not specifically planned although potential uses were cited as irrigation, recreation, fishing, flood control, and hydroelectric power production.

Two land areas, each consisting of about 1,500 acres, were mentioned as potentially irrigable from the reservoir. One area includes downstream lands along McElmo Creek and the San Juan River and the other mesa lands above the reservoir north of Aneth Point that could be served by pumping. The lands have not been classified as to suitability for irrigation by McElmo Creek water which has a relatively high concentration of soluble salts brought into the creek in return flows from irrigated lands in the Montezuma Valley Area. McElmo Creek water is now being successfully used for irrigation of lands that have good internal drainage characteristics. Return flows to the creek will be increased as a result of more water being provided to lands in the Montezuma Valley Area of Colorado by the recently authorized Dolores Project.

Irrigation pumping from San Juan River

Nine land areas comprising a total of 19,610 acres in the Utah portion of the Navajo Reservation that could be irrigated by pumping from the San Juan River have been identified by the Bureau of Indian Affairs. Seven of the smaller areas involving a total of 3,960 acres would require pump lifts of less than 200 feet while the two larger areas comprising 15,650 acres would require lifts of 500 feet or more. Data concerning the location and size of each tract and the pump lift and water conveyance distance from the San Juan River required for each appear in the following tabulation.

Potential pump areas

Location	Area (acres)	Pump lift (feet)	Distance to high point (feet)
1 mile SE of Aneth School, secs. 34-35, T. 41 S., R. 25 E.	500	100	4,500
6 miles SE of Bluff, T. 41 S., R. 22 E.	8,900	600	25,000
8 miles SW of Bluff, T. 41 S., R. 21 E.	6,750	500	31,000
3 miles SW of Bluff, secs. 3 and 4, T. 41 S., R. 21 E.	160	180	5,000
2 miles SE of Montezuma Creek, P.O. secs. 3, 4, and 5, T. 41 S., R. 24 E.	800	60	2,600
2 miles SE of Montezuma Creek, P.O. secs. 3, 4, 5, 8, 9, and 10, T. 41 S., R. 24 E.	800	180	7,000
2 miles west of Montezuma Creek, P.O. sec. 36, T. 40 S., R. 23 E., and sec. 1, T. 41 S., R. 23 E.	700	195	2,000
3 miles west of Montezuma Creek, P.O. secs. 2 and 3, T. 41 S., R. 23 E.	700	195	8,000
4 miles west of Montezuma Creek, P.O. secs. 33 and 34, T. 40 S., R. 23 E.	300	180	6,000

Colorado River Storage Project

Of the numerous dam and reservoir sites in the deep canyons of the Colorado River and its principal tributaries, four have been developed as units of the Colorado River Storage Project. These are Glen Canyon on the Colorado River, Navajo on the San Juan River, Curecanti on the Gunnison River (two of three dams currently constructed), and Flaming Gorge on the Green River. A number of other sites could be developed as additional units of the project in order to provide additional river control, power generation, sediment retention, recreation, fish and wildlife propagation, and other benefits. Several of these sites are on the Colorado and San Juan Rivers in the San Juan study area.

Colorado River

Construction of the Glen Canyon Dam and the resulting inundation of the Dark Canyon Dam site have removed from further consideration these two storage sites in the San Juan study area that were cited as development potentialities in the Colorado River Basin Report of 1946. The Moab and Dewey Dam sites on the section of the Colorado River above Moab, also described in the basin report, are still undeveloped. Recent investigations have added the New Dewey Dam site on this section of the river as a third potential that would avoid certain objections made to developments at the other two sites.

Moab Site

The Moab Dam site is located immediately upstream from Moab. A dam that would raise the river level 138 feet would create a 183,000-acre-foot capacity reservoir that would extend up the Colorado River 20 miles to the Dewey Dam site. The reservoir would encroach upon the Arches National Monument. A powerplant installed at the dam would have a capacity of 60,000 kilowatts.

Dewey Site

The Dewey Dam site is about 3 miles below the mouth of the Dolores River. A dam that would raise the river level 320 feet would form a reservoir of 8.2 million-acre-foot capacity. The reservoir, extending 55 miles up the Colorado River and 20 miles up the Dolores River, would have a surface area of 70,400 acres. The great amount of evaporation from a reservoir of this size is the basis for serious objections to project development. A powerplant at the dam would have a capacity of 140,000 kilowatts.

New Dewey Site

The New Dewey Dam site is located about 15 miles downstream from the Dewey site. The maximum reservoir development possible at this site would raise the water level about 285 feet to an elevation of 4,280 feet. At this level the reservoir would have a capacity of 3,250,000 acre-feet and a surface area of 30,300 acres. No appraisal has been made of the justification of a development at the New Dewey site as a unit of the Colorado River Storage Project. Interest in the site was created because the water area exposed to evaporation would be far less than at the Dewey site. The Arches National Monument since its enlargement in January 1969 extends to the Colorado River along the lower 2 or 3 miles of the New Dewey Reservoir site. This section of the reservoir would be confined by a steep escarpment along the river, however, so that it would encroach only narrowly into the edge of the monument.

San Juan River

The Great Bend Dam site on the San Juan River, once considered a development potential, will be inundated to a depth of about 200 feet when Lake Powell behind Glen Canyon Dam is completely filled. Consideration of a reservoir at the Goosenecks site has also been discontinued because of the scenic value of the site and its inclusion in the Goosenecks State Park. The Slick Horn and Bluff Dam sites on the San Juan River, mentioned in the Colorado River Basin Report of 1946, are discussed below. The Mexican Hat site, previously discussed in connection with the Mexican Hat Project, is an alternative to the Bluff site. Another alternative to the Bluff site is the Lime Ridge site, also discussed below.

Slick Horn Canyon Site

Named Slick Horn because of the seepage from oil sands that coat the water and canyon walls, this reservoir site is on the San Juan River 70 miles below Bluff, Utah, at river elevation 3,750 feet. Here a dam could be constructed to raise the water surface elevation about 200 feet and form a reservoir with 300,000 acre-feet of capacity. Plans made in 1946 included installation of a powerplant with 30,000 kilowatts of capacity. It may be found desirable to limit the height of the dam to avoid backing water into the Goosenecks State Park located approximately 15 miles upsteam. A successful project at this site would be dependent on construction of an upstream reservoir at the Mexican Hat or other site to retain the high sediment load carried by the San Juan River.

Bluff Site

In the canyon of the San Juan River 13 miles below Bluff, Utah, is the Bluff Dam site at river elevation of 4,135 feet. The 1946 plans were for a reservoir capacity of 3 million acre-feet that would require a dam

to raise the water surface about 340 feet. It was estimated at that time that a powerplant with an installed capacity of 52,000 kilowatts could generate 289 million kilowatt-hours of energy annually.

A Bluff Reservoir large enough for sediment control would inundate the town of Bluff and would evaporate excessive quantities of water from its large surface area. For these reasons the site is less favorable than the Mexican Hat site.

Lime Ridge Site

The Lime Ridge Dam site on the San Juan River is about 7 airline miles upstream from Mexican Hat, Utah, at a canyon section called the "Narrows." Preliminary studies of the site were made in 1965 by engineering consultants for the San Juan County Water Conservancy District. Plans developed at that time included a concrete arch dam 204 feet high and 470 feet long at the crest. The reservoir behind the dam would have 250,000 acre-feet of capacity and a water surface area of 6,900 acres. A 25,000-kilowatt-capacity power installation was planned. Part of the power generated would be used to pump water for irrigation of lands above the reservoir.

The limited capacity of a Lime Ridge Reservoir that would not encroach on the town of Bluff would result in a rather short reservoir life because of sediment deposition. In this respect the Mexican Hat Reservoir would be more desirable.

Green and Dolores Rivers

No favorable opportunities for hydroelectric power developments are known on the Green and Dolores Rivers in the San Juan study area. This reach of the Green River is entirely within the Canyonlands National Park. Present flows of the Dolores River will be so depleted by construction of the authorized San Miguel and Dolores Projects as to make unjustified any downstream power development.