UNITED STATES DEPARTMENT OF THE INTERIOR

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BUREAU OF RECLAMATION

MICHAEL W. STRAUS, Commissioner

E. O. LARSON, Regional Director

SOUTH SAN JUAN PROJECT

NEW MEXICO

STATUS REPORT

June 1952

Region 4

Salt Lake City, Utah

IN REPLY REFER TO:

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

Post Office Box 640
Durango, Colorado

June 11, 1952

To: Regional Director

From: Area Engineer, Durango, Colorado

Subject: Status Report on Investigations of Potential South San Juan Project, New Mexico, and Potential Upstream Hydropower in San Juan River Drainage

Submitted herewith is the subject report presenting information and findings of the preliminary investigations made to date. The report is intended to serve the Bureau of Reclamation as a guide in programming further work on project investigations and to aid New Mexico and Colorado State officials and other interests in appraising and selecting plans for development of the available San Juan River water resources.

As indicated by the estimated benefits and costs of the various project sizes and plans of development investigated, the South San Juan project, with the exception of Plan A, would be economically justified. Completion of a detailed project investigation thus would be warranted. The size and plan of development for this project, however, are yet to be selected by State and other interests as part of the broader problem of selecting projects for the utilization of San Juan River waters. Until such selections are made, detailed investigations of the South San Juan project cannot be intelligently programmed. Reasonably firm selections at an early date are therefore desirable.

The cursory study made to evaluate the potential hydroelectric power in the San Juan River Basin, upstream from Navajo Reservoir site, indicates a cost of about 10 mills per kilowatt-hour for production of approximately 550,000,000 kilowatt-hours of firm salable energy measured at an assumed interconnecting point near Navajo Dam site on San Juan River. Cursory studies of alternative possibilities of producing equivalent power indicate a cost of about 8 mills per kilowatt-hour for fuel-electric generation and an average cost of about 5.5 mills per kilowatt-hour for hydroelectric generation by the potential Colorado River Storage project. Therefore, the development of firm energy at the upstream hydroelectric sites in the San Juan River Basin would not be justified in the near future. Possible modifications of the plans to produce peaking hydroelectric power at these sites as well as firm power have not been studied. Such studies could well be made in the future in the event that no transmountain diversions were made by the potential San Juan-Chama project.

/s/ William F. Crabtree

UNITED STATES
DEPARTMENT OF THE INTERIOR
Oscar L. Chapman, Secretary

BUREAU OF RECLAMATION
Michael W. Straus, Commissioner
E. O. Larson, Regional Director

S O U T H S A N J U A N P R O J E C T
NEW MEXICO

STATUS REPORT

Region 4

Salt Lake City, Utah

CONTENTS

CONTENTS

CONTENTS

MAPS AND DRAWINGS

S Y N O P S I S

Under the broad caption "South San Juan project", various possibilities have been investigated for diverting water of the San Juan River and its tributaries for the irrigation of some of the vast expanses of arable dry land located within the river basin and south of the river in northwestern New Mexico. The possibilities that appear most promising have been investigated in reconnaissance scope and are compared in this report. A comparison of the various alternatives for the South San Juan project is only one of the steps necessary in the formulation of a plan for the over-all development of the San Juan River. These alternatives must be weighed against the other potentialities for using the limited water supply, New Mexico's compact apportionment of Upper Colorado River Basin water, including possibilities for exporting part of the water southeastward to the Rio Grande Basin before a final choice of the basin plan can be made by the State and other interests concerned. This report, although treating primarily only one phase of the basin situation, provides data that will be useful in considering the broader problem.

In addition to data on the South San Juan project, the report presents in Chapter VIII the results of a cursory analysis of potential power developments on the San Juan River and its tributaries upstream from the most favorable storage site (Navajo) for the South San Juan project. The effect on these power potentialities of the various alternatives for irrigation development on the San Juan River likewise should be considered in formulating the basin plan.

Among the earliest plans for the South San Juan project was one (Plan A) that would divert water high on streams tributary to the San Juan River in Colorado and convey it southward 90 airline miles to lands in the southeastern part of the basin. Later, the Bureau of Indian Affairs investigated the Shiprock project that would store water lower down on the San Juan River at the Navajo Reservoir site and release it for use on Indian lands south of Shiprock, N. Mex. Investigations were then made of possibilities for joint use of the Shiprock project storage and diversion facilities, with enlargement as necessary, to irrigate lands east of the Shiprock project area. These possibilities also have been explored as a part of the South San Juan project investigations.

The scale of development of the Shiprock project, yet to be finally determined, will affect the plan and economy of the South San Juan project. In this reconnaissance analysis three different Shiprock project acreages were assumed at 100,000 acres, 113,900 acres, and 121,700 acres. Upon each of these three bases the South San Juan project was projected for economic comparisons as an incremental addition at two different acreages. Each of these six projections was studied under alternatives of the pumps for the South San Juan project being powered by electric motor or by direct-connected hydraulic turbines, making a total of 12 alternatives in

all. Separate analyses of the South San Juan project to irrigate areas of 20,450 acres and 67,700 acres were made to determine the relative economy of the project through a wide range in scale of development. Because of water supply limitations, the large acreage for the South San Juan project was reduced to 57,000 when the project was analyzed with the 121,700-acre Shiprock project as a base. The six plans involving a direct-connected hydraulic-turbine pumping unit are identified as D-1 to D-6, and those that would provide pumping power by electric motors are identified as E-1 to E-6.

The 20,450-acre South San Juan projects would irrigate only lands outside of the Navajo Indian Reservation, whereas one-third or more of the lands served by the larger South San Juan projects would be within the reservation.

Investigation of Plan D-2 was commenced in 1949 and has been done in greater detail than the investigation of other plans more recently undertaken. Plan D-2 provides for the irrigation of 67,700 acres in the South San Juan project as an incremental addition to a 113,900-acre Shiprock project. The other plans for building on the Shiprock project base have been evaluated in this report to some extent by projections from data assembled in the Plan D-2 study. The more extensive treatment given Plan D-2 in the report does not mean an endorsement of that plan over the other alternatives. The various alternative plans of development are described briefly in Chapter I. More detailed data assembled in the investigation, particularly of Plan D-2, are presented in Chapters II to VII, inclusive.

Comparative physical and economic data for each plan of development for the South San Juan project are presented in Table I following this discussion. No distinction was made in the economic analysis between Indian and non-Indian-owned lands, the same productive and repayment ability being assumed for both. In appraising all D and E plans, it was assumed that the Shiprock project would be economically justified if constructed independently. Costs and benefits attributable to D and E plans therefore were taken as the additional costs and benefits of the combined projects over and above those of the Shiprock project alone.

In the analysis of the project, construction costs were estimated as of July 1951. Data on agricultural economics were based on the 1939-1944 price period and the results increased by 50 percent where appropriate to approximate the long-term price-projection level of 215 (1910-14=100), recently adopted by the Bureau of Reclamation. Operation, maintenance, and replacement costs, also originally estimated at 1939-1944 prices, were adjusted to represent 180 percent of 1940 costs in conformity with the Bureau's long-term price-projection level for such costs.

It was assumed in these studies that the South San Juan project will participate in the benefits and revenues of the Colorado River Storage

project in accordance with the plan described in the Bureau of Reclamation report of December 1950, entitled Colorado River Storage Project and Participating Projects. Thus in the benefit-cost analysis the South San Juan project was assigned an annual cost of $2.35 an acre-foot of stream depletion as its pro rata share of the cost of river regulation provided by the storage project. It was also assumed that the South San Juan project would receive repayment assistance from power revenues of the Colorado River Storage project through the Upper Colorado River Account. Such assistance for the Shiprock project is recommended in the 1950 report, and it is assumed that such assistance will also be recommended for the South San Juan project when its eligibility to participate has been determined.

Plan A is shown by the table to have the highest annual equivalent cost per acre and the lowest benefit per acre of any of the alternatives. The estimates indicate that its benefit-cost ratio would only be about 0.6 to 1. Moreover, it would make less attractive the power potentialities outlined in Chapter VIII. Further consideration of Plan A is concluded to be unjustified.

If one of the acreages mentioned for the Shiprock project were selected, the 12 alternative D and E plans as presented would at once be reduced to four. The four would consist of a large plan (67,700 or 57,000 acres) and a small plan (20,450 acres), each with alternatives of hydraulic-turbine- and electric-motor-driven pumps.

Regardless of the Shiprock project acreage selected, some generalities stand out in comparing the South San Juan project alternatives. Each D plan (hydraulic turbine) has a higher construction cost but a lower operation and maintenance cost than its E-plan (electric motor) counterpart. The E-plan operation and maintenance costs are so high, largely because of electric energy costs, that they exceed the payment ability of the water users.

Under the D plans the water users would be able to fully pay the operation and maintenance costs and a small amount on construction. Because of their higher construction costs, however, the D plans have substantially lower benefit-cost ratios than the corresponding E plans, the ratios varying from 1.16 to 1.29 for the D plans while the ratios for the E plans range from 1.73 to 2.02.

A true cost comparison of the D and E plans may be made by converting all costs to average annual equivalents per acre as is done in Column 18 of Table I. This shows that the various D plans would be 35 to 70 percent more costly per acre than their counterpart E plans. Because the E plans would not be able to pay their operation, maintenance, and replacement costs and also something on construction, however, they would not meet one criterion for participating projects recommended in the Bureau's

report on the Colorado River Storage project and participating projects. The D plans, notwithstanding their greater over-all cost, would not be excluded by this criterion.

Interesting economic comparisons between the large projects and the small projects are noted in Table I. With hydraulic pumping (D plans), the large projects have slightly lower over-all costs per acre and consequently higher benefit-cost ratios than small projects. The large projects, with about triple the irrigated acreage, have substantially higher net benefits (benefits in excess of costs). With electric pumping (E plans), the large projects have slightly higher over-all costs per acre and lower benefit-cost ratios, but far higher net benefits than the small projects.

The comparisons in Table I are based on amortizing construction costs over a 100-year period at 2.5-percent interest. If a shorter period or a higher interest rate were assumed, the comparisons would be even more favorable to the E plans. The analyses indicate that the South San Juan project would be economically justifiable and that the relative justifiability would be substantially the same for any size of development ranging from about 20,000 acres up to the limits of the available water supply.

If the South San Juan project were limited to the irrigation of lands outside the Navajo Indian Reservation that can be served by gravity flow from the Shiprock project canal, it would serve only about 2,270 acres. The added cost of constructing the Shiprock project facilities large enough to irrigate these lands probably would not exceed $750 an acre, and the added annual operation and maintenance cost is estimated at about $1.25 an acre. Both of these costs are materially less than corresponding costs for any of the larger plans that would require pumping.

The Hammond project that would divert the natural flow of the San Juan River to irrigate 3,670 acres of land on the south side of the river near Bloomfield, N. Mex., has been recommended for authorization as a participating project with the Colorado River Storage project. As an alternative, the Hammond project lands also might be served by an enlargement of the Shiprock project canal. The desirability of this alternative has not been investigated but should receive attention in future studies.

Authorization to construct a dam and power plant on the San Juan River at the Navajo site as a unit of the Colorado River Storage project was recommended in the December 1950 report previously mentioned. The unit was intended for power production and to assure deliveries of Colorado River water at Lee Ferry as required by the Colorado River Compact. The report mentioned possible need of the storage site for irrigation of lands in the San Juan Basin and cited a provision in the Upper Colorado River Basin Compact of 1946 providing that if such need

develops, use of the site for irrigation would have preference over use for river regulation for compact purposes, or power production.

The Shiprock and South San Juan project studies have been made on the assumption that these projects would have exclusive use of the site. The required reservoir capacities have been estimated variously from 437,000 acre-feet to 546,000 acre-feet for the Shiprock project alone and from 524,300 acre-feet to 1,954,000 acre-feet for the combined Shiprock and South San Juan projects. A capacity of 1,200,000 acre-feet was planned for the Navajo Reservoir as a unit of the Colorado River Storage project. Possibilities for joint use of the site to accomplish so far as possible the purposes of all three of the projects as well as for any replacement storage needs of the potential upstream San Juan-Chama transmountain diversion project should be investigated in future studies.

Potential hydropower development at Navajo Dam, or at the drop from the combined highline canal to the Shiprock Gravity Canal, with water releases for project needs have not been appraised under the several project plans. In either case, however, the electric-energy production would be governed by the amounts and seasonal distribution of diversions for project needs and would have no material effect on the relative economic justifiability of the South San Juan project.

It is not within the purview of this report to segregate one or more plans for the South San Juan project as being most worthy of further investigation. Prerequisite to such a selection are decisions on the broader questions mentioned in the first paragraph of this discussion.

Table I
SOUTH SAN JUAN PROJECT--ALTERNATIVE PLANS
SUMMARY OF PHYSICAL PLANS, COSTS, BENEFITS, AND REPAYMENT

Project plan	Irrigated area South San Juan project (acres) Total	Indian reservation lands	Non-reservation lands	Type of pumping energy	Annual electric pumping energy (Kw.-hr.)	Navajo Reservoir capacity (ac.ft.) For Shiprock project alone	Additional for South San Juan	Total for both projects	Canal capacity (c.f.s.) For Shiprock project alone	Additional for South San Juan	Total for both projects	Estimated project costs 1/ Construction cost (July 1951 prices) Total	Per acre	Annual operation, 2/ maintenance, and replacement costs (180% of 1940 prices) Total	Per acre	Average annual 3/ equivalent cost (amortization in 100 years at 2-1/2%) Total	Per acre	Average annual equivalent benefit Total	Per acre	Net annual equivalent benefits 4/	Ratio of benefits to unity costs	Average annual payment capacity per acre	Probable payment on construction costs Annual payment Amount per acre	Payment in 40 yrs. Total for project	Total amount	Percent of cost
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
"A"	70,000	34,290	35,710	None	0							$161,528,000	$2,308	$ 316,000	$ 4.51	$5,171,000	$74	$3,150,000	$45	-$2,021,000	0.61	$4.30	-$.21			0
100,000-acre Shiprock project																										
D-1	67,700	28,800	38,900	Hydraulic turbine	0	437,000	1,480,000	1,917,000	1,215	1,415	2,630	137,828,000	2,036	242,000	3.57	4,545,000	67	5,754,000	85	1,209,000	1.27	5.74	2.17	$147,000	$5,880,000	4
E-1	67,700	29,170	38,530	Electric motor	172,120,000	437,000	527,000	964,000	1,215	1,415	2,630	63,788,000	942	933,000	13.78	3,105,000	46	5,754,000	85	2,649,000	1.85	5.74	-8.04			0
D-4	20,450	0	20,450	Hydraulic turbine	0	437,000	337,000	774,000	1,215	425	1,640	43,988,000	2,151	85,000	4.16	1,469,000	72	1,738,000	85	269,000	1.18	5.74	1.58	32,000	1,280,000	3
E-4	20,450	0	20,450	Electric motor	53,224,000	437,000	87,000	524,000	1,215	425	1,640	16,058,000	785	277,000	13.54	840,000	41	1,738,000	85	898,000	2.07	5.74	-7.80			0
113,900-acre Shiprock project																										
D-2	67,700	28,800	38,900	Hydraulic turbine	0	499,000	1,455,000	1,954,000	1,535	1,415	2,950	136,013,000	2,009	252,000	3.72	4,498,000	66	5,754,000	85	1,256,000	1.28	5.74	2.02	137,000	5,480,000	4
E-2	67,700	29,170	38,530	Electric motor	172,120,000	499,000	750,000	1,249,000	1,535	1,415	2,950	70,977,000	1,048	936,000	13.82	3,316,000	49	5,754,000	85	2,438,000	1.73	5.74	-8.08			0
D-5	20,450	0	20,450	Hydraulic turbine	0	499,000	267,000	766,000	1,535	425	1,960	43,618,000	2,133	87,000	4.25	1,450,000	71	1,738,000	85	288,000	1.20	5.74	1.49	30,000	1,200,000	3
E-5	20,450	0	20,450	Electric motor	53,224,000	499,000	115,000	614,000	1,535	425	1,960	18,029,000	882	279,000	13.64	901,000	44	1,738,000	85	837,000	1.93	5.74	-7.90			0
121,700-acre Shiprock project																										
D-3	57,000	19,150	37,850	Hydraulic turbine	0	546,000	1,126,000	1,672,000	1,715	1,185	2,900	116,921,000	2,051	195,000	3.42	3,838,000	67	4,845,000	85	1,007,000	1.26	5.74	2.32	132,000	5,280,000	4
E-3	57,000	19,520	37,480	Electric motor	137,751,000	546,000	659,000	1,205,000	1,715	1,185	2,900	62,225,000	1,092	764,000	13.40	2,840,000	50	4,845,000	85	2,005,000	1.71	5.74	-7.66			0
D-6	20,450	0	20,450	Hydraulic turbine	0	546,000	276,000	822,000	1,715	425	2,140	42,012,000	2,054	84,000	4.11	1,401,000	68	1,738,000	85	337,000	1.24	5.74	1.58	32,000	1,280,000	3
E-6	20,450	0	20,450	Electric motor	53,224,000	546,000	138,000	684,000	1,715	425	2,140	18,416,000	900	282,000	13.79	913,000	45	1,738,000	85	825,000	1.90	5.74	-8.05			0

1/ Additional cost of joint project over cost of Shiprock project.
2/ Includes cost of pumping power for E- plans at 3 mills per kilowatt-hour.
3/ Includes $2.35 per acre-foot of stream depletion as credit to Colorado River Storage project for river regulation, interest on expenditures during construction, and allowance for salvage value at end of 100 years (see Chapter VII for method of estimating).
4/ Column 19 less column 17.

CHAPTER I

PLANS OF DEVELOPMENT

Thirteen plans of development for the South San Juan project are described in this chapter. Plan A is entirely distinct since it would divert and use water in a different part of the San Juan River Basin than the other plans. Plans D-1 to D-6, inclusive, for hydraulic-powered pumping and Plans E-1 to E-6, inclusive, for electric-powered pumping are closely related. Each would share in the use of the storage and diversion facilities planned by the Bureau of Indian Affairs for its Shiprock project.

Under the electric pumping plan, water for the South San Juan project lands would be conveyed from Navajo Reservoir through an enlarged Shiprock project gravity canal to the pump location. Under the direct-connected hydraulic-turbine pumping plan, water would be diverted for the South San Juan and Shiprock projects from the Navajo Reservoir through a highline canal to a point about 28 miles below Navajo Dam. Here water for the Shiprock project would be dropped to the Shiprock main gravity canal through the pumping plant and thus used for lifting water to the South San Juan project lands. The elevation of the highline canal diverting from Navajo Reservoir was adjusted in such a manner that the water for the Shiprock project, when dropped to the Shiprock project gravity canal, would provide sufficient energy to operate the turbines for lifting the water to the required elevation for the South San Juan project lands.

The water supply available for the Shiprock and South San Juan projects was assumed to be that remaining in the San Juan River after allowances were made for existing development, potential within-basin projects, and the potential Weminuche Pass diversions to San Luis Valley as more fully discussed in Chapter III. Since the analyses were made for comparative purposes, no allowance was made for the potential San Juan-Chama transmountain diversion to the Rio Grande Basin.

Plan A

Plan A was one of the first plans studied in the reconnaissance investigation of the South San Juan project. Its general layout is shown on Drawing No. 524-406-95 on the following page.

The plan involves the construction of five storage reservoirs and a long canal system. The canal system would intercept the headwaters of San Juan River and its tributaries at several points in Colorado above elevation 7,500 feet and by gravity flow would convey the water

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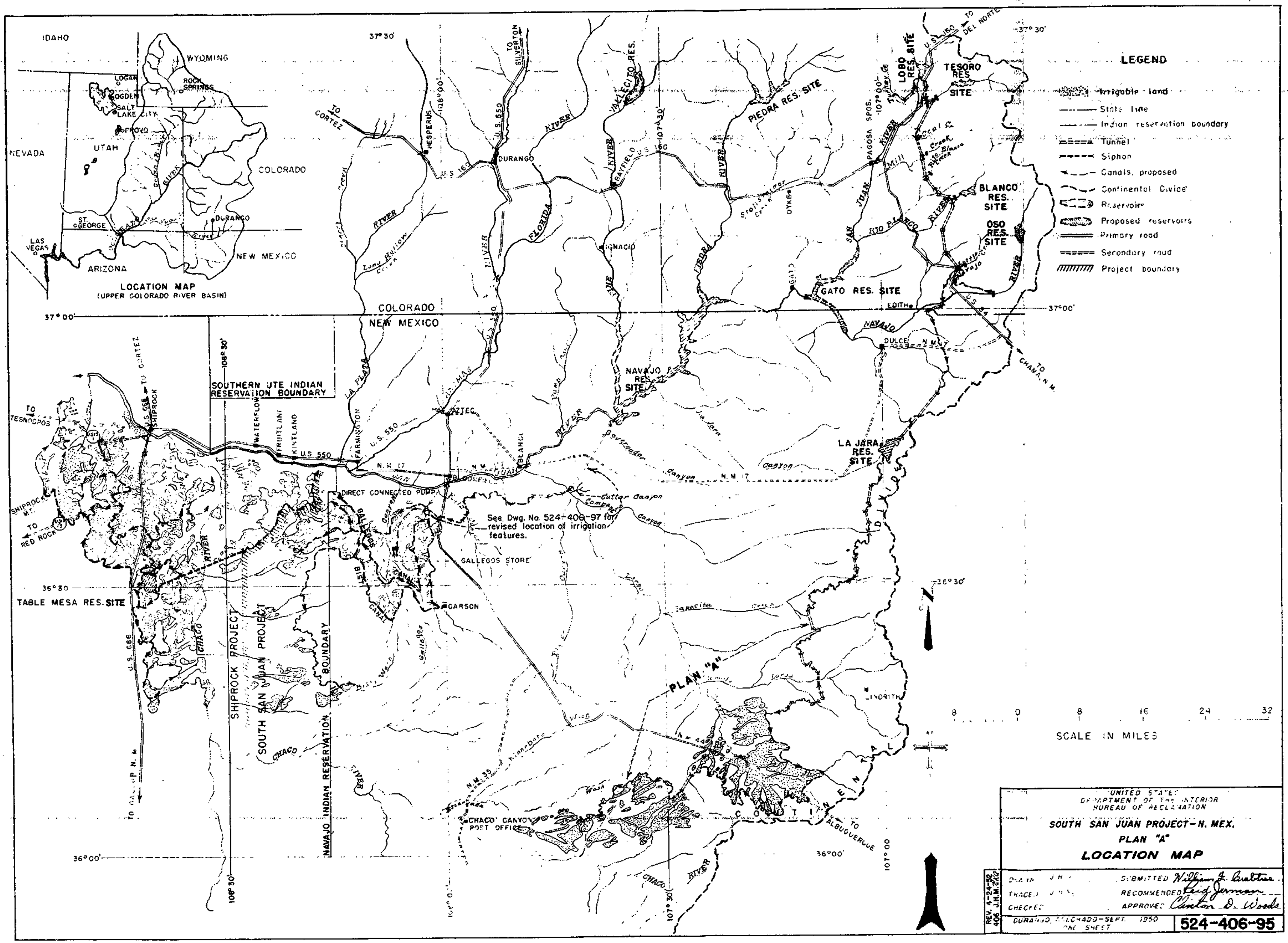
LEGEND
Irrigable land
State line
Indian reservation boundary
Tunnel
Siphon
Canals, proposed
Continental Divide
Reservoir
Proposed reservoirs
Primary road
Secondary road
Project boundary
LOCATION MAP
(UPPER COLORADO RIVER BASIN)
IDAHO
WYOMING
NEVADA
UTAH
COLORADO
ARIZONA
NEW MEXICO
COLORADO
NEW MEXICO
SOUTHERN UTE INDIAN RESERVATION BOUNDARY
SHIPROCK PROJECT
SOUTH SAN JUAN PROJECT
NAVAJO INDIAN RESERVATION BOUNDARY
TABLE MESA RES. SITE
PIEDRA RES. SITE
LOBO RES. SITE
TESORO RES. SITE
BLANCO RES. SITE
OSO RES. SITE
GATO RES. SITE
NAVAJO RES. SITE
LA JARA RES. SITE
VALLECITO RES.
DURANGO
FARMINGTON
AZTEC
BLOOMFIELD
GALLEGOS STORE
CARSON
CHACO CANYON POST OFFICE
DIRECT CONNECTED PUMPS
See Dwg. No. 524-406-97 for revised location of irrigation features.
PLAN "A"
SCALE IN MILES
8 0 8 16 24 32
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
SOUTH SAN JUAN PROJECT—N. MEX.
PLAN "A"
LOCATION MAP
SUBMITTED
RECOMMENDED
APPROVED
DURANGO, COLORADO—SEPT. 1950
524-406-95

90 airline miles south for irrigation of lands in New Mexico. Four of the reservoirs would be located on streams above the intercepting canal, and the fifth would be at an offstream site about midway along the canal to reregulate the diverted flows for meeting seasonal irrigation needs. The main canal would consist of a series of open earth canals, bench flumes, tunnels, and siphons. The conveyance system, including reservoir feeder canals, main canal, and main laterals, would have a total length of about 265 miles. The reservoirs and canal collection systems north of the Colorado-New Mexico State line would be practically the same as in the San Juan-Chama project plan for transmountain diversion of water to the Rio Grande Basin.

Water supply and operation studies, with allowances made for the potential downstream within-basin developments including a Shiprock project of 113,900 acres, indicate that an adequate supply could be developed for irrigation of approximately 70,000 acres of new land under this plan. Of this acreage, nearly half would be within the boundary of the Jicarilla Indian Reservation.

The features included in Plan A, their capacities, and estimated costs are tabulated on pages 4 and 5. The project construction cost is estimated at $161,528,000 or $2,308 an acre, and annual operation, maintenance, and replacements costs are estimated to total $316,000 or $4.51 an acre. The average annual equivalent cost per acre is estimated as shown below.

	Total cost	Average annual equivalent cost
Construction cost	$161,528,000	
Interest during construction	10,096,000	
Total construction and interest cost	$171,624,000	
Less present worth of salvage value at end of 100 years	-4,843,000	
Net present worth of project investment	$166,781,000	
Amortization of net present worth of project investment over 100 years at 2½ percent		$4,555,000
Operation, maintenance, and replacements		316,000
Assigned costs of Colorado River Storage project		300,000
Total average annual equivalent cost for project		$5,171,000
Total average annual equivalent cost per acre		$74

Table II

SOUTH SAN JUAN PROJECT--ALTERNATIVE PLAN A

SUMMARY OF COST ESTIMATES--FEEDER AND MAIN CANALS AND LATERALS

Main canals	Capacity (c.f.s.)	Length (miles)	July 1951 construction costs[1]	O&M and replacement costs[2]
Turkey Creek to West Fork	250	5.32	$2,104,000	$2,020
West Fork to East Fork	400	3.96	995,000	2,300
East Fork to Rio Blanco	800	14.68	22,548,000	9,260
Rio Blanco to Navajo River	900	9.49	15,062,000	6,230
Navajo River to Continental Divide	1,000	23.41	10,554,000	24,090
Continental Divide to LaJara Reservoir	1,000	7.45	17,093,000	5,170
LaJara Outlet Canal	1,200 - 1,300	85.50	38,465,000	100,710
Distribution Canal	1,000 - 250	105.45	8,593,000	82,900
Subtotal		255.26	$115,414,000	$232,680
Feeder canals				
East Fork	300	0.54	506,000	$200
Coal Creek	40	0.04	11,000	10
Mill Creek	40	0.06	4,000	10
Rito Blanco	60	0.95	36,000	160
Rio Blanco	150	0.42	274,000	110
Navajo--Little Navajo	100 - 300	7.95	411,000	2,900
Subtotal		9.96	$1,242,000	$3,390
Laterals (70,000 acres)			$3,723,000	$41,270
Total			$120,379,000	$277,340

1/ Includes contingencies, engineering and overhead.
2/ Based on 180 percent of 1940 costs.

Table III

SOUTH SAN JUAN PROJECT--ALTERNATIVE PLAN A
SUMMARY OF COST ESTIMATES--STORAGE AND DIVERSION DAMS

Storage dams and reservoirs	Maximum water surface area (acres)	Dam height (feet)	Total capacity (acre-feet)	July 1951 construction cost 1/	Operation and maintenance cost 2/	Replacement cost 2/
Lobo	1,200	180	90,000	$6,458,000	$4,260	$2,210
Tesoro	750	193	60,000	5,292,000	3,450	1,820
Blanco	1,200	165	60,000	6,594,000	3,450	2,260
Oso	1,075	120	50,000	3,633,000	3,140	1,240
LaJara	2,290	208	167,000	18,793,000	5,860	6,450
Subtotal	6,515		427,000	$40,770,000	$20,160	$13,980
Diversion dams						
Turkey Creek				$40,000	$480	$20
East Fork				40,000	480	20
Coal Creek				19,000	230	10
Mill Creek				24,000	280	10
Rito Blanco				40,000	480	20
Rio Blanco				122,000	1,470	40
Navajo				54,000	640	10
Little Navajo				40,000	480	10
Subtotal				$379,000	$4,540	$140
Total				$41,149,000	$24,700	$14,120
Total (Table II / Table III)				$161,528,000	$302,040	$14,120

1/ Includes contingencies, engineering, and overhead.
2/ Based on 180 percent of 1940 costs.

The project lands under this plan would lie at an average elevation of 6,700 feet. In view of the climatic conditions and the type of farming and crop yields that could be expected in the area, the total average annual equivalent irrigation benefits would probably not exceed $45 an acre. A comparison of this benefit with the cost gives a benefit-cost ratio of about .6 to 1 for Plan A. Because of this unfavorable benefit-cost ratio, detailed investigations of the plan are not justified.

Shiprock Project as a Base for D- and E-Series Plans

The D- and E-series plans are considered as potentialities for the South San Juan project, but physically and economically they should be viewed as extensions of the potential Shiprock project. Each of the alternative plans would share in the use of the storage and diversion facilities of the Shiprock project, and each would irrigate lands east of or higher than lands planned to be irrigated by the Shiprock project. For an understanding of the D- and E-series plans, therefore, some knowledge of the Shiprock project plan is necessary.

River regulation for the Shiprock project would be provided by the Navajo Reservoir on the San Juan River. The reservoir would be formed by a dam at the Navajo site about 19.5 river miles upstream from Blanco, N. Mex., and 3¼ miles east of Farmington, N. Mex. The dam would be about 3.5 miles downstream from the confluence of the Pine and San Juan Rivers. The acreage of the potential Shiprock project has not been finally determined but it has been studied in sizes of 100,000, 113,900, and 121,700 acres. The plans for each of these three different sizes of Shiprock project have been used as bases in the comparative analyses of the various plans for the South San Juan project as presented in this report.

Navajo Dam and Reservoir data for the Shiprock project alone are summarized in the following table.

Table IV
SHIPROCK PROJECT
NAVAJO DAM AND RESERVOIR DATA

Shiprock project acreage	Reservoir capacity--(Acre-feet)				Reservoir water surface elevation	
	Active storage	Dead storage	Silt storage above dead storage	Total storage	Normal	Dead
100,000	214,000	15,000	208,000	437,000	5,957	5,783
113,900	280,000	10,000	209,000	499,000	5,968	5,775
121,700	322,000	14,000	210,000	546,000	5,976	5,782

A main canal for each of the three sizes of project, consisting of a series of tunnels, siphons, and open-earth and concrete-lined canals, would head at the reservoir and extend west along the south side of the river to project lands located in the Navajo Indian Reservation. Pertinent data pertaining to the main canal are summarized in the following table.

Table V
SHIPROCK PROJECT
MAIN CANAL DATA

Shiprock project acreage	Diversion capacity (c.f.s.)	Earth unlined and clay-lined canals (miles)	Concrete-lined canal (miles)	Tunnel (miles)	Siphon (miles)	Total length (miles)
100,000	1,215	48.77	15.62	14.17	14.76	93.32
113,900	1,535	48.99	15.64	13.98	14.76	93.37
121,700	1,715	48.90	15.76	14.50	14.71	93.87

The general location of the potential Shiprock project and of possible extensions of it to include the 67,700-acre or 57,000-acre South San Juan project under plans D-1, D-2, D-3, E-1, E-2, and E-3 are shown on Drawing No. 524-406-97 on page 11. Extensions for a 20,450-acre South San Juan project under plans D-4, D-5, D-6, E-4, E-5, and E-6 are shown on Drawing No. 524-406-98 on page 15.

Plan D-1

Under plan D-1, 67,700 acres of land would be irrigated in the South San Juan project area, including 28,800 acres in the Navajo Indian Reservation but outside the Shiprock project area. The Navajo Reservoir, in order to serve both projects, would be constructed to a capacity of 1,917,000 acre-feet including an active capacity of 740,000 acre-feet. The joint Main Gravity Canal from Navajo Dam to a hydraulic-turbine-driven pumping plant would be constructed approximately 268 feet higher than the canal planned for the 100,000-acre Shiprock project alone and would have a capacity of 2,630 second-feet and a length of 28 miles. This section of the canal would serve by gravity 1,760 acres of South San Juan project lands on Pauline Mesa but it would not be practicable to release water down the steep incline to the scattered tracts of land shown on the map near the mouth of Largo and Munoz Canyons. The water remaining for both projects at the end of the joint Main Gravity Canal on the east side of Kutz Canyon would drop 243 feet through a penstock to hydraulic-turbine-driven pumps. At the pumps the water would separate into three flows. That for the Shiprock project would provide pumping power and then continue by gravity flow in the Shiprock project canal, and that for the South San Juan project would be pumped through

two pipes to the main distribution canals. In one pipe with a capacity of 597 second-feet, water would be raised 286 feet above the pumps to the Gallegos Canal from which 29,370 acres would be irrigated. In the other pipe with a capacity of 744 second-feet, water would be raised 407 feet above the pumps to the Bisti Canal from which the remaining 36,570 acres of project land would be irrigated.

A lateral system to distribute water to all project lands would be required. Only about 1,000 acres are expected to require drainage by artificial means.

Plan D-2

The same South San Juan project area would be served under Plan D-2 as under Plan D-1. The Navajo Reservoir would be constructed to a capacity of 1,954,000 acre-feet, including an active capacity of 1,025,000 acre-feet. The joint Main Gravity Canal would be constructed approximately 245 feet higher than the canal planned for the 113,900-acre Shiprock project alone and would have a capacity of 2,950 second-feet and a length of 26 miles. Water for both projects at the end of the joint canal would drop 225 feet through a penstock to hydraulic-turbine-driven pumps. From the pumps, water would separate in the same manner as in Plan D-1 with the same capacity in each line. The water pumped to the Gallegos Canal would be raised 292 feet and to the Bisti Canal 413 feet.

The same lateral system and drainage system would be required as in Plan D-1.

Plan D-3

Under Plan D-3, 57,000 acres of land would be irrigated in the South San Juan project area, including 19,150 acres in the Navajo Indian Reservation but outside the Shiprock project area. The same lands would be irrigated as in Plan D-1 except that the Bisti Canal would not be extended to 10,700 acres in the southern part of the area. The Navajo Reservoir would be constructed to a capacity of 1,672,000 acre-feet, including an active capacity of 980,000 acre-feet. The joint Main Gravity Canal from Navajo Dam to the hydraulic-turbine-driven pumping plant would be constructed approximately 207 feet higher than the canal planned for the 121,700-acre Shiprock project alone and would have a capacity of 2,900 second-feet and a length of 26 miles. This section of the canal would serve by gravity the same 1,760 acres of South San Juan project lands on Pauline Mesa as would be served by Plans D-1 and D-2. The remaining water for both projects would drop 190 feet through a penstock to hydraulic-turbine-driven pumps. In one discharge line with a capacity of 597 second-feet, water would be raised

285 feet above the pumps to the Gallegos Canal, from which 29,370 acres would be irrigated. In the other pipe, with a capacity of 526 second-feet, water would be raised 406 feet above the pumps to the Bisti Canal from which the remaining 25,870 acres of project land would be irrigated.

A lateral system to distribute water to all project lands would be required. The same acreage as in Plan D-1 is expected to require drainage by artificial means.

Plan E-1

Plan E-1 would irrigate substantially the same 67,700 acres as would be served by Plan D-1. The principal difference in the two plans is in the means of conveyance of water from the Navajo Reservoir to the land. Under Plan E-1 the Shiprock Main Canal planned for the 100,000-acre Shiprock project alone would be enlarged to a capacity of 2,630 second-feet to convey South San Juan water from Navajo Dam to a pumping plant, a distance of 38 miles. Approximately 2,270 acres below the main canal near the mouth of Largo and Munoz Canyons, on Pauline Mesa, and in the Gallegos Basin would be irrigated by gravity flow and the remaining 65,430 acres would be served with water pumped from the main canal by electric-motor-driven pumps. Pauline Mesa lands shown on the map as being above the Shiprock Main Canal would not be irrigated.

The first pumping plant would be located at the entrance to Kutz tunnel (under New Mexico Highway No. 44). It would lift 1,329 second-feet of water 295 feet to the Gallegos Canal at an elevation of 6,000 feet. The 579 second-feet of the water delivered to this canal would be used to irrigate 28,490 acres. The remaining 750 second-feet of water would flow in the canal 20 miles to a second pumping plant where it would be lifted 135 feet to the Bisti Canal that would extend in two directions from the pump and would serve 36,940 acres of project land.

With the Shiprock Main Canal diverting from the Navajo Reservoir 268 feet lower than the Main Gravity Canal in Plan D-1, less dead storage capacity in the reservoir would be required. Under Plan E-1 a total Navajo Reservoir capacity of 964,000 acre-feet would be required for flow regulation and sediment deposition. An active capacity of 740,000 acre-feet and a 212,000 acre-foot reservation for sediment storage would be above the reservoir outlet at elevation 5,779 and 12,000 acre-feet of capacity would be below the outlet. A period of 100 years would elapse before sediment would begin to encroach on the portion of the active capacity required for irrigation storage.

A lateral and drainage system as described in Plan D-1 would be required to serve the project lands.

Plan E-2

The same South San Juan project area would be served under this plan as in Plan E-1. The Shiprock Main Canal planned for the 113,900-acre Shiprock project alone would be enlarged to a capacity of 2,950 second-feet to convey water for both projects as in Plant E-1. The first electric-motor-driven pump would lift 1,329 second-feet of water 299 feet to the Gallegos Canal, and part of the water would be used to irrigate 28,490 acres under that canal. The second pumping plant would lift 750 second-feet of water for the remaining 36,940 acres the same 135 feet as in Plan E-1 to the Bisti Canal.

With the joint Shiprock Main Canal diverting from the Navajo Reservoir 245 feet lower than the canal in Plan D-2, less dead storage capacity in the reservoir would be required. A total reservoir capacity of 1,249,000 acre-feet would be required, of which 1,025,000 acre-feet would be active capacity, 11,000 acre-feet would be dead storage, and 213,000 acre-feet would meet silt storage requirements for 100 years.

The same lateral and drainage system would be required as in Plan D-1.

Plan E-3

Under this plan 57,000 acres of land would be irrigated in the South San Juan project area, including 19,520 acres in the Navajo Indian Reservation but outside the Shiprock project area. The same lands would be irrigated as in Plans E-1 and E-2 except that the Bisti Canal would not be extended to 10,700 acres in the southern part of the area near Bisti Wash. The Shiprock Main Canal planned for the 121,700-acre Shiprock project alone would be enlarged to a capacity of 2,900 second-feet to convey water for both projects as in Plans E-1 and E-2. The pumps would be driven by electric motors. The first pump, located in the same place as in Plans E-1 and E-2, would lift all South San Juan project water at that point 296 feet to the Gallegos Canal which would head at an elevation of 6,000 feet and which would serve 28,490 acres. The second pump would lift the water not used under this canal a further distance of 135 feet to the Bisti Canal at an elevation of 6,136 feet to irrigate the remaining 26,240 acres of land.

With the joint Shiprock Main Canal diverting from the Navajo Reservoir 207 feet lower than the canal in Plan D-3, less dead storage capacity in the reservoir would be required. A total reservoir capacity of 1,205,000 acre-feet would be required, of which 980,000 acre-feet would be active capacity, 12,000 acre-feet would be dead storage, and 213,000 acre-feet would meet silt storage requirements for 100 years.

The same lateral and drainage system would be required as in Plan D-3.

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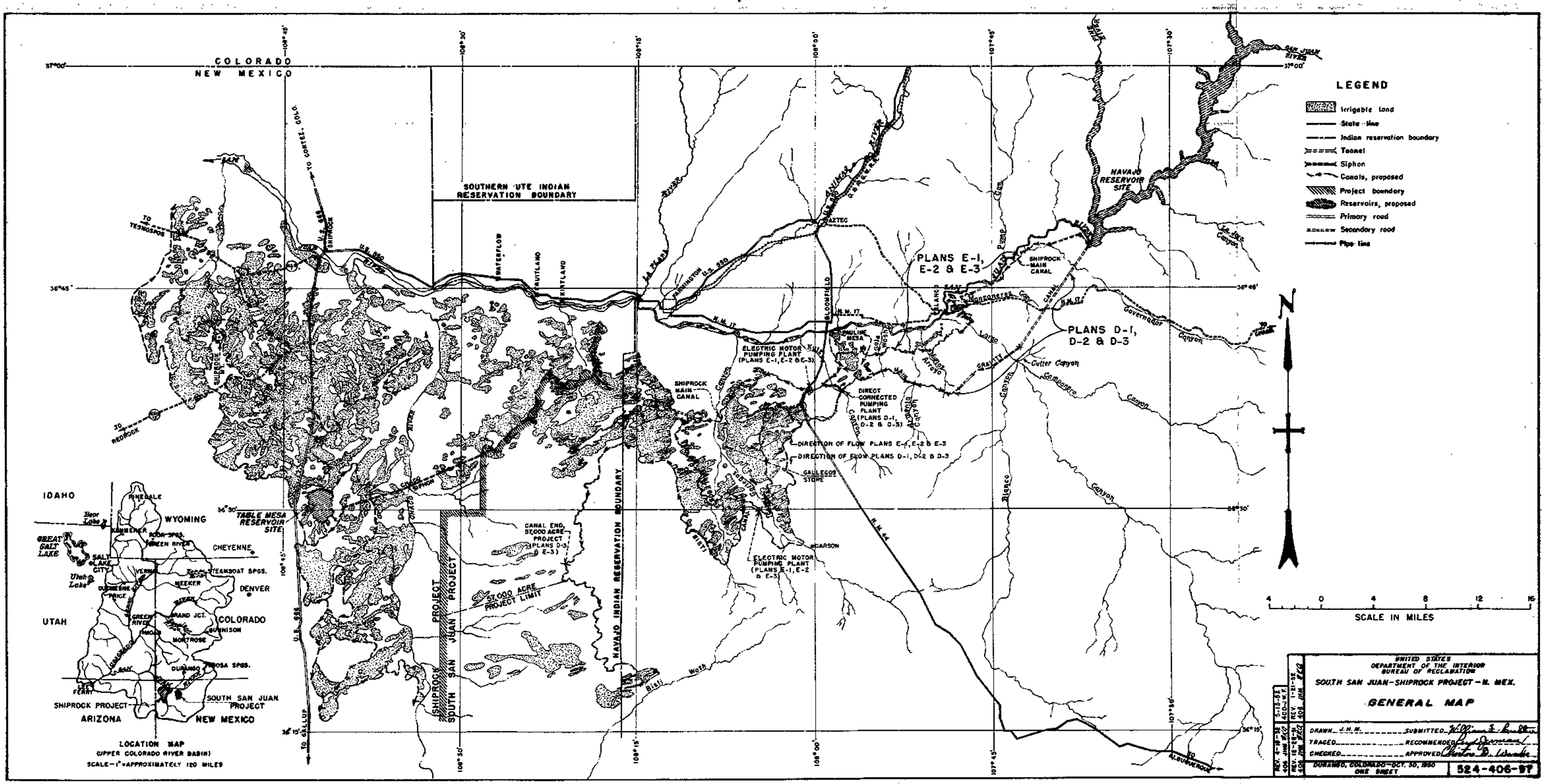
COLORADO
NEW MEXICO
SOUTHERN UTE INDIAN RESERVATION BOUNDARY
NAVAJO RESERVOIR SITE
PLANS E-1, E-2 & E-3
PLANS D-1, D-2 & D-3
SHIPROCK MAIN CANAL
ELECTRIC MOTOR PUMPING PLANT (PLANS E-1, E-2 & E-3)
DIRECT CONNECTED PUMPING PLANT (PLANS D-1, D-2 & D-3)
DIRECTION OF FLOW PLANS E-1, E-2 & E-3
DIRECTION OF FLOW PLANS D-1, D-2 & D-3
GALLEGOS STORE
CARSON
TABLE MESA RESERVOIR SITE
CANAL END, 57,000 ACRE PROJECT PLANS D-3 & E-3
57,000 ACRE PROJECT LIMIT
NAVAJO INDIAN RESERVATION BOUNDARY
SHIPROCK PROJECT
SOUTH SAN JUAN PROJECT
AZTEC
BLOOMFIELD
FARMINGTON
WATERFLOW
FRUITLAND
KIRTLAND
SHIPROCK
TO GALLUP
TO CORTEZ, COLO.
TO ALBUQUERQUE
Cutter Canyon
Bisti Wash
LEGEND
Irrigable land
State line
Indian reservation boundary
Tunnel
Siphon
Canals, proposed
Project boundary
Reservoirs, proposed
Primary road
Secondary road
Pipe line
SCALE IN MILES
IDAHO
WYOMING
UTAH
COLORADO
ARIZONA
NEW MEXICO
CHEYENNE
DENVER
SHIPROCK PROJECT
SOUTH SAN JUAN PROJECT
LOCATION MAP
(UPPER COLORADO RIVER BASIN)
SCALE-1"=APPROXIMATELY 120 MILES
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
SOUTH SAN JUAN-SHIPROCK PROJECT - N. MEX.
GENERAL MAP
DRAWN J.H.M.
TRACED
CHECKED
SUBMITTED
RECOMMENDED
APPROVED
DURANGO, COLORADO-OCT. 30, 1950
ONE SHEET
524-406-97

Plan D-4

This plan is for a small South San Juan project of 20,450 acres of nonreservation lands and provides for pumping by hydraulic-turbine prime movers. The 1,640 second-feet of water for the South San Juan project and the 100,000-acre Shiprock project would be conveyed 30 miles through a highline Main Gravity Canal from the Navajo Reservoir to a point 105 feet below the site of the drop described in Plan D-1. This section of the canal would serve 1,430 acres of South San Juan project lands on Pauline Mesa, but it would not serve the scattered tracts of land shown on the map as near the mouths of Largo and Munoz Canyons. The remaining water for both projects at the end of the joint Main Gravity Canal would drop 138 feet through a penstock to hydraulic-turbine-driven pumps. At the pumps the water would separate into two flows. That for the Shiprock project would provide pumping power and then continue by gravity flow in the Shiprock project canal, and that for the remaining South San Juan project lands would be pumped to the Carson Canal at an elevation of 6,104 feet. The water would be raised 375 feet above the pumps in an 8-foot-diameter pipe with a capacity of 387 second-feet to irrigate 19,020 acres.

Navajo Reservoir for this plan would have a total capacity of 774,000 acre-feet, of which 302,000 acre-feet would be active, 425,000 acre-feet would be dead storage, and 47,000 acre-feet would meet silt storage requirements. With these capacities, sedimentation estimates indicate a 100-year period of operation before silt deposition would begin to encroach on the active irrigation capacity.

A lateral system to distribute water to all project lands would be required. Only about 400 acres of the project lands are expected to require drainage by artificial means.

Plan D-5

The same South San Juan project area would be served under this plan as in Plan D-4. The Navajo Reservoir would be constructed to a capacity of 766,000 acre-feet, including an active capacity of 390,000 acre-feet. The joint Main Gravity Canal would be constructed 151 feet higher than the canal planned for the 113,900-acre Shiprock project alone and would have a capacity of 1,960 second-feet and a length of 30 miles. Water for both projects at the end of the joint canal would drop 119 feet through a penstock to hydraulic-turbine-driven pumps. From the pumps, water would separate in the same manner as in Plan D-4. The water would be raised 381 feet above the pumps to irrigate the same acreage with the same penstock size and capacity as in Plan D-4.

The same lateral and drainage system would be required as in Plan D-4.

Plan D-6

The same South San Juan project area would be served under this plan as in Plans D-4 and D-5. The Navajo Reservoir would be constructed to a capacity of 822,000 acre-feet including an active capacity of 460,000 acre-feet. The joint Main Gravity Canal would be constructed 140 feet higher than the canal planned for the 121,700-acre Shiprock project alone and would have a capacity of 2,140 second-feet and a length of 30 miles.

Water for both projects at the end of the joint Main Gravity Canal would drop 109 feet through a penstock to hydraulic-turbine-driven pumps. From the pumps, water would separate the same as in Plans D-4 and D-5. The water would be raised 374 feet above the pumps to irrigate the same acreage with the same penstock size and capacity as in Plans D-4 and D-5.

The same lateral and drainage system would be required as in Plan D-4.

Plan E-4

The same South San Juan project area would be served under this plan as in Plan D-4, except that lands on Pauline Mesa above the Shiprock Main Canal would not receive water but the scattered tracts near the mouths of Largo and Munoz Canyons would be irrigated. The principal difference in D-4 and E-4 plans is in the means of conveyance of water from Navajo Reservoir to the land. Under Plan E-4 the Shiprock Main Canal planned for the 100,000-acre Shiprock project alone would be enlarged to a capacity of 1,640 second-feet to convey water for both projects from Navajo Dam to a pumping plant, a distance of 38 miles. The same 2,270 acres irrigated by gravity as in Plan E-1 would be served with this plan. The 370 second-feet of water for the remaining 18,180 acres would be pumped 395 feet in a 7-foot-diameter pipe from a plant located at the entrance to Kutz tunnel (under New Mexico Highway No. 44) to the Carson Canal.

With the Shiprock Main Canal diverting from the Navajo Reservoir 175 feet lower than the Main Gravity Canal in Plan D-4, less storage capacity in the reservoir would be required. A total reservoir capacity of 524,000 acre-feet would be required, of which 302,000 acre-feet would be active capacity, 12,000 acre-feet would be dead storage, and 210,000 acre-feet would meet silt storage requirements above dead storage elevation for 100 years.

The same lateral and drainage system as described in Plan D-4 would be required to serve the project lands.

Plan E-5

The same South San Juan project area would be served under this plan as in Plan E-4. The Shiprock Main Canal planned for the 113,900-acre Shiprock project alone would be enlarged to a capacity of 1,960 second-feet to convey water for both projects as in Plan E-4. The 370 second-feet of water for the Carson Canal would be raised 397 feet in a 7-foot-diameter pipe by a pumping plant in the same location as in Plan E-4.

With the Shiprock Main Canal diverting from the Navajo Reservoir 151 feet lower than the canal in Plan D-5, less storage capacity in the reservoir would be required. A total reservoir capacity of 614,000 acre-feet would be required, of which 390,000 acre-feet would be active capacity, 13,000 acre-feet would be dead storage, and 211,000 acre-feet above dead storage elevation would meet silt storage requirements for 100 years.

The same lateral and drainage system would be required as in Plan D-4.

Plan E-6

The same South San Juan project area would be served under this plan as in Plans E-4 and E-5. The Shiprock Main Canal planned for the 121,700-acre Shiprock project alone would be enlarged to a capacity of 2,140 second-feet to convey water for both projects as in Plans E-4 and E-5. The 370 second-feet of water for the Carson Canal would be raised 396 feet in a 7-foot diameter pipe by a pumping plant in the same location as in Plans E-4 and E-5.

With the joint Shiprock Main Canal diverting from the Navajo Reservoir 140 feet lower than the canal in Plan D-6, less storage capacity in the reservoir would be required. A total reservoir capacity of 684,000 acre-feet would be required, of which 460,000 acre-feet would be active capacity, 13,000 acre-feet would be dead storage, and 211,000 acre-feet above dead storage elevation would meet silt storage requirements for 100 years.

The same lateral and drainage systems would be required as in Plan D-4.

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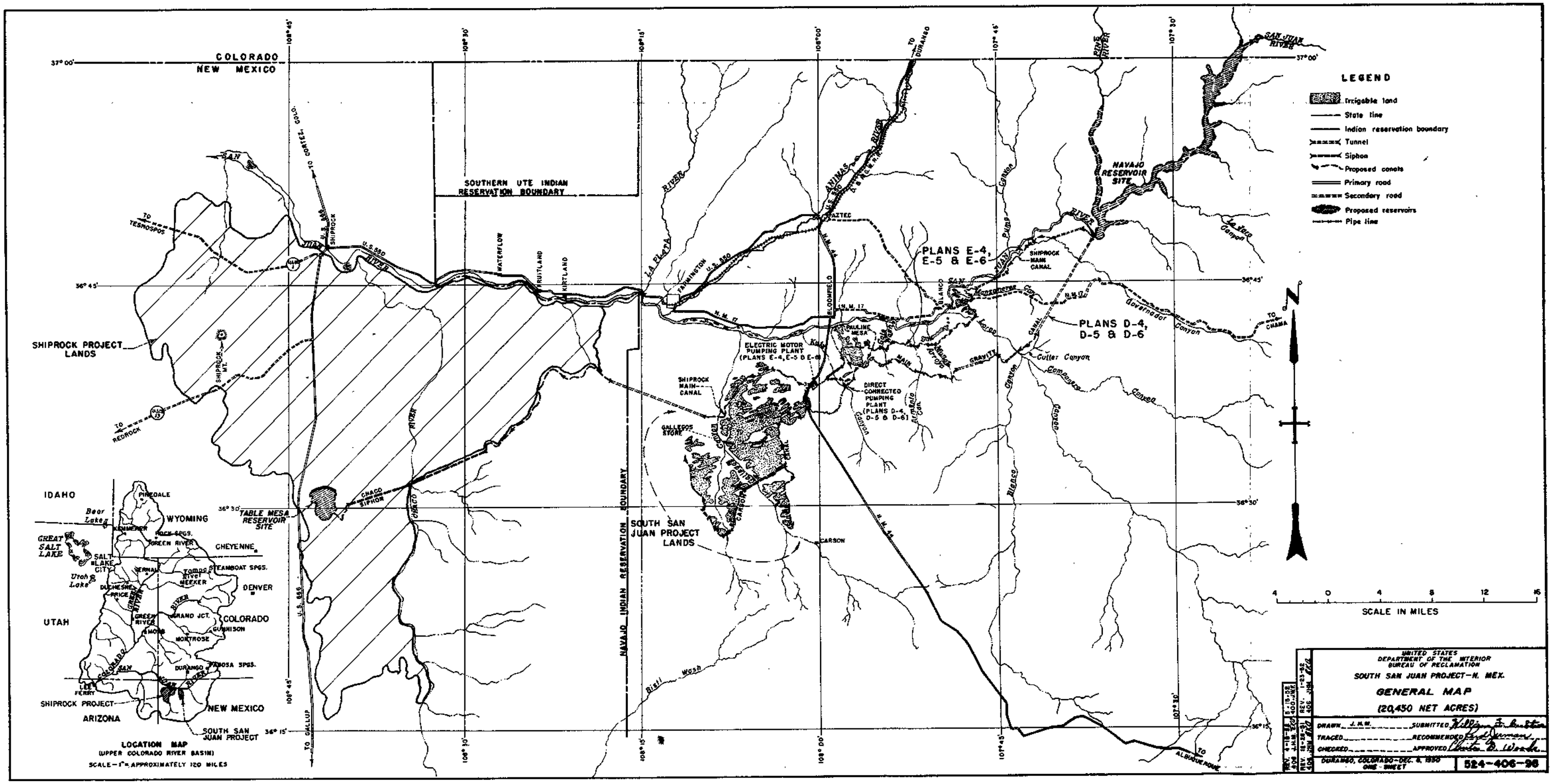

LEGEND
Irrigable land
State line
Indian reservation boundary
Tunnel
Siphon
Proposed canals
Primary road
Secondary road
Proposed reservoirs
Pipe line
COLORADO
NEW MEXICO
SOUTHERN UTE INDIAN RESERVATION BOUNDARY
NAVAJO INDIAN RESERVATION BOUNDARY
SHIPROCK PROJECT LANDS
SOUTH SAN JUAN PROJECT LANDS
TABLE MESA RESERVOIR SITE
NAVAJO RESERVOIR SITE
CHACO SIPHON
SHIPROCK MAIN CANAL
ELECTRIC MOTOR PUMPING PLANT (PLANS E-4, E-5 & E-6)
DIRECT CONNECTED PUMPING PLANT (PLANS D-4, D-5 & D-6)
PLANS E-4, E-5 & E-6
PLANS D-4, D-5 & D-6
GALLEGOS STORE
CARSON
AZTEC
BLOOMFIELD
FARMINGTON
KIRTLAND
FRUITLAND
WATERFLOW
SHIPROCK
BLANCO
SAN JUAN RIVER
ANIMAS RIVER
LA PLATA RIVER
PINE RIVER
CHACO RIVER
TO DURANGO
TO CORTEZ, COLO.
TO TESNOSPOS
TO REDROCK
TO GALLUP
TO ALBUQUERQUE
TO CHAMA
SCALE IN MILES
LOCATION MAP
(UPPER COLORADO RIVER BASIN)
SCALE—1" = APPROXIMATELY 120 MILES
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
SOUTH SAN JUAN PROJECT—N. MEX.
GENERAL MAP
(20,450 NET ACRES)
DURANGO, COLORADO—DEC. 6, 1950
ONE SHEET
524-406-96

CHAPTER II

G E N E R A L D I S C U S S I O N S

Location and Physical Geography

The South San Juan project area is located in San Juan County in the northwest corner of New Mexico and lies astride a section of the east boundary of the Navajo Indian Reservation. The project lands lie on the mesas south of the San Juan River between Farmington and Bloomfield. The relatively flat relief of the mesa lands is marked by shallow arroyos and sand dunes formed by wind action. Tributaries of the Chaco River, Gallegos Canyon, and a few other minor tributaries of San Juan River drain the area which slopes generally to the northwest. The arable lands considered range in elevation from 5,400 to 6,135 feet. They lie between the narrow dunes and are located generally in the broad swales which slope moderately to the main drainages. The project area lies near the center of a broad, geologic structural basin located within the broader San Juan River Basin.

San Juan River, second largest tributary of the Colorado River, heads on the western slope of the Continental Divide in southwestern Colorado. The river drains a total of 25,000 square miles in the general region of the common boundary corner of Colorado, New Mexico, Arizona, and Utah. The greater part of the stream run-off, however, comes from the San Juan and La Plata Mountains. Several mountain peaks on the northeast rim of the basin reach more than 13,000 feet above sea level. From these heights the basin drops in elevation to 3,260 feet at the mouth of the San Juan River.

With elevation differences of nearly 2 miles between highest and lowest points, the San Juan River Basin area is one of extreme contrast in topography and climate. High tree-clad mountain areas with numerous clear, fish-stocked streams and small lakes rapidly give way to fertile foothill valleys and mesas. These valleys and mesas merge into a vast, broken and barren, but picturesque and highly colored plateau area through which the lower portion of the San Juan and its silt-laden tributaries flow in deeply entrenched rocky gorges to the Colorado River.

Rich in prehistoric Indian ruins, in natural wonders, and in spectacular scenic beauty, the basin has great recreational value. Its eight National monuments, one National Park, and numerous other points of interest attract many vacationists.

CHAPTER II GENERAL DISCUSSIONS

Climate

Climate in the South San Juan project area is temperate and semi-arid. The summers are characterized by warm days and cool nights while the winters are cold. Temperatures range from a minimum of 15°F. below zero to a maximum of about 100°F. The frost-free period is about 150 days and the mean annual temperature is about 50°F. The average annual precipitation is 8.99 inches at the Bloomfield station. About half of this occurs during the growing season, making irrigation necessary for successful crop production. With irrigation climatic conditions are favorable for growing most field crops, a variety of garden crops, and such fruits as apples, pears, peaches, cherries, and apricots.

Population

The population of San Juan County was 8,330 in 1920, 14,700 in 1930, 17,110 in 1940, and 18,120 in 1950. Nearly half the county population in 1940 was Indian. Farmington, N. Mex., with a 1950 population of 3,600, is the largest town in the county and is located 10 miles north of the project area.

Principal trading centers are located at Farmington, N. Mex., and Durango, Colo. Durango, with a 1950 population of 7,500, is located about 75 miles northeast of the project area. Schools, churches and recreational facilities are located at Farmington, Aztec, and Bloomfield. School busses transport students from outlying areas in the county to centrally located schools.

Present Development

The project lands are almost totally undeveloped at the present time. With the limited rainfall they support only a very sparse vegetation and are now used mostly by Indians for the grazing of sheep. The most highly developed agricultural area near the project is that around Farmington and adjacent small towns where farmers are successfully raising fruits and other crops by diverting irrigation water directly from the San Juan River and tributary streams.

A number of small industries help to support the local economy. These are located outside of the project area in or near the commercial and trading centers of the region. Mining of coal for local use and of precious metals such as gold, silver, uranium, and vanadium is carried on in the San Juan Basin. Lumbering and natural gas production are other local industries. Proven fields in the San Juan Basin contain great quantities of natural gas and recently constructed pipelines are conveying gas from the basin to the west coast and to Albuquerque, N. Mex. Both oil and natural gas have been found within the project area.

A new industry established in the region is the manufacturing of gasoline from natural gas. Three such plants are now located near Farmington and Bloomfield. A large number of Indians on nearby reservations are engaged on a small scale in the manufacture of hand-made jewelry and hand-woven rugs.

The nearest rail facilities available to the project are the narrow-gage line at Aztec and Farmington and the standard-gage line at Albuquerque and Gallup. Albuquerque and Gallup are 194 and 123 miles, respectively, from Farmington by highway. New Mexico State Highway No. 44 traverses the project area connecting with United States Highway No. 66 at Albuquerque and United States Highway No. 550 at Aztec, N. Mex.

Need for Development

The need for additional irrigation development in the San Juan River Basin in New Mexico involves the long-run needs for resource development essential to continued normal economic growth. In addition to normal growth an urgent need is anticipated in the near future for settlement opportunities that new irrigation developments can provide. Workers who are now migrating by the hundreds into the area to take part directly or indirectly in the new natural gas and oil industry will tend to remain in the area.

Added to this increased population will be those workers and dependents involved in the related industry, manufacture of gas and oil from coal deposits, which will surely develop at some future date. A somewhat slower but steady growth is anticipated from the mining and processing of uranium ores. The expanded population of the area will likely cause an increase in the production of various products, thus increasing the tonnage of imports and probably bringing a standard-gage railroad into the area. With the increased population the local market for foodstuffs will expand, and with a standard-gage rail outlet an outside market for all agricultural products that can be produced in the area could be developed and secured. The ultimate result will be an increased demand for settlement opportunities on farms. The present limited supply of developed farms and the anticipated continuing high prices for them will narrowly restrict farming opportunities unless new lands are brought into production. The expansion in farm land which can be made without irrigation is negligible.

With an increase in population and new industries, additional electric generating capacity will be needed. Some new capacity is reported to be immediately desirable. No detailed studies of the potential local power load growth have been made, however. Additional and more complete processing of the basin's wood, food, and mineral products rather than their export in raw and semifinished form could be accomplished within the basin if sufficient electric power were available.

The South San Juan project and the Indian Shiprock project in the first stage of development could meet the need for flood control. The need is particularly great at Farmington and Shiprock. The Navajo Dam as planned would remove a serious flood hazard in those areas. It would permit the storage of water for irrigation and abate pollution.

Undeveloped Resources

Although some progress has been made in the development of the many natural resources of the San Juan River Valley and the San Juan Basin, it is only a "drop in the bucket" compared to future possibilities.

In or near the project area and throughout most of the San Juan Basin are tremendous undeveloped bodies of coal. Some of these deposits are reported to be of excellent coking quality while others are valuable for the potential production of synthetic gas and oil and related products. Because of the lack of suitable rail transportation, most of the coal mining in the basin has been for local use. The project area is situated roughly in the center of a natural gas field reputed to be the largest undeveloped field in the United States. A pipeline to carry a part of the gas produced to centers in Arizona and California is now under construction. Gas to meet the demands of the central portion of New Mexico is also supplied from this field. Large deposits of uranium minerals on the Navajo Reservation near "Four Corners Area" have been discovered, and intensive prospecting of the reservation and areas adjacent to it is in progress. Large-scale mining and processing of this ore have not been started. North of the project area, in the Colorado portion of the basin, are huge stands of timber, particularly pine and spruce, which are only partially utilized at present. Undeveloped or partially developed mineral resources in the Colorado area include tungsten, vanadium, uranium, gold, silver, lead, and zinc.

Many undeveloped resources center around potential irrigation projects in the San Juan River Valley and the development of the valley's waters for the production of hydroelectric power. Fertile valleys, terraces, and mesas contain thousands of acres of new land that, with irrigation, will support productive farmsteads and be the means of livelihood for hundreds of new farm families.

Economic Conditions

General economic conditions in the region and in communities bordering the project area have been favorable in recent years. These conditions have resulted from several factors, the most important being good farm prices. Other factors contributing to the improved conditions are the

increased farming along the San Juan River and the activity in the oil and natural gas fields around Farmington. Paradoxically, these conditions have little effect on the project area itself because of its sparsely settled and undeveloped nature. Because of the limited development of agricultural and other natural resources on the Navajo Indian Reservation, economic conditions are poor among the Navajo Indians even when conditions are favorable throughout the Nation as a whole.

Past Investigations

Several investigations of water storage and irrigation possibilities along the San Juan River in the general area of the South San Juan and Shiprock projects have been made since the turn of the century by Federal, State, and private interests. These investigations have been largely of a reconnaissance nature. In the early investigations no plans sufficiently attractive for development were formulated. In later investigations rather detailed surveys and estimates of storage possibilities in the headwaters of San Juan River and tributaries in connection with plans for transmountain diversions to the Rio Grande Basin were made by the Bureau of Reclamation. Results of these studies are covered in the report on Rio Grande Joint Investigations, 1937. In 1939 the Bureau of Reclamation began an investigation of the potential Shiprock project. This investigation was discontinued during World War II and later resumed by the Bureau of Indian Affairs, leading to the present plans for the Shiprock project.

An inventory of possible water resource developments in the San Juan River Basin was given in the report entitled, The Colorado River, released by the Bureau of Reclamation in March 1946. This report contains the general results of studies made to that time.

Present Investigations

The present reconnaissance investigation was initiated in 1946. Field work on investigations of the plans described in this report included a reconnaissance land classification, fly-line surveys of canal lines, a topographic survey of Navajo Dam site, and collection of basic economic data. Geologic studies of the Navajo Dam and Reservoir sites, including diamond drilling and test pit exploration, were made by Bureau of Reclamation personnel for the Bureau of Indian Affairs in connection with the latter agency's investigations of the Shiprock project. Office work has included the making of detailed water supply studies, the preparation of rough plans and cost estimates, the making of rough economic analyses of agricultural development of project lands and repayment abilities, and the compiling of the reconnaissance report.

A committee of the Department of the Interior, composed of representatives of the Division of Project Planning and Regions 4 and 5 of the Bureau of Reclamation and representatives of the Bureau of Indian Affairs, was appointed in the latter part of 1950 to compile and coordinate technical engineering and economic data related to potential developments that would utilize New Mexico's compact allotment of Upper Colorado River Basin water. This committee is known as the San Juan River, New Mexico Technical Committee. A representative of the State of New Mexico has acted as consultant to the committee and assisted in its studies and compilations. Responsibilities of the committee are:

> "* * * to present to the (New Mexico) State Engineer or other responsible State official the essential findings of the investigations by the Bureau of Reclamation Regions 4 and 5 and by the Bureau of Indian Affairs and to interpret these findings to him, to assist him in making comparative studies involving various combinations off projects to utilize San Juan River water within New Mexico's (compact) allotment and to advise him on technical matters relating to the advisability of including such projects * * *"

The committee has compiled and coordinated related technical data with primary attention being given to the hydrologic phases. Results of investigations of the South San Juan project have been made available to the committee. A Report of the Technical Committee on Use of Waters of San Juan River in New Mexico was prepared for the Secretary of the Department of the Interior on January 26, 1951. A committee progress report was later prepared for the Secretary on March 7, 1952.

Acknowledgments

Work of the investigation has been carried on by the Bureau of Reclamation in cooperation with the State of New Mexico through its State Engineer and its Interstate Stream Commission. The investigations have been made in close cooperation between the Bureau of Reclamation and Bureau of Indian Affairs to coordinate the water supply studies and plans and estimates for the South San Juan and Shiprock projects. Applicable information in previous reports and publications relating to the area and work of the San Juan River, New Mexico Technical Committee have been freely drawn upon in making the investigation and preparing the report.

CHAPTER III

W A T E R S U P P L Y

Water Resources

The source of irrigation water for the South San Juan and Shiprock projects is the San Juan River at the Navajo Dam site, located about 3.5 miles below the mouth of Pine River. The flow at the Blanco gage is considered to be representative of the flow at the dam site since any inflow from the tributary drainage area between these two points is practically negligible and consists almost entirely of flash run-off from local storms.

The average annual recorded run-off of the San Juan River near Blanco for the years 1930 to 1951 was 1,010,800 acre-feet. This recorded run-off was adjusted to allow for new upstream developments during this period and for all potential within-basin upstream developments and the potential Weminuche Pass diversions to San Luis Valley. These adjusted flows, tabulated by months in Table VII on the following page, represent the water available for regulation at the Navajo Reservoir site for the South San Juan and Shiprock projects and for other potential and existing downstream developments. The adjusted flows average 885,900 acre-feet annually. Requirements for other potential and existing downstream developments are estimated to average 23,000 acre-feet annually after allowing for irrigation diversions by-passing the Blanco gage and for estimated usable return flows below the gage. Thus an average of 862,900 acre-feet annually would be available for regulation at the Navajo site for the South San Juan and Shiprock projects, assuming no transmountain diversion to the potential San Juan-Chama project.

Potential upstream developments considered in determining modified flows of San Juan River at Blanco consist of the Dulce, O'Neal Park, and Pine River extension projects; irrigation of miscellaneous lands above Rosa, N. Mex.; and transmountain diversions to San Luis Valley from Pine River and Weminuche Creek. Table VIII on page 24 lists the acreages of the various projects and areas located upstream from the Navajo Dam site. Should any of the potential developments fail to be realized, the modified flows at Blanco would be increased accordingly.

Table VII

MODIFIED FLOW OF SAN JUAN RIVER NEAR BLANCO--ADJUSTED FOR UPSTREAM WITHIN-BASIN DEVELOPMENTS AND WEMINUCHE PASS DIVERSIONS

Unit--1,000 acre-feet

Year	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Total
1928	49	29	37	34	83	94	185	108	27	19	14	16	695
1929	21	15	14	17	69	169	266	216	61	166	162	77	1253
1930	32	20	17	31	47	177	141	125	55	59	16	18	738
1931	14	17	14	19	27	61	113	81	31	20	34	50	481
1932	24	15	15	54	139	341	434	308	132	71	27	23	1583
1933	16	16	17	18	37	46	118	195	50	19	46	31	609
1934	17	16	17	18	34	72	69	15	11	9	18	11	307
1935	11	13	14	21	45	172	245	420	172	61	53	31	1258
1936	17	13	14	14	92	236	244	79	19	54	45	29	856
1937	29	17	14	21	99	342	403	196	66	23	13	24	1247
1938	15	13	15	17	96	230	288	347	83	21	66	45	1236
1939	28	20	18	15	95	140	191	69	8	6	36	18	644
1940	15	12	14	19	45	69	132	52	10	16	21	40	445
1941	22	22	19	51	116	248	680	542	252	59	65	227	2303
1942	94	46	35	32	63	407	296	261	53	26	22	25	1360
1943	17	16	17	29	54	154	136	89	47	35	21	25	640
1944	18	20	14	18	39	119	295	336	95	22	13	36	1025
1945	20	17	14	27	43	137	265	153	50	33	10	33	802
1946	13	12	13	18	26	49	55	52	24	34	13	29	338
1947	24	17	12	21	31	35	148	83	29	74	46	62	582
1948	25	18	16	26	35	190	316	295	49	31	12	28	1041
1949	16	15	17	23	62	195	265	403	152	33	18	28	1227
1950	18	14	15	27	34	103	105	75	36	10	20	10	467
1951	9	9	8	12	18	24	88	73	10	21	18	10 1/	300
Mean 1930-51	22.5	17.2	15.9	24.1	58.0	161.2	228.5	193.1	65.2	33.5	28.8	33.9	885.9

1/ Estimated to complete the year.

Note: Compiled in January 1951 by the San Juan River, New Mexico Technical Committee. In computing the modified flow at Blanco, the recorded flow at Blanco was adjusted for the effects of the ultimate Pine River and Dulce projects in New Mexico and Colorado, the O'Neal Park, Carracas, and other small miscellaneous projects above the Colorado-New Mexico State line, and the Weminuche Pass diversion.

TABLE VIII
NET ACREAGES ABOVE NAVAJO DAM SITE

Project or area	Presently irrigated lands		New lands	Total
	With essentially a full supply	Requiring supplemental water		
Dulce project	1,840		14,950	16,790
O'Neal Park project	2,140		5,400	7,540
Pine River project extension	33,160		35,840	69,000
Misc. areas above Rosa, N.Mex.				
San Juan River above Pagosa Springs	1,680	0	320	2,000
Coal Creek	0	290	0	290
Four Mile Creek	0	3,240	20	3,260
Mill Creek	210	380	130	720
Echo Canyon	0	660	0	660
Rio and Rito Blanco	780	290	50	1,120
San Juan River-Gate to Pagosa Springs	260	0	210	470
San Juan River-Carracas project	250	0	1,420	1,670
Stollsteimer and Lower Piedra	960	840	1,060	2,860
Total	41,280	5,700	59,400	106,380

Water Rights

Two compacts among interested States and a treaty between the United States and Mexico govern the division of Colorado River waters. The Colorado River Compact of 1922 allocates waters to the upper and lower basins. Waters allocated the upper basin are divided among the States in the upper basin by the Upper Colorado River Basin Compact of 1949. The Mexican Water Treaty of 1945 defines Mexico's rights to the use of water from the Colorado River system.

The Upper Colorado River Basin Compact establishes the obligation of each State of the upper division with respect to the deliveries of water required to be made at Lee Ferry by the Colorado River Compact. Article 3 of the upper basin compact allocates to the State of Arizona the consumptive use of 50,000 acre-feet per annum and apportions the remainder of the upper basin's water among Colorado (51.75 percent), New Mexico (11.25 percent), Utah (23 percent), and Wyoming (14 percent). The compact apportions the consumptive use of waters of the San Juan River

and its tributaries between the States of Colorado and New Mexico as follows:

"The State of Colorado agrees to deliver to the State of New Mexico from the San Juan River and its tributaries which rise in the State of Colorado a quantity of water which shall be sufficient, together with water originating in the San Juan Basin in the State of New Mexico, to enable the State of New Mexico to make full use of the water apportioned to the State of New Mexico by Article III of this Compact, subject, however, to the following:

(a) A first and prior right shall be recognized as to:

(1) All uses of water made in either State at the time of the signing of this Compact; and

(2) All uses of water contemplated by projects authorized, at the time of the signing of this Compact, under the laws of the United States of America whether or not such projects are eventually constructed by the United States of America or by some other entity.

(b) The State of Colorado assents to diversions and storage of water in the State of Colorado for use in the State of New Mexico, subject to compliance with Article IX of this Compact.

(c) The uses of the waters of the San Juan River and any of its tributaries within either State which are dependent upon a common source of water and which are not covered by (a) hereof, shall in times of water shortages be reduced in such quantity that the resulting consumptive use in each State will bear the same proportionate relation to the consumptive use made in each State during times of average water supply as determined by the Commission; provided, that any preferential uses of water to which Indians are entitled under Article XIX shall be excluded in determining the amount of curtailment to be made under this paragraph.

(d) The curtailment of water use by either State in order to make deliveries at Lee Ferry as required by Article IV of this Compact shall be independent of any and all conditions imposed by this Article and shall be made by each State, as and when required, without regard to any provisions of this Article.

(e) All consumptive use of the waters of the San Juan River and its tributaries shall be charged under the apportionment of Article III hereof to the State in which the use is made; provided, that consumptive use incident to the diversion, impounding or conveyance of water in one State for use in the other shall be charged to the latter State."

In connection with the San Juan River water available for use in New Mexico, the following is quoted from the San Juan River, New Mexico Technical Committee report of January 26, 1951.

"The problem in New Mexico is to select projects to utilize the water available to New Mexico under the Upper Colorado River Basin Compact. Article VI of that Compact provides that the uses are to be measured in terms of man-made depletions of the virgin flow at Lee Ferry. The committee made no attempt to estimate the magnitude of future salvage of channel losses between sites of use and Lee Ferry. Neither did it attempt to estimate the extent of future curtailments of use to meet the obligation of New Mexico under the Mexican Water Treaty. In the committee's analysis these two unevaluated items were assumed to offset each other and uses in New Mexico were calculated on the basis of depletions at the sites of use. New Mexico's permissible depletion under these assumptions is estimated to be 838,000 acre-feet annually. Anticipated depletions by present projects and future projects for which New Mexico has committed uses, are as follows:

Use by present developments	80,000	acre-	feet
Reserve for New Mexico's share of main stem reservoir losses	92,000	"	"
Reserve for Navajo Reservoir losses	26,000	"	"
Reserve for Hammond Project	8,400	"	"
Reserve for La Plata Unit of Animas-La Plata Project	3,500	"	"
Reserve for authorized Indian Projects (Hogback Project Extension and Fruitland Project)	28,100	"	"
Subtotal	238,000	"	"

"These calculations indicate about 600,000 acre-feet available for additional future potential projects in New Mexico."

Potential developments are known that would utilize more water of the San Juan River than is available. Several of the potential projects in New Mexico are competitive with potential projects in Colorado to varying degrees for use of common sources of water. In these cases the State of Colorado agreed in the Upper Colorado River Basin Compact, however, to by-pass sufficient water of the San Juan River system to allow New Mexico to use its apportioned share of the upper basin water. Several of the potential projects in New Mexico are also competitive with each other for common sources of water, and most of the potential projects in New Mexico are competitive with each other to varying degrees for use of New Mexico's apportioned share of the Upper Colorado River Basin water.

In the final selection of projects to utilize New Mexico's water, consideration will need be given to the balancing of the number and size of the projects with the physical limitations of local water supplies as well as with the amount of water available under the State's apportionment. Consideration must also be given to the water requirements of existing rights as well as to the relative priorities yet to be established of the various new projects.

This report presents comparative data for the South San Juan project under various plans so that this project can be compared with other potential developments in selecting the size and number of those that should be constructed to utilize San Juan River water in New Mexico. Uses under several combinations of potential projects are roughly estimated later in this chapter under Stream Depletions to indicate the relationship of the various combinations to physical limitations of water supply and to the limitation of the compact apportionment.

Water Requirements--South San Juan and Shiprock Projects

In estimating the amount and seasonal distribution of irrigation requirements of the South San Juan and Shiprock projects, consideration was given to the length of growing season, type of crops grown, effective precipitation, consumptive use requirements, farm application efficiencies, lateral and main canal conveyance losses, and usable return flows. The estimated net diversion requirements of the South San Juan and Shiprock projects were derived as indicated in Tables IX and X.

The diversion requirements of 4.5 and 5.0 acre-feet per acre as measured at Navajo Dam site for the South San Juan and Shiprock projects, respectively, were estimated by the San Juan River, New Mexico Technical Committee. These diversion requirements were adopted for use in the studies presented in this report. Future refinement in the estimates of diversion requirements may result in adoption of different quantities in the final studies. Any changes in the requirements would affect accordingly the total acreage under the various plans of these two projects that could be irrigated within the limits of the dependable water supply available.

Table IX

WATER REQUIREMENTS--SOUTH SAN JUAN PROJECT

Month	Consumptive use of irrigation water on cropped lands		Farm losses (5% of delivery)	Farm delivery requirement	Conveyance losses within project area (laterals)		Gross requirement at head of project	Re-diverti-ble return flow	Net requirement at head of project	Conveyance losses (Main Canal)		Diversion requirement at Navajo Dam	
	Ac.-ft. per acre	% of annual	Ac.-ft. per acre	Ac.-ft. per acre	% of gross requirement	Ac.-ft. per acre	Ac.-ft. per acre	Ac.-ft. per acre	Ac.-ft. per acre	% of net requirement	Ac.-ft. per acre	Ac.-ft. per acre	% of annual
April	0.05	3.2	0.07	0.12	35	0.07	0.19	0.02	0.17	4.0	0.01	0.18	4.0
May	0.27	17.5	0.37	0.64	28	0.25	0.89	0.08	0.81	3.2	0.03	0.84	18.7
June	0.39	25.3	0.54	0.93	23	0.28	1.21	0.11	1.10	2.7	0.03	1.13	25.1
July	0.39	25.3	0.54	0.93	23	0.28	1.21	0.11	1.10	2.7	0.03	1.13	25.1
August	0.26	16.9	0.36	0.62	22	0.18	0.80	0.08	0.72	2.7	0.02	0.74	16.4
Sept.	0.14	9.1	0.19	0.33	26	0.12	0.45	0.07	0.38	2.8	0.01	0.39	8.7
Oct.	0.04	2.6	0.06	0.10	30	0.04	0.14	0.05	0.09	3.3	0.00	0.09	2.0
Total	1.54	100.0	2.13	3.67	25	1.22	4.89	0.52	4.37	3.0	0.13	4.50	100.0

1/ Derived by applying Blaney-Criddle method 2/, by months, to the cropping pattern listed below, using Bloomfield climatological data.

Crops	Percent of area
Alfalfa	26.7
Pasture	11.2
Small grains and beans	28.7
Corn and other annuals	22.7
Orchard	10.7
Total	100.0

2/ Described in Determining Water Requirements in Irrigated Areas from Climatological and Irrigation Data, August 1950, by Harry F. Blaney and Wayne D. Criddle, published by Soil Conservation Service, United States Department of Agriculture.

Table X

WATER REQUIREMENTS--SHIPROCK PROJECT

Month	Consumptive use of irrigation water on cropped lands 1/		Farm losses (58% of delivery)	Farm delivery requirement	Conveyance losses within project area (laterals)		Gross requirement at head of project	Re-diverti-ble return flow	Net requirement at head of project	Conveyance losses (Main Canal)		Diversion requirement at Navajo Dam 3/	
	Ac.-ft. per acre	% of annual	Ac.-ft. per acre	Ac.-ft. per acre	% of gross requirement	Ac.-ft. per acre	Ac.-ft. per acre	Ac.-ft. per acre	Ac.-ft. per acre	% of net requirement	Ac.-ft. per acre	Ac.-ft. per acre	% of annual
April	0.06	3.7	0.08	0.14	35	0.08	0.22	0.02	0.20	14	0.03	0.23	4.6
May	0.31	19.0	0.43	0.74	28	0.29	1.03	0.08	0.95	12	0.13	1.08	21.6
June	0.41	25.2	0.57	0.98	23	0.30	1.28	0.15	1.13	9	0.11	1.24	24.8
July	0.42	25.8	0.58	1.00	23	0.30	1.30	0.16	1.14	9	0.11	1.25	25.0
August	0.27	16.5	0.37	0.64	22	0.18	0.82	0.14	0.68	9	0.07	0.75	15.0
Sept.	0.12	7.4	0.17	0.29	26	0.10	0.39	0.08	0.31	11	0.04	0.35	7.0
Oct.	0.04	2.4	0.05	0.09	30	0.04	0.13	0.04	0.09	13	0.01	0.10	2.0
Total	1.63	100.0	2.25	3.88	25	1.29	5.17	0.67	4.50	10.0	0.50	5.00	100.0

2/

1/ Derived by applying Blaney-Criddle Method, by months, to the cropping pattern listed below, using Bloomfield and Shiprock climatological data weighted equally.

Crops	Percent of area
Alfalfa	30
Pasture	10
Small grains and beans	31
Corn and other annuals	28
Orchard	1
Total	100

2/ Described in Determining Water Requirements in Irrigated Areas from Climatological and Irrigation Data, August 1950, by Harry F. Blaney and Wayne D. Criddle, published by Soil Conservation Service, United States Department of Agriculture.

3/ Does not take into account the operation of Table Mesa Reservoir. Refer to Tables XI and XII.

Table Mesa Reservoir Operation

Table Mesa Reservoir site is so situated within the Shiprock project area that it can furnish 47,000 acres of land in that project with terminal storage. During June, the month of maximum irrigation requirement, the lands below the reservoir can be served entirely by water diverted to and stored in this reservoir during the off-peak month. This has the effect of reducing the capacity of the main canal from the Navajo Dam site that would otherwise be required. Table Mesa Reservoir would have 2,500 acre-feet of dead storage and 127,500 acre-feet of active storage. Tables XI and XII show the normal annual operation of Table Mesa Reservoir for Shiprock projects of 100,000 acres and 113,900 acres, respectively.

Navajo Reservoir Operation

Simulated monthly operation studies of Navajo Reservoir for four different combinations of sizes of Shiprock and South San Juan projects were prepared for the period 1928 to 1951 and summarized for the 22-year period 1930 to 1951. The studies were started with a full reservoir following the September 1927 flood. Reservoir capacities were chosen so as to give an average annual irrigation shortage of approximately 6 percent. The sizes of projects and reservoir capacities, exclusive of anticipated silt deposition, were as shown below.

	Project acreage		Reservoir capacity	
Study	Shiprock	San Juan	Dead	Active
1	113,900	0	130,000	280,000
2	113,900	20,450	215,000	395,000
3	100,000	57,000	475,000	580,000
4	113,900	67,700	475,000	1,025,000

The required release at the Navajo Reservoir for the four studies are summarized in Table XIII. Tables XIV to XVII show the annual summary of Navajo Reservoir operation studies 1 to 4, respectively.

The active capacity of Navajo Reservoir, exclusive of anticipated silt deposition, was plotted against the annual water requirements for the four studies. The resulting curve, shown on page 38, was used to obtain the required active capacity of Navajo Reservoir for the various project plans presented in Chapter I.

Table XI
NORMAL OPERATION
TABLE MESA RESERVOIR
SHIPROCK PROJECT--100,000 ACRES

Unit--1,000 acre-feet

Month	Releases from Navajo Reservoir to Shiprock project	Conveyance losses (percent of reservoir releases)	Deliveries to Shiprock project					Total requirement of lands below Table Mesa (47,000 acres)		Demand on storage	Evaporation losses 1/	Reservoir content at end of month 2/
			Total	Direct flow: To lands above Table Mesa (53,000 acres) Ac.-ft. per acre	Direct flow: To lands above Table Mesa (53,000 acres) 1,000 ac.-ft.	Direct flow: To lands below Table Mesa	To storage (inflow to Table Mesa)	Ac.-ft. per acre	1,000 ac.-ft.			
Nov.	23.3	8	21.4				21.4					23.9
Dec.	24.2	8	22.2				22.2					46.1
Jan.	24.2	8	22.2				22.2					68.3
Feb.	21.8	8	20.0				20.0					88.3
Mar.	24.2	8	22.2				22.2				0.7	109.8
Apr.	48.1	14	41.4	0.20	10.6	9.4	21.4	0.20	9.4	0	1.2	130.0
May	83.8	12	73.7	0.95	50.4	23.3	0	0.95	44.6	21.3	1.1	107.6
June	65.8	9	59.9	1.13	59.9	0	0	1.13	53.1	53.1	0.8	53.7
July	69.1	9	62.9	1.14	60.4	2.5	0	1.14	53.6	51.1	0.1	2.5
Aug.	74.8	9	68.1	0.68	36.0	32.0	0.1	0.68	32.0	0	0.1	2.5
Sept.	34.9	11	31.1	0.31	16.4	14.6	0.1	0.31	14.6	0	0.1	2.5
Oct.	10.5	13	9.1	0.09	4.8	4.2	0.1	0.09	4.2	0	0.1	2.5
Total	504.7	10	454.2	4.50	238.5	86.0	129.7	4.50	211.5	125.5	4.2	

1/ Based on an annual rate of 2.90 feet of depth from the exposed reservoir water surface.

2/ Dead storage 2,500 acre-feet; active storage 127,500 acre-feet.

Table XII
NORMAL OPERATION
TABLE MESA RESERVOIR
SHIPROCK PROJECT--113,900 ACRES

Unit--1,000 acre-feet

Month	Releases from Navajo Reservoir to Shiprock project	Conveyance losses (percent of reservoir releases)	Deliveries to Shiprock project: Total	Direct flow: To lands above Table Mesa (53,000 acres): Ac.-ft. per acre	Direct flow: To lands above Table Mesa (53,000 acres): 1,000 ac.-ft.	Direct flow: To lands below Table Mesa	To storage (inflow to Table Mesa)	Total requirement of lands below Table Mesa (47,000 acres): Ac.-ft. per acre	Total requirement of lands below Table Mesa (47,000 acres): 1,000 ac.-ft.	Demand on storage	Evaporation losses 1/	Reservoir content at end of month 2/
Nov.	23.5	8	21.6				21.6					24.1
Dec.	23.5	8	21.6				21.6					45.7
Jan.	23.5	8	21.6				21.6					67.3
Feb.	23.5	8	21.6				21.6					88.9
Mar.	23.5	8	21.6				21.6				0.7	109.8
Apr.	51.4	14	44.2	0.20	13.4	9.4	21.4	0.20	9.4		1.2	130.0
May	96.8	12	85.2	0.95	63.6	21.6	0	0.95	44.6	23.0	1.1	105.9
June	83.1	9	75.6	1.13	75.6	0	0	1.13	53.1	53.1	0.8	52.0
July	88.5	9	80.5	1.14	76.3	4.2	0	1.14	53.6	49.4	0.1	2.5
Aug.	85.3	9	77.6	0.68	45.5	32.0	0.1	0.68	32.0	0	0.1	2.5
Sept.	39.8	11	35.4	0.31	20.7	14.6	0.1	0.31	14.6	0	0.1	2.5
Oct.	11.8	13	10.3	0.09	6.0	4.2	0.1	0.09	4.2	0	0.1	2.5
Total	574.2	10	516.8	4.50	301.1	86.0	129.7	4.50	211.5	125.5	4.2	

1/ Based on an annual rate of 2.90 feet of depth from the exposed reservoir water surface.

2/ Dead storage 2,500 acre-feet; active storage 127,500 acre-feet.

Table XIII
REQUIRED RELEASES AT NAVAJO RESERVOIR

Unit—1,000 acre-feet

Month	For lands below Navajo Reservoir 1/	For South San Juan project			For Shiprock project 2/		Total required releases of Navajo Reservoir 3/			
		20,450 acres	57,000 acres	67,700 acres	100,000 acres	113,900 acres	Study 1	Study 2	Study 3	Study 4
Nov.					23	23	23	23	23	23
Dec.					24	24	24	24	24	24
Jan.					24	24	24	24	24	24
Feb.					22	23	23	23	22	23
Mar.					24	24	24	24	24	24
Apr.	4	4	10	12	48	51	55	59	62	67
May	3	17	48	57	84	97	100	117	135	157
June	4	23	64	77	66	83	87	110	134	164
July	4	23	65	77	69	89	93	116	138	170
August	4	15	42	50	75	85	89	104	121	139
Sept.	3	8	22	26	35	39	42	50	60	68
Oct.	1	2	5	6	11	12	13	15	17	19
Total	23	92	256	305	505	574	597	689	784	902

1/Includes releases of 5 acre-feet per acre to 820 acres under the Bloomfield-Porter ditch and 3,670 acres under the Hammond project, but does not include the demands of 4,410 acres of presently irrigated land, the diversions for which are already reflected in the recorded flow of the Blanco gage. The requirement of lands below the mouth of the Animas River would be met from inflows and return flows.

2/ Refer to Table Mesa Reservoir Operation Studies, Tables XI and XII.

3/ Study 1 Serves a 113,900-acre Shiprock project.
Study 2 Serves a 113,900-acre Shiprock project and a 20,450-acre South San Juan project.
Study 3 Serves a 100,000-acre Shiprock project and a 57,000-acre South San Juan project.
Study 4 Serves a 113,900-acre Shiprock project and a 67,700-acre South San Juan project.

Table XIV
ANNUAL SUMMARY--NAVAJO RESERVOIR OPERATION--STUDY 1
SHIPROCK PROJECT ALONE--113,900 ACRES

Unit--1,000 acre-feet

Year	Modified run-off at Navajo Dam site	Total irrigation demand at Navajo Dam site	Storable flow	Demand on storage	Reservoir evaporation losses 1/	Active reservoir content		Spill	Average South San Juan and Shiprock project irrigation shortages	
						Maximum	End of season (Oct.31)		1,000 acre-feet	% of total irrigation demand
1929							280			
1930	738	597	246	105	15	280	186	220		
1931	481	597	59	175	12	177	58			
1932	1,583	597	1,037	51	13	280	254	777		
1933	609	597	161	149	14	280	184	68		
1934	307	597	27	317	11	178	0		117	20.6
1935	1,258	597	689	28	11	280	278	372		
1936	856	597	412	153	15	280	174	348		
1937	1,247	597	791	141	13	280	164	647		
1938	1,236	597	751	112	13	280	253	537		
1939	644	597	257	210	15	280	85	200		
1940	445	597	94	246	8	115	27		102	17.9
1941	2,303	597	1,744	38	13	280	280	1,440		
1942	1,360	597	886	123	15	210	164	864		
1943	640	597	185	142	13	280	165	29		
1944	1,025	597	548	120	13	280	204	376		
1945	802	597	356	151	13	280	164	232		
1946	338	597	18	277	8	154	16		119	20.9
1947	582	597	105	120	7	51	51		57	10.0
1948	1,041	597	590	146	13	280	157	325		
1949	1,227	597	733	103	13	280	212	562		
1950	467	597	67	197	12	250	70			
1951	300	597	0	297	5	56	0		232	40.8
Mean	885.9	597.0	443.4	154.6	12.0	232.3	149.0	318.0	28.5	5.0

1/ Based on an annual rate of 2.90-foot depth from exposed reservoir surface.

Table XV

ANNUAL SUMMARY--NAVAJO RESERVOIR OPERATION--STUDY 2
SOUTH SAN JUAN PROJECT 20,450 ACRES; SHIPROCK PROJECT 113,900 ACRES

Unit--1,000 acre-feet

Year	Modified run-off at Navajo Dam site	Total irrigation demand at Navajo Dam site	Storable flow	Demand on storage	Reservoir evaporation losses 1/	Active reservoir content		Spill	Average South San Juan and Shiprock project irrigation shortages	
						Maximum	End of season (Oct. 31)		1,000 acre-feet	% of total irrigation demand
1929							395			
1930	738	689	200	151	20	395	250	174		
1931	481	689	40	248	15	240	34		7	0.1
1932	1,583	689	968	74	17	395	342	569		
1933	609	689	115	195	18	391	244			
1934	307	689	23	405	13	237	0		151	22.8
1935	1,258	689	612	43	16	395	366	187		
1936	856	689	386	219	19	395	216	298		
1937	1,247	689	745	187	19	395	228	527		
1938	1,236	689	697	150	20	395	304	438		
1939	644	689	234	279	16	395	129	127		
1940	445	689	71	315	11	136	24		150	22.7
1941	2,303	689	1,667	53	16	395	395	1,227		
1942	1,360	689	840	169	20	395	228	818		
1943	640	689	160	209	17	349	162			
1944	1,025	689	500	164	17	395	268	213		
1945	802	689	310	197	19	395	228	134		
1946	338	689	16	367	13	217	13		149	22.5
1947	582	689	80	187	9	46	46		149	22.5
1948	1,041	689	544	192	16	395	222	160		
1949	1,227	689	664	126	19	395	300	441		
1950	467	689	58	280	16	328	62			
1951	300	689	0	389	8	48	0		335	50.7
Mean	885.9	689.0	405.9	209.0	16.1	324.0	193.7	241.5	42.8	6.5

1/ Based on an annual rate of 2.90-foot depth from exposed reservoir surface.

Table XVI

ANNUAL SUMMARY—NAVAJO RESERVOIR OPERATION—STUDY 3

SOUTH SAN JUAN PROJECT—57,000 ACRES; SHIPROCK PROJECT—100,000 ACRES

Unit—1,000 acre-feet

Year	Modified run-off at Navajo Dam site	Total irrigation demand at Navajo Dam site	Storable flow	Demand on storage	Reservoir evaporation losses 1/	Active reservoir content		Spill	Average South San Juan and Shiprock project irrigation shortages	
						Maximum	End of season (Oct. 31)		1,000 acre-feet	% of total irrigation demand
1929							580			
1930	738	784	163	209	29	580	366	139		
1931	481	784	36	339	22	356	41			
1932	1,583	784	906	107	29	580	485	326		
1933	608	784	88	264	27	482	382			
1934	307	784	20	497	19	275	0		214	28.3
1935	1,258	784	541	67	26	509	448			
1936	856	784	363	291	29	580	319	172		
1937	1,247	784	698	235	30	580	358	394		
1938	1,236	784	640	188	30	580	467	333		
1939	644	784	211	351	27	580	232	48		
1940	445	784	51	390	18	223	22		147	19.4
1941	2,303	784	1,589	70	30	580	580	931		
1942	1,360	784	794	218	30	580	358	768		
1943	640	784	138	282	26	458	188			
1944	1,025	784	453	212	27	580	398	4		
1945	802	784	264	246	29	580	358	29		
1946	338	784	14	460	21	347	11		120	15.9
1947	582	784	57	259	17	44	44		252	33.3
1948	1,041	784	498	241	25	503	276			
1949	1,227	784	596	153	30	580	453	236		
1950	467	784	56	373	24	477	112			
1951	300	784	0	484	16	97	0		388	51.3
Mean	885.9	784.0	371.6	269.8	25.5	461.4	281.6	153.6	51.0	6.7

1/ Based on an annual rate of 2.90-foot depth from exposed reservoir surface.

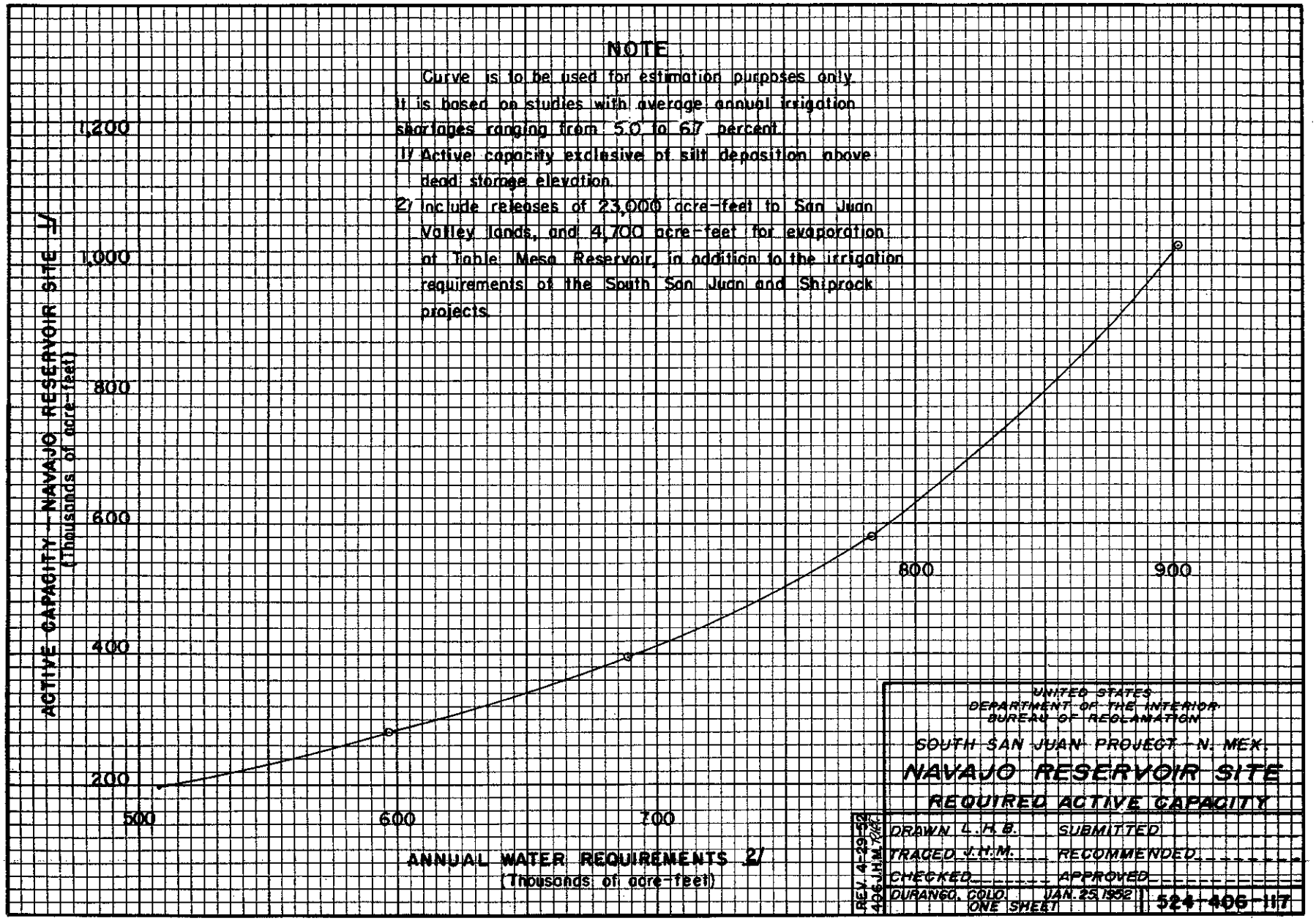
Table XVII

ANNUAL SUMMARY--NAVAJO RESERVOIR OPERATION--STUDY 4
SOUTH SAN JUAN PROJECT--67,700 ACRES; SHIPROCK PROJECT--113,900 ACRES

Unit--1,000 acre-feet

Year	Modified run-off at Navajo Dam site	Total irrigation demand at Navajo Dam site	Storable flow	Demand on storage	Reservoir evaporation losses	Active reservoir content 1/		Spill	Average South San Juan and Shiprock project irrigation shortages	
						Maximum	End of season (Oct. 31)		1,000 acre-feet	% of total irrigation demand
1929							945			
1930	738	902	150	314	32	1,025	698	51		
1931	481	902	34	455	27	688	250			
1932	1,583	902	846	165	35	1,025	867	29		
1933	609	902	56	349	32	859	542			
1934	307	902	15	610	24	535	0		77	8.8
1935	1,258	902	449	93	26	421	330			
1936	856	902	334	380	26	606	258			
1937	1,247	902	639	294	32	854	571			
1938	1,236	902	575	241	36	1,025	829	40		
1939	644	902	183	441	32	980	539			
1940	445	902	44	501	24	530	58			
1941	2,303	902	1,492	91	36	1,025	1,025	398		
1942	1,360	902	734	276	38	1,025	741	704		
1943	640	902	129	391	31	834	448			
1944	1,025	902	394	271	30	783	541			
1945	802	902	215	315	31	708	410			
1946	338	902	12	576	19	399	9		182	20.8
1947	582	902	46	366	16	42	42		369	42.2
1948	1,041	902	438	299	22	443	159			
1949	1,227	902	522	197	27	634	457			
1950	467	902	50	485	24	475	0		2	.2
1951	300	902	0	602	15	0	0		617	70.6
Mean	885.9	902.0	334.4	350.5	28.0	678.0	422.6	55.5	56.7	6.5

1/ Based on an annual rate of 2.90-foot depth from the exposed water surface.


NOTE
Curve is to be used for estimation purposes only. It is based on studies with average annual irrigation shortages ranging from 5.0 to 6.7 percent.
1/ Active capacity exclusive of silt deposition above dead storage elevation.
2/ Include releases of 23,000 acre-feet to San Juan Valley lands, and 4,700 acre-feet for evaporation at Table Mesa Reservoir, in addition to the irrigation requirements of the South San Juan and Shiprock projects.
ACTIVE CAPACITY--NAVAJO RESERVOIR SITE 1/
(Thousands of acre-feet)
1,200
1,000
800
600
400
200
500
600
700
800
900
ANNUAL WATER REQUIREMENTS 2/
(Thousands of acre-feet)
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
SOUTH SAN JUAN PROJECT - N. MEX.
NAVAJO RESERVOIR SITE
REQUIRED ACTIVE CAPACITY
DRAWN L.H.B. SUBMITTED
TRACED J.H.M. RECOMMENDED
CHECKED APPROVED
DURANGO, COLO. JAN. 25 1952
ONE SHEET
REV. 4-29-52 406.J.H.M.TRAC.
524-406-117

Stream Depletion

During January 1951 the San Juan River, New Mexico Technical Committee estimated depletion rates for all potential New Mexico projects. These rates were adopted for the studies covered in this report. These were based on the net irrigable acreage to be cropped but include allowances for consumptive use from incidental areas adjacent to and below the farm land, return flow channels, and areas along the main canals.

The chart on page 40 shows the relation of the sizes of the San Juan-Chama, Shiprock, and South San Juan projects within the physical limitations of the available water supply of the San Juan River after allowing for other potential stream depletions upstream from Navajo Dam site and for requirements of other existing and potential developments downstream from Navajo Dam site. Region V of the Bureau of Reclamation has prepared reconnaissance studies for average annual San Juan-Chama diversions of 163,000 acre-feet, 235,000 acre-feet, and 264,000 acre-feet.

Potential New Mexico stream depletions, exclusive of those from the San Juan-Chama, Shiprock, and South San Juan projects, are shown in Table XVIII. Committed uses by the State of New Mexico were separated from those for which reconnaissance investigations have not been completed. Table XIX shows potential New Mexico stream depletions for 15 combinations of projects and indicates the amount by which the potentials exceed 838,000 acre-feet, New Mexico's approximate permissible annual stream depletion under the terms of the Upper Colorado River Basin Compact. In this table the San Juan-Chama project was not included in combinations in which the available water supply would limit the project to an average annual diversion of less than 163,000 acre-feet.

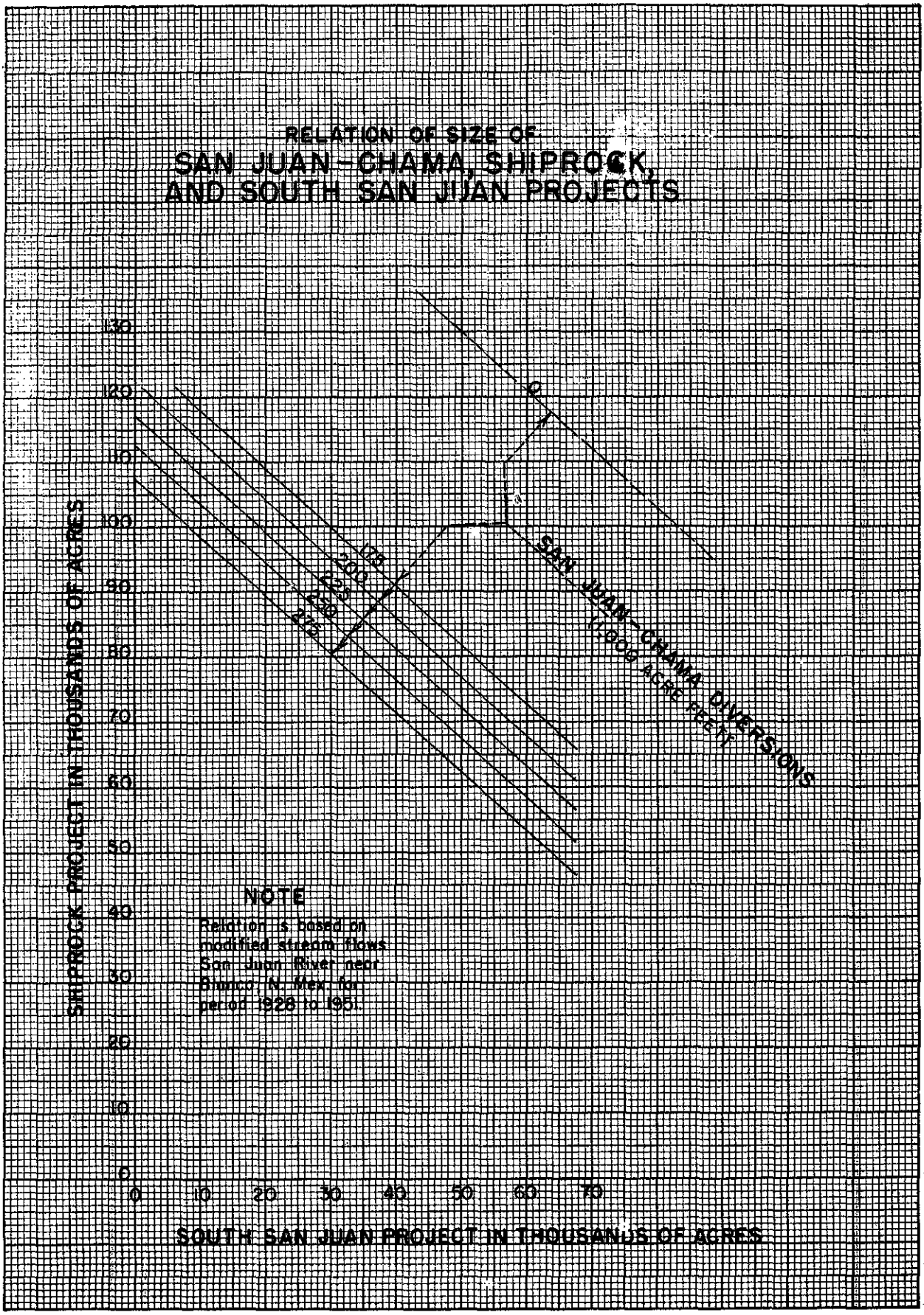

RELATION OF SIZE OF
SAN JUAN-CHAMA, SHIPROCK,
AND SOUTH SAN JUAN PROJECTS
SHIPROCK PROJECT IN THOUSANDS OF ACRES
SOUTH SAN JUAN PROJECT IN THOUSANDS OF ACRES
0
10
20
30
40
50
60
70
80
90
100
120
130
SAN JUAN-CHAMA DIVERSIONS
1,000 ACRE FEET
NOTE
Relation is based on modified stream flows San Juan River near Blanco, N. Mex. for period 1928 to 1951.

Table XVIII
POTENTIAL NEW MEXICO STREAM DEPLETIONS
EXCLUSIVE OF SHIPROCK, SOUTH SAN JUAN, AND SAN JUAN-CHAMA PROJECTS

Project or use	Net irrigable area (acres)	Depletion rate (ac.-ft. per acre) 1/	Total depletion (1,000 acre-feet)
Committed uses by State of New Mexico			
Present developments			80.0
Reserve for New Mexico's share of main stem reservoir losses			92.0
Hammond project	3,670	2.3	8.4
Authorized Indian projects			
Hogback	9,820 2/	2.3	22.6
Fruitland	910	2.3	2.1
Subtotal			(205.1)
Other potential uses 3/			
Dulce project			
San Juan Basin	7,730	1.2	9.3
Rio Grande Basin	3,740	2.5	9.3
Pine River project	960	2.0	1.9
Animas-La Plata project			
LaPlata division (supplemental)	3,800	0.7	2.7
LaPlata division (new)	3,780	2.3	8.7
McDermott division	10,310	2.0	20.6
Meadows division	8,750	2.5	21.9
Monument Rocks division	17,000	2.5	42.5
Animas division 4/	10,000	2.1	21.0
Reservoir evaporation New Mexico's share			7.6
Miscellaneous areas			
San Juan River	1,260	2.3	2.9
Animas River	1,000	2.0	2.0
Future municipal and industrial uses			20.0
Subtotal			(170.4)
Total			375.5

1/ Depletion rates compiled in January 1951 by San Juan River, New Mexico Technical Committee.

2/ Does not include 1,480 acres authorized under the Hogback project but eventually to be served under the Shiprock project.

3/ Include only rough estimates as reconnaissance investigations have not been completed on the projects in this listing.

4/ Formerly referred to as Eden Canal project.

Table XIX
POTENTIAL NEW MEXICO STREAM DEPLETIONS

Plan	Project acreage: Shiprock	Project acreage: South San Juan	Stream depletion (1,000 acre-feet): Shiprock project 1/	South San Juan project 1/	Sub-total	San Juan-Chama project 2/	Sub-total	Committed uses by State of N. Mex. 3/	Sub-total	Other potential uses 3/	Total	Depletion in excess of N.Mex. allocation (838,000 acre-feet)
-	100,000	0	260.2	0	260.2	264.0	524.2	205.1	729.3	151.8 4/	881.1	43.1
-	113,900	0	296.5	0	296.5	235.0	531.5	205.1	736.6	170.4	907.0	69.0
-	121,700	0	316.7	0	316.7	200.0	516.7	205.1	721.8	170.4	892.2	54.2
D-1	100,000	67,700	260.2	177.6	437.8		437.8	205.1	642.9	170.4	813.3	
E-1	"	"	260.2	158.7	418.9		418.9	205.1	624.0	170.4	794.4	
D-2	113,900	67,700	296.5	174.9	471.4		471.4	205.1	676.5	170.4	846.9	8.9
E-2	"	"	296.5	161.4	457.9		457.9	205.1	663.0	170.4	833.4	
D-3	121,700	57,700	316.7	147.4	464.1		464.1	205.1	669.2	170.4	839.6	1.6
E-3	"	"	316.7	136.4	453.1		453.1	205.1	658.2	170.4	828.6	
D-4	100,000	20,450	260.2	61.4	321.6	220.0	541.6	205.1	746.7	170.4	917.1	79.1
E-4	"	"	260.2	47.0	307.2	220.0	527.2	205.1	732.3	170.4	902.7	64.7
D-5	113,900	20,450	296.5	56.6	353.1		353.1	205.1	558.2	170.4	728.6	
E-5	"	"	296.5	47.3	343.8		343.8	205.1	548.9	170.4	719.3	
D-6	121,700	20,450	316.7	56.0	372.7		372.7	205.1	577.8	170.4	748.2	
E-6	"	"	316.7	47.8	364.5		364.5	205.1	569.6	170.4	740.0	

1/ Based on an allowance of 2.5 acre-feet per acre for Shiprock project and 2.2 acre-feet per acre for South San Juan project. Also includes Navajo Reservoir evaporation, allocated incrementally. That is, the Shiprock project was charged in each case with the evaporation that would occur without a South San Juan project, and the remainder of the evaporation for the plan was charged to the South San Juan project.

2/ Limited by available water supply. Refer to chart on page 40.

3/ Refer to Table XVIII.

4/ Does not include depletion of Dulce project, which would be excluded with a San Juan-Chama diversion of 264,000 acre-feet.

CHAPTER IV

DESIGNS AND ESTIMATES

The following discussion describes features of the South San Juan project and presents estimates of project construction costs and of annual operation, maintenance, and replacement costs. Designs and estimates for all project features are based on reconnaissance investigations. The descriptions presented refer to Plan D-2 unless otherwise indicated. This is done, not with the idea that Plan D-2 is favored, but because much of the basic work prepared for this plan has been prepared in greater detail.

Project Works

Navajo Dam and Reservoir

Navajo Dam site is located on the San Juan River in northwestern New Mexico, about 19.5 river miles upstream from the small town of Blanco, N. Mex., and 34 miles east of Farmington, N. Mex. It is about 3.5 miles downstream from the confluence of the Pine and San Juan Rivers. The dam would be a rolled earth-fill embankment. It would rise 410 feet above stream bed and by means of a cut-off trench would be extended an additional 25 feet to bedrock. The crest elevation would be 6,135 feet. Normal water surface elevation would be 6,110 feet at the crest of the uncontrolled spillway. The total volume of fill in the dam would be about 26,000,000 cubic yards.

Initially Navajo Reservoir would have a total normal capacity of 1,954,000 acre-feet, including an active irrigation capacity of 1,025,000 acre-feet and a dead storage capacity of 865,000 acre-feet below outlet level. Silt deposition in a 100-year period is estimated to be 218,000 acre-feet. In addition to the active irrigation capacity, 64,000 acre-feet of space above dead storage elevation has been reserved for silt deposition. The balance of the 218,000 acre-feet of silt would be deposited below dead storage water surface elevation. Thus it would be 100 years before silt deposition would begin to encroach on the active capacity required for irrigation. When at normal water surface elevation, the reservoir would have an area of about 16,850 acres and it would extend about 35 miles up the San Juan River to a point about 5 miles beyond the town of Arboles, Colo.

Normal capacities of the Navajo Reservoir for the Shiprock project alone and for other combinations of South San Juan and Shiprock projects are shown in Table XX on the following page.

Table XX
NAVAJO DAM AND RESERVOIR DATA
SHIPROCK AND SOUTH SAN JUAN PROJECTS

1	2	3	4	5	6	7	8
	South San Juan project area	Navajo Reservoir capacity (acre-feet)				Reservoir Water surface elevation	
Plan No.	(acres)	Active storage[1/]	Dead storage	Silt above dead storage	Total storage	Normal	Dead
	100,000-acre Shiprock project						
-	0	214,000	15,000	208,000	437,000	5,957	5,783
D-1	67,700	740,000	1,140,000	37,000	1,917,000	6,108	6,049
E-1	67,700	740,000	12,000	212,000	964,000	6,030	5,779
D-4	20,450	302,000	425,000	47,000	774,000	6,009	5,956
E-4	20,450	302,000	12,000	210,000	524,000	6,972	5,779
	113,900-acre Shiprock project						
-	0	280,000	10,000	209,000	499,000	5,968	5,775
D-2	67,700	1,025,000	865,000	64,000	1,954,000	6,110	6,020
E-2	67,700	1,025,000	11,000	213,000	1,249,000	6,059	5,778
D-5	20,450	390,000	295,000	81,000	766,000	6,008	5,928
E-5	20,450	390,000	13,000	211,000	614,000	5,986	5,780
	121,700-acre Shiprock project						
-	0	322,000	14,000	210,000	546,000	5,976	5,782
D-3	57,000	980,000	608,000	84,000	1,672,000	6,092	5,987
E-3	57,000	980,000	12,000	213,000	1,205,000	6,055	5,779
D-6	20,450	460,000	270,000	92,000	822,000	6,015	5,921
E-6	20,450	460,000	13,000	211,000	684,000	5,996	5,780

1/ Obtained from Drawing No. 524-406-117, page 38.

Diversion, spillway, and outlet works. During the construction period the river flow would be diverted through a tunnel in the right abutment. The tunnel would discharge a maximum of 20,000 second-feet.

An open channel spillway with a capacity of about 17,000 second-feet would be located on the right abutment. The spill would be uncontrolled over an ogee spillway crest at elevation 6,110 feet. The water surface would be at elevation 6,129 feet during maximum spillway discharge. This spillway, together with the super storage above the spillway crest, is designed to care for a peak inflow flood discharge of 175,000 second-feet having a volume of 306,000 acre-feet in 93 hours.

Outlet works for the Shiprock-South San Juan Main Canal of Plan D-2 would have a capacity of 2,950 second-feet at water surface elevation 6,020 feet and would be installed in the left abutment.

Accessibility. New Mexico State Highway No. 44 is the nearest paved highway to the Navajo site. It passes through Bloomfield approximately 26 miles from the site. A narrow-gage line of the Denver and Rio Grande Western Railroad passes through Aztec, N. Mex., 35 miles from the site. The nearest standard-gage railhead is at Gallup, N. Mex., 138 miles from Bloomfield and 164 miles from the dam site.

The highways from both Aztec and Gallup to Bloomfield are paved and the bridges are capable of handling heavy trucking. From Bloomfield to the dam site the roads would have to be improved or rebuilt to accommodate heavy trucking.

Rights-of-way and relocation. A portion of the Denver and Rio Grande Western Railroad narrow-gage line between Antonito and Durango, Colo., would have to be relocated. Sections of Colorado State Highways Nos. 151 and 172 also would require relocation. The roads consist of second class or unimproved sections.

The major right-of-way costs involved would be in obtaining the land and improvements of the town of Arboles.

The cost of rights-of-way, clearing, and relocation of utilities for different capacity reservoirs has been taken from a curve based on the estimated costs for six different reservoir sizes.

Geology. The rock at the dam site is principally sandstone with minor beds of shale. It belongs to the Wasatch formation. The rock is moderately hard, fairly massive, and is considered completely adequate to support a dam of the height contemplated. Drilling at the site showed the rock to be reasonably tight with no unfavorable conditions. The maximum depth of overburden in the river channel is 34 feet. Except for riprap, suitable construction materials can be found

in the area. Riprap would have to be brought in from a distance of 80 or 90 miles.

Conveyance System

The water for both the South San Juan and the Shiprock projects would be conveyed from Navajo Reservoir in a common canal and conduit for approximately 26 miles. At the end of the common canal and conduit the entire flow would be dropped through a penstock to a hydraulic-driven turbine pumping plant located on the east side of Kutz Canyon. Water for the South San Juan project would be pumped across Kutz Canyon to the mesa near the eastern edge of the project lands. Water for the Shiprock project, after providing pumping power, would be conveyed in a canal and conduit to the west side of Kutz Canyon where it would be carried in the Shiprock Canal west to the Shiprock lands.

The water required for the South San Juan project would be pumped to two canals, the Gallegos Canal and the Bisti Canal. A total of about 65,940 acres of the South San Juan project would be irrigated by pumping under Plan D-2. The 1,760 acres located on Pauline Mesa would be irrigated directly from the Main Gravity Canal.

Canal capacities for all plans have been selected on the basis of meeting the monthly diversion requirement of the most severe month plus 10 percent for anticipated daily fluctuations.

Main Gravity Canal. The Main Canal, with an initial capacity of 2,950 second-feet, would head at the left abutment of Navajo Dam at elevation 6,020 feet about 295 feet above stream bed. The required capacity of the Shiprock Gravity Canal for the 113,900-acre Shiprock project alone would be 1,535 second-feet as compared to the combined capacity of 2,950 second-feet required for the South San Juan and Shiprock projects. It would extend 26 miles to a point 5.3 miles southeast of Bloomfield, N. Mex., in Kutz Canyon. It would consist of 6 tunnels with a total length of 13.33 miles, 5 siphons with a total length of 4.89 miles, 2.41 miles of earth canal, 3.12 miles of clay-lined canal, and 2.63 miles of concrete-lined canal. The elevation at the end of this section of canal would be 5,948 feet. Approximately 1,760 acres of land on Pauline Mesa would be served directly from this canal.

The location of the various main gravity canal lines for the D- and E-series plans has been based on previously surveyed canal lines, field reconnaissance altimeter spot elevations, and aerial photographs used with a stereoscope.

Pumping plant. At the end of the Main Gravity Canal the water for the Shiprock project and a maximum of 1,341 second-feet of the water

for the South San Juan project would be dropped through a 21.5-foot diameter penstock 7,180 feet long to hydraulic-driven pumps located on the east side of Kutz Canyon. The energy developed in this 225-foot drop would be used to energize various turbine-driven pumps with an aggregate horsepower of 37,230. The pumps would discharge into two pipes to the main distribution canals. One discharge line with a capacity of 597 second-feet would extend approximately 13,100 feet to the Gallegos Canal. The other discharge line 11 feet in diameter with a capacity of 744 second-feet would extend about 15,500 feet to the Bisti Canal.

Gallegos Canal. The Gallegos Canal would head at the end of the discharge line at water surface elevation 6,015 feet. It would have an initial capacity of 597 second-feet and would serve a total of 29,370 acres. The total length would be about 45.23 miles, consisting of 40.73 miles of earth canal, 1.20 miles of bench flumes and concrete-lined sections, 2.37 miles of tunnel, and 0.93 of a mile of siphon.

Bisti Canal. The Bisti Canal would begin at the discharge end of the pump lift at water surface elevation 6,136. It would have an initial capacity of 744 second-feet and would serve a total of about 36,570 acres. The total length of 74.00 miles would consist of 71.02 miles of earth canal, 1.96 miles of siphon, 0.76 of a mile of tunnel, and 0.26 of a mile of bench flumes and concrete-lined sections.

Lateral system. The lands of the South San Juan project would require a complete lateral distribution system. There are no existing ditch systems that could be utilized. In general the mesa lands have easy slopes and good drainage. The average cost of a complete distribution system at July 1950 prices on other typical Bureau of Reclamation projects already constructed is about $50.00 per acre. Since a detailed layout of the lateral distribution system required for a typical project area has not been made to date, the average figure of $50.00 per acre was assumed to be sufficient for the cost of the lateral system over the entire project area. The total cost of the lateral distribution system for the 67,700 acres is thus estimated at $3,385,000. Indexed to July 1951 prices, this total cost would be $3,601,000.

Drainage system. In general there are adequate natural drainage channels throughout the project area. About 1,000 acres in isolated areas, however, are expected to require supplemental drainage ditches. The cost of drains for these isolated areas is estimated at $30.00 per acre at July 1950 prices or at a total of $30,000 for the 67,700-acre project. Indexed to July 1951 prices, this total would be $32,000.

Project Cost Estimates

Estimated costs of the South San Juan Project are summarized in Table I, page vi. Construction costs are estimated at July 1951 prices and operation, maintenance, and replacement costs are estimated at 180 percent of 1940 costs to reflect the long-term price-projection level. Construction costs include costs of rights-of-way, relocation of existing utilities, overhead, contingencies, and preconstruction investigations.

Facilities used jointly by the South San Juan and Shiprock projects are the Navajo Reservoir and the Main Gravity Canal extending from the reservoir to the hydraulic turbine-driven pumping plant. The cost of these joint-use features attributable to the South San Juan project is that portion of the total costs over and above the cost of the smaller features that would be required for the Shiprock project alone. Only that portion of the cost of joint-use facilities attributable to the South San Juan project is included in the summary of costs in Table I.

CHAPTER V

PROJECT LANDS

Land Classification

A reconnaissance land classification survey was made in 1946 and 1947 of the large area lying east of the Navajo Indian Reservation between the San Juan River and the Continental Divide in New Mexico. An inventory was made of the location, extent, and quality of the arable lands suitable for sustained crop production under irrigation farming. This inventory was made as a basis for formulating plans for serving lands in the area from the San Juan River. Factors of surface topography, soil characteristics, and drainage were correlated in the establishment of different classes of land.

The survey involved the separation of irrigated from nonirrigated lands and arable from nonarable lands. Arable lands were also divided into two classes, Classes 1 and 2, on the basis of productive capacity and costs of land development for irrigation farming. This division was made on the assumption that irrigation water would be available at reasonable cost. Lands placed in Class 1 are highly suitable for irrigation farming, being capable of producing sustained yields of a wide range of climatically adapted crops at reasonable costs. Class 2 lands comprise those of moderate suitability for irrigation farming, being measurably lower in productive capacity and requiring higher land development costs than Class 1 lands. Nonarable lands include all those not meeting the minimum requirements for Class 2 lands.

In the land classification survey soil samples were collected from auger borings 5 feet deep, with at least one boring made for each square mile classified. The samples were analyzed for salt content, reaction or pH factor, and lime content. Recording of the locations and logs of the borings and the delineation of the various land classes were done in the field on photographic base maps on a scale of 2 inches to the mile. Standards used in the classification are shown in Table XXI.

Lands in the Navajo Indian Reservation included in the potential Shiprock project were covered by a detailed land classification survey completed in June 1949. This survey was made by the Bureau of Indian Affairs with Bureau of Reclamation personnel and was made to Bureau of Reclamation standards. The classification covered the lands in the reservation 150 to 200 feet in elevation above the Shiprock Gravity Canal. Other high lands in the eastern portion of the reservation that would be served by a large South San Juan project were mapped in a reconnaissance classification made by the Bureau of Reclamation in 1933 in connection with similar work being done throughout the Upper Colorado River Basin.

Table XXI
STANDARDS FOR
RECONNAISSANCE LAND CLASSIFICATION
SOUTH SAN JUAN AREA

Land characteristics	Class 1	Class 2
Soils (s)		
Texture	Sandy loam to friable clay loam	Loamy sand to permeable clay
Depth		
To sand, gravel, or cobble	30" plus of good free working soil	(1) Sandy loam or heavier--20" plus (2) Loamy sand--30" plus
To impervious subsoil material	48" plus	36" plus
To penetrable lime zone	18" with 28" penetrable	12" with 36" penetrable
Alkalinity	pH less than 9.0 unless soil is calcareous. Total salts are low and evidence of black alkali is absent.	pH 9.0 or less unless soil is calcareous. Total salts are low and evidence of black alkali is absent.
Salinity	Total salts not to exceed 0.2%. May be slightly higher in open permeable soils and under good drainage conditions.	Total salts not to exceed 0.5%. May be slightly higher in open permeable soils with good drainage.
Topography (t)		
Slopes		
Irregular slopes (old dunes)	Less than 2% in predominant slope	3% or less of predominant slope
Smooth slopes, reasonably large-sized bodies sloping in the same plane	3% or less	7% or less
Surface	No heavy grading required. May require small amount of leveling.	Moderate grading may be required, but in amounts generally found feasible in like areas where irrigation is practiced.

Table XXI (Cont'd)
STANDARDS FOR
RECONNAISSANCE LAND CLASSIFICATION
SOUTH SAN JUAN AREA

Land characteristics	Class 1	Class 2
Topography (Cont'd) Rocks and rocky soil	No rock in place. No loose rock that will interfere with ordinary cultivation.	No rock in place. Only scattered loose rock large enough to interfere with cultivation.
Drainage (d) Soil and topography	Soil and topographic conditions such that no specific drainage requirement is anticipated.	Soil and topographic conditions such that some drainage will probably be required, but with reclamation by artificial means appearing feasible at reasonable cost.
Nonarable Lands (Class 6)	Includes lands which do not meet the minimum requirements for Class 2, also small areas of arable lands lying within large bodies of nonarable land where these would obviously not make usable fields.	

Results of Classification

Of the total 2,500,000 acres covered in the inventory survey east of the Navajo Indian Reservation, 555,134 acres or about 22 percent was classed as arable. Of the arable land, 19,474 acres or 3.5 percent was mapped as Class 1 and 535,660 acres or 96.5 percent was mapped as Class 2.

Arable lands in the large South San Juan project of 67,700 acres include 62,700 acres of Class 2 land and only 5,000 acres, about 7 percent, of Class 1 land. Thus for purposes of the reconnaissance study, all arable lands of the South San Juan project can be assumed as equivalent to Class 2 land. The acreages given are net acreages with appropriate reductions made for public rights-of-way, farmsteads, and other minor uncropped areas.

Topography

Topography varies greatly over the project area. In general the surface is relatively level to steeply undulating or hummocky with frequent interruptions in general gradient. This uneven surface is mainly the result of the wind action which forms a number of nonarable sand dune tracts which are interspersed among the arable tracts. Generally the soil is deep enough on the arable land to permit any necessary leveling without reducing the quality of the land. The project lands are dissected by the tributaries of the Gallegos, Kutz, and Ojo Amarillo Canyons and the lower Chaco River, all of which flow north to the San Juan River.

Soils

The geological materials from which some of the project soils have developed lie beneath the soils. These materials consist largely of calcareous sediments of the Tertiary age, including such formations as the Torrejon and Puerco and the Ojo Alamo sandstone. Other geological formations outside the area evidently contributed to a large portion of the soil material as a result of wind action.

The soils have developed largely under the controlling influences of a continental arid climate and a subsequently limited vegetative cover. As a result of the dry climate and sparse vegetative cover, the soils are relatively low in organic matter, light-colored, and normally highly calcareous both at and below the surface. Having developed under a light rainfall, they are generally unleached and have lost little of the elements of fertility present in the parent material. Most of the soils, having been developed from sandstone, are generally light-textured and light brown in color. They are principally aeolian in nature as indicated by the considerable wind action and many sand dunes present. These ridges of blown sand, which run generally in a northeasterly direction, are not considered arable. They are constantly shifting or reforming and thus encroach on present arable land. Typical 5-foot profiles show a single-grained structure and deep, light-textured soils. The soils consist mainly of brown sandy loams, loamy sands, and sands, the texture becoming more sandy as the soil depth is increased. The sandy subsoils are usually well leached of toxic soluble salts and, where undisturbed, they are characterized by bands of lime accumulation. Small rocks and gravel are sometimes present in the subsoil.

Drainage

The light-textured aeolian soils of the project area provide excellent internal drainage and the numerous natural drainage channels provide adequate surface drainage over most of the area. A few small enclosed basins in the dune area, however, are expected to require construction of supplemental drainage ditches.

Alkalinity and Salinity

The light-textured aeolian soils of the project area are relatively free of toxic soluble salts or excessive alkalinity. In general, they contain less than 0.1 percent total soluble salts, are moderately to highly calcareous, and have a pH reaction of less than 8.0.

CHAPTER VI

A G R I C U L T U R A L E C O N O M Y

Introduction

This chapter deals with a reconnaissance evaluation of the agricultural economy as it would be expected to develop on the lands of a large South San Juan project. The economy in San Juan County, N. Mex., and that of the entire San Juan Basin was considered in anticipating the economy that would be expected to develop on the project. The farming area along the San Juan River extending upstream from Farmington, N. Mex., (elevation 5,300 feet) to the Colorado State line (elevation 6,200 feet) was considered comparable in climate, growing season, and type of crops grown to that of the project area which ranges from 5,400 feet to 6,135 feet in elevation.

Primary data used in the study were obtained from San Juan County court house records and from the county agent. Secondary data were obtained from the following sources: agricultural statistics of the United States Department of Agriculture, Bureau of Agricultural Economics reports, Department of Commerce agricultural census records (1940 and 1945), Pine River project crop reports, Columbia Basin joint investigation, restudy of size of farm units in Columbia Basin, Uncompahgre project report, and New Mexico State Experiment Station publications.

Present Land Use

Because of the arid climatic conditions, dry farming is not practicable in the area. The present use of project lands is therefore limited to grazing. The range-carrying capacity of these lands is about the same as that of the nearby Navajo Indian Reservation lands which has been estimated at nine cows per section of land (about 1/6 AUM per acre), having an annual value of not over $0.30 an acre.1/ This value is considered negligible compared to the production value of the lands under irrigation, and therefore the productive capacity of the lands without irrigation was ignored in the study.

Project lands are now largely in Federal and Indian ownership. Of the irrigable area, about 43 percent is Indian-owned and about 57 percent non-Indian-owned or controlled. About 91 percent of the Indian-owned land is within the boundaries of the Navajo Indian Reservation and

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1/ Type of Farming and Ranching Areas, New Mexico State College Bulletin No. 267.

about 9 percent is outside the reservation. A preliminary estimate indicates the present ownership of non-Indian lands to be as follows: public domain or other Federal land about 75 percent, State land about 4 percent, and privately owned land about 21 percent.

The reconnaissance land classification showed about 93 percent of the land to be Class 2 with respect to its relative suitability for irrigation farming. For the purpose of this economic study, all arable lands in the project were therefore considered the equivalent of Class 2.

Anticipated Land Use

It is expected that farming on the project would follow a similar pattern to that of the presently irrigated area along the San Juan River in New Mexico. Under mature development, however, a slightly more intensive type of farming could be expected to be practiced on project lands. Principal crops in this area are alfalfa, corn, field beans, and apples. The 1945 census showed San Juan County as the largest apple-producing county in the State of New Mexico.

In the selection of representative farm units for this project, the Production and Marketing Administration records of 154 farms along the San Juan River were studied. The average size of farm included 37.4 acres of crop land plus some range land pasture. A farm of this size is considered too small for a family unless fruit or vegetables are raised. For this study three distinct types of farms have been analyzed to represent the more important types of farming expected to develop on the South San Juan project. The anticipated types of farms and a weighted average compared to present farming practices along the San Juan River are shown in Table XXII. From the analyses fruit-crop farms on the project would be expected to average about 32 acres in size. A dairy-field crop farm would approximate 85 acres and a general crop-livestock farm about 138 acres. Of the total project area, it is anticipated that 26 percent would be in fruit-crop farms, 52 percent in dairy-field crop farms, and 22 percent in general crop-livestock farms.

The entire area of the South San Juan project, consisting of both non-Indian and Indian lands, has been analyzed on the basis of type of farming, payment capacities, and benefits that would be expected from the area under management efficiency equivalent to that of non-Indian operators.

The average size farm (all types of farming) under anticipated conditions would be about 63.4 acres as compared with the present average of 37.4 acres, exclusive of pasture land, along the San Juan River. Anticipated land use is based on a full water supply with no significant shortages.

Table XXII
ANTICIPATED LAND USE PER FARM

Item	Present		Anticipated on project				
	Average 154 farms		Estimated average (1,135 farms)		Fruit-crop (578 farms)	Dairy-crop (441 farms)	General crop-livestock (116 farms)
Crops	Acres	Percent	Acres	Percent	Acres	Acres	Acres
Alfalfa	11.7	31.2	15.96	25.2	6	24	35
Corn	10.5	28.0	11.10	17.5		22	25
Beans (dry)	5.3	14.1	5.42	8.6		10	15
Wheat	3.1	8.2	5.77	9.1	3	7	15
Barley	1.9	5.1	5.92	9.3	5	5	14
Potatoes	1.1	3.0	1.16	1.8		3	
Orchard	2.4	6.6	6.36	10.0	12	0.5	0.5
Garden	0.5	1.3	1.26	2.0	2	0.5	0.5
Pasture(rotation)		1/	6.67	10.5	2	8	25
Farmstead & waste		1/	3.78	6.0	2	5	8
Total	37.4	100.0	63.40	100.0	32	85	138
Total gross irrigable area in project			71,989 2/		18,496	37,485	16,008
Livestock	Number		Number		Number	Number	Number
Dairy cows	3		6.0		2	12	3
Beef cows	7		1.6		--	--	16
Brood sow	1		1.9		1	3	2
Chickens			75		50	100	100

1/ 13.9 acres of land listed by the Production and Marketing Administration were farmstead and grazing land, but not classified as to the exact acreage of each. Farms also averaged 90 acres of dry grazing land.

2/ Total gross area less approximately 4,289 acres in farmstead and waste leaves 67,700-acres net irrigable area in project.

Crop Yields and Prices

Estimated crop yields are based on records from the following sources: Pine River project crop reports, Department of Commerce Census of Agriculture, Farmers' Home Administration, and interviews with the county agent and farmers in San Juan County. Adjustments were made on the basis that sufficient commercial fertilizer would be used to maintain original fertility of the soil. Crop yields used are for marketable products.

The 1939-1944 price period has been used as the base period for this study.

Primary source of prices was the Colorado and New Mexico Agricultural Statistics. Table XXIII shows average crop yields and prices used in the analysis.

Table XXIII
CROP YIELDS AND PRICES (1939-1944)

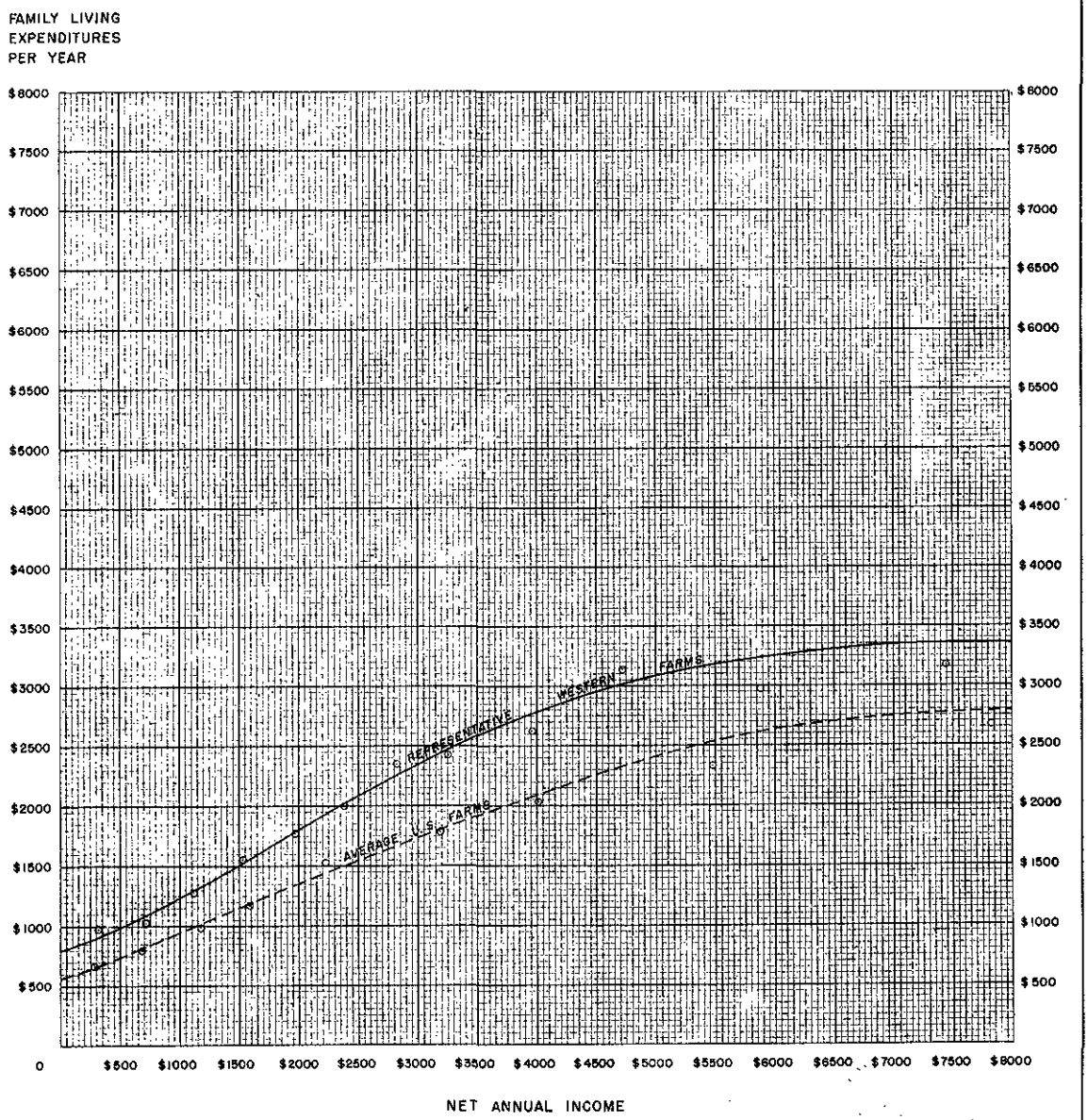
Item	Unit	Yield per acre	Price
Crops			
Alfalfa	ton	3.0	$11.00
Corn	bu.	38.0	.92
Oats	bu.	40.0	.53
Barley	bu.	40.0	.62
Wheat	bu.	30.0	.90
Beans	cwt.	11.5	4.20
Potatoes	bu.	120.0	.65
Apples	bu.	155.0	1.25
Garden (commercial)	acre		220.00
Orchard (home use)	acre		150.00

Family Living Allowance

The family living allowance for conditions anticipated with project development was determined from a relationship between income and family living costs. It is generally conceded that as the net income of the family becomes higher the amount spent for living expenses also becomes higher. It is not in direct relationship, however, because living expenditures tend to level out as income increases. This is depicted in the chart, Family Living Expenses in Relation to Income, on the following page. This study complies with the minimum living allowance in studies made by the Bureau of Reclamation so that full-time farmers would have units of sufficient size to yield an income that would allow a family living expense of at least $1,500 above farm operating expenses. This family living allowance includes cash living expenses and the value of farm-furnished products used by the family and the value of farm housing. In this study, an allowance was made to cover the $1,500 level of living plus a reasonable amount for capital accumulation or debt retirement and life insurance not included in the $1,500. To keep in line with the recently adopted long-term price-projection level of 215 (1910-14 = 100), an adjustment has been made in the financial summary of the farm budget by increasing the payment capacity per net irrigable acre by 50 percent. This adjustment then reflects an increase in the family living allowance from $1,500 to $2,250.

FAMILY LIVING EXPENDITURES IN RELATION TO FARM INCOME

LONG-TERM PROJECTED PRICE LEVEL
OF 215 (1910-14=100)



Capital Accumulation and Debt Retirement

With the development of a new farm, a provision should be made for long-term loans that are available to farmers for land improvement, construction of new farm buildings and a dwelling. In addition to the previously mentioned standard of living, an allowance of about $120 to $200 should be provided to cover capital accumulation and debt retirement.

In this study 2-percent interest on total investment has been allowed as an additional expense in the farm budget for capital accumulation and debt retirement. This was added to the normal charge of 3-percent interest on total farm investment. This additional interest charge is estimated to meet normal requirements for long-term loans and permit the average farmer to acquire a debt-free farm over a 35- to 45-year period.

Markets

The industrial expansion and resultant increase in population of the southwestern United States have opened new markets to the San Juan area that were not anticipated a decade ago. Truck transportation has been largely responsible for opening these markets to the farmers of the San Juan Basin.

At the present time, most of the crops grown are for local consumption or use. The most important export crops are apples and pinto beans. With a large increase in irrigated acreage, however, a better and more stable source of supply could be expected for outside markets. This would result in more intensive farming of high-value crops for export from the area.

Method of Study

The two methods used in estimating the capacity of farmers to pay toward irrigation water costs were the farm budget analysis and the income-to-land method.

Farm Budget Analysis

This method provides for a systematic and detailed outlining of the organization and operation of representative family-sized farm units. Consideration was given to anticipated yields, income, and expenditures for a normal year. From these data net farm income and payment capacity may be determined.

Income-to-Land Method

This method provides for an analysis of the gross income (share of crops), expenses, and net income properly accruing to land and fixed capital. The method is based on the premise that some of the receipts are income-to-land and other fixed capital, while the balance is income to operating capital and management. The accuracy of this method is dependent on determining the proper proportion of income and expenses belonging to land. The farm lease agreement in the area is generally used as a basis for the division of income and expenses. In San Juan County, N. Mex., only about 10 percent of the farms were operated by tenants, and therefore tenant agreements are not sufficient to be considered entirely reliable. This income-to-land method, however, was used to check the results of the farm budget method.

Investment Value of Land

Class 2 irrigable land has been estimated to have an investment value of $5 per acre for the 1939-1944 period. Most of the land in the project area is public domain with no improvements. The following summary shows estimated average costs per acre of land to prepare it for irrigation farming.

Table XXIV
COST OF LAND AND IMPROVEMENTS PER GROSS IRRIGABLE ACRE
(1939-1944 PERIOD)

Item	Estimated cost per acre
Class 2 irrigable land	$5.00
Clearing land	5.00
Level, plow, float, and corrugate	10.00
Ditches and structures	10.00
Engineering and contingencies	5.00
Total cost per acre	$35.00

Representative Farm Units

The farm lands that would be developed are expected to be comparable in most respects to the adequately irrigated full-time farms now being operated along the San Juan River. After due consideration of all influencing factors, three farm budgets were selected as representative of full-time farms anticipated for the project. Details of the organization of those farm units are presented in the following paragraphs.

Farm Budget Summary, Fruit-Crop Farm

The farm budget summary included as Table XXV on page 62 covers information developed for a 32-acre fruit-crop farm with mature development. This type of farm is considered representative of the small fruit or crop specialty farms expected to develop on the project area. It is realized that many fruit crops such as peaches, pears, apricots, grapes, and other similar crops may also be grown. Apples were used in the analysis, however, since more data were available locally on apple production than on any other crop and since apples are the most important fruit-cash crop now grown in the area.

Farm Budget Summary, Dairy-Field Crop Farm

The farm budget summary included as Table XXVI on page 63 covers information developed for an 85-acre dairy-field crop farm with mature development. This type of farm is considered representative of the average type farm built around a dairy enterprise. Orchard and gardens would be small and used primarily for production for home consumption on the farm. Dry beans and potatoes would be the most important cash crops.

Farm Budget Summary, General Crop-Livestock Farm

The farm budget summary included as Table XXVII on page 64 covers information developed on a 138-acre general crop-livestock farm with mature development. This farm is considered representative of an average type farm built around livestock and general field crops. Orchards and gardens would be small and used primarily for production for home consumption on the farm. Alfalfa and corn would be the primary surplus feed crops grown. Dry field beans would be one of the most important cash crops.

Payment and Amortization Capacity

One purpose of the farm budget analysis is to determine the capacity of representative farm units on the project to pay costs of furnishing irrigation water for the farm. The amount remaining after deductions for farm-operating and family living expenses from the gross farm income is the amount available for payment of irrigation costs. The amount remaining after deductions for the annual costs for operation, maintenance, and replacements of irrigation facilities from the payment capacity is the amortization capacity or the annual amount available to pay on construction costs of the project works. In order to show economic feasibility under the new price level, as recently adopted, the payment capacity per acre has been increased by 50 percent. Also the annual operation, maintenance, and replacement costs have been increased to 180 percent of 1940 costs and a 25-percent contingency factor has been applied in the estimates of amortization capacity.

Table XXV

SUMMARIZED BUDGET FOR FRUIT-CROP FARM WITH PROJECT DEVELOPMENT--SOUTH SAN JUAN PROJECT 1/

Crops and livestock	Percent of area	Acres or numbers	Unit	Production: Average yield per acre or animal	Production: Total	Value 2/: Unit	Value 2/: Total	Disposition of produce 2/: Farm	Disposition of produce 2/: Family use	Disposition of produce 2/: Sales value	Income to land: Part	Income to land: Value
Orchard (apples)	37.5	12	bu.	155	1,860	$1.25	$2,325		$22	$2,303	1/4	$581
Alfalfa	18.8	6	ton	3	18	11.00	198	$117		81	1/2	99
Barley	15.6	5	bu.	40	200	.62	124	113		11	1/3	41
Wheat	9.4	3	bu.	30	90	.90	81	73		8	1/3	27
Truck garden	6.2	2	acre			220.00	440		44	396	1/4	110
Pasture	6.3	2	AUM	8	16	2.00	32	32			1/2	16
Pasture aftermath 4/		(6)	AUM	.5	3	2.00	6	6				
Farmstead and waste	6.2	2	acre									
Total crops	100.0	32					$3,206	$341	$66	$2,799		$874
Dairy cows												
Butterfat		2	lbs.	240	480	$.36	$173	$6	$63	$104		
Cull beef			lbs.	168	336	.061	20			20		
Veal beef			lbs.	70	140	.11	15			15		
Dairy heifers			lbs.	80	160	.10	16			16		
Hogs												
Cull sows		1	lbs.	104	104	.078	8			8		
Market hogs			lbs.	1,750	1,750	.10	175		40	135		
Chickens												
Meat		50	lbs.	6.8	341	.16	55		34	21		
Eggs			doz.	8.5	420	.24	100		32	68		
Total livestock							$562	$6	$169	$387		
Total crops and livestock							$3,768	$347	$235	$3,186		$874

Current Farm Expenses	Farm budget	Income to land
General expenses	$400	$271
Interest 3/	132	99
Taxes	12	12
Insurance		
Depreciation and repair	304	212
Auto farm share	148	
Electricity	24	
Tractor	195	
Crop expense		
Seed	67	
Harvesting	28	
Fertilizer	8	
Dusting and spraying	94	
Hired labor	40	
Orchard depreciation (5%)	90	
Livestock expenses		
Feed	11	
Supplies and veterinary	15	
Baby chicks	13	
Miscellaneous		
2% of above	31	
Total	$1,612	$594

Farm Investment	Farm budget	Income to land
Land	$2,875	$2,875
Farm buildings	394	394
House	1,500	1,500
Fences	102	102
Domestic water system	540	540
Machinery and equipment	2,305	
Livestock	203	
Feed and supplies	72	
Total	$7,991	$5,411

Level of Living	
Cash, family	$1,164
Home-used produce	235
Use of dwelling	226
Living allowance	$1,625
Capital accumulation	160
Level of living	$1,785

Farm Work	Days
Crops	184
Livestock	65
Miscellaneous	7
Total	256
Work by operator	235
Family	12
Hired	9
Total	256

Financial Summary	Farm budget	Income to land
Crop sales	$2,799	$874
Livestock	215	
Livestock products	172	
Farm privileges	461	
Total	$3,647	$874
Farm expenses	1,612	594
Net farm income	$2,035	$280
Family living allowance	1,625	
Payment capacity per farm	$410	$280
Payment capacity per net irrigable acre 1/	$13.67	$9.33
Irrigation operation and maintenance costs per net irrigable acre	3.29	3.29
Available for construction charges per net irrigable acre	$10.38	$6.04

Footnotes to Budget Summary

1/ Budget made for 32-acre farm of Class 2 land. Net irrigable area, which excludes farmstead and waste areas, is 30 acres.

2/ Values at average prices for 1939-1944 period.

3/ Interest at 5 percent, of which 2 percent is used for capital accumulation and debt retirement.

4/ Duplicated acreage.

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Table XXVI

SUMMARIZED BUDGET FOR DAIRY-FIELD CROP FARM WITH PROJECT DEVELOPMENT--SOUTH SAN JUAN PROJECT 1/

Crops and livestock	Percent of area	Acres or numbers	Unit	Production: Average yield per acre or animal	Production: Total	Value 2/: Unit	Value 2/: Total	Disposition of produce 2/: Farm	Disposition of produce 2/: Family use	Disposition of produce 2/: Sales value	Income to land: Part	Income to land: Value
Alfalfa	28.2	24	ton	3.0	72	$11.00	$792	$680		$112	1/2	$396
Corn	25.9	22	bu.	38.0	836	.92	769	304		465	1/3	256
Dry beans	11.8	10	cwt.	11.5	115	4.20	483	21		462	1/3	161
Pasture (rotation)	9.4	8	AUM	8.0	64	2.00	128	128			1/2	64
Wheat	8.2	7	bu.	30.0	210	.90	189	108		81	1/3	63
Barley	5.9	5	bu.	40.0	200	.62	124	79		45	1/3	41
Potatoes	3.5	3	bu.	120.0	360	.65	234			234	1/4	57
Orchard (home use)	.6	0.5	acre			150.00	75		$22	53	1/4	19
Garden (home use)	.6	0.5	acre			220.00	110		44	66	1/4	27
Pasture aftermath 4/		(55)	AUM	.5	27.5	2.00	55	55				
Farmstead and waste	5.9	5	acre									
Total crops	100.0	85					$2,959	$1,375	$66	$1,518		$1,084
Dairy cows												
Butterfat		12	lbs.	240	2,880	$.36	$1,037	$35	$63	$939		
Cull beef			lbs.	168	2,016	.061	123			123		
Veal beef			lbs.	70	840	.11	92			92		
Dairy heifers			lbs.	80	960	.10	96			96		
Hogs												
Cull sows		3	lbs.	104	312	.078	24			24		
Market hogs			lbs.	1,750	5,250	.10	525		40	485		
Chickens												
Meat		100	lbs.	6.8	680	.16	109		34	75		
Eggs			doz.	8.5	850	.24	204		32	172		
Total livestock							$2,210	$35	$169	$2,006		
Total crops and livestock							$5,169	$1,410	$235	$3,524		$1,084

Current Farm Expenses	Farm budget	Income to land
General expenses	$475	$298
Interest 3/	217	162
Taxes	12	12
Insurance	355	260
Depreciation and repairs	148	
Auto farm share	24	
Electricity	263	
Tractor expense		
Crop expenses		
Seed	90	
Harvesting	91	
Fertilizer	30	
Dusting and spraying	38	
Hired labor	84	
Planting expense	21	
Livestock expense		
Feed	20	
Supplies and veterinary	70	
Baby chicks	26	
Miscellaneous		
2% of above	38	
Total	$2,002	$732

Farm Investment

	Farm budget	Income to land
Land	$2,850	$2,850
Farm buildings	816	816
House	1,500	1,500
Fences	262	262
Domestic water system	540	540
Equipment	1,854	
Livestock	1,393	
Feed and supplies	289	
Total	$9,504	$5,968

Level of Living

Cash, family	$1,114
Home-used produce	235
Use of dwelling	226
Living allowance	$1,575
Capital accumulation	190
Level of living	$1,765

Farm Work

	Days
Crops	170
Livestock	232
Miscellaneous	17
Total	419
Work by operator	290
Family	105
Hired	24
Total	419

Financial Summary

	Farm budget	Income to land
Crop sales	$1,518	$1,084
Livestock	895	
Livestock products	1,111	
Farm privileges	461	
Total	$3,985	$1,084
Farm expenses	2,002	732
Net income	$1,983	$352
Family living allowance	1,575	
Payment capacity per farm	$408	$352
Payment capacity per net irrigable acre 1/	$5.10	$4.40
Irrigation operation and maintenance per net irrigable acre	3.29	3.29
Available for construction charges per net irrigable acre	$1.81	$1.11

Footnotes to Budget Summary

1/ Budget made for 85-acre farm of Class 2 land. Net irrigable area, which excludes farmstead and waste area, is 80 acres.

2/ Values at average prices for 1939-1944 period.

3/ Interest at 5 percent, of which 2 percent is used for capital accumulation and debt retirement.

4/ Duplicated acreage.

Table XXVII

SUMMARIZED BUDGET FOR GENERAL CROP-LIVESTOCK FARM WITH PROJECT DEVELOPMENT--SOUTH SAN JUAN PROJECT 1/

Crops and livestock	Percent of area	Acres or numbers	Unit	Production: Average yield per acre or animal	Production: Total	Value 2/: Unit	Value 2/: Total	Disposition of produce 2/: Farm	Disposition of produce 2/: Family use	Disposition of produce 2/: Sales value	Income to land: Part	Income to land: Value
Alfalfa	25.4	35	ton	3	105	$11.00	$1,155	$643		$512	1/2	$577
Corn	18.1	25	bu.	38	950	.92	874	5		869	1/3	291
Pasture (rotation)	18.1	25	AUM	8	200	2.00	400	400			1/2	200
Beans (dry field)	10.9	15	cwt.	11.5	173	4.20	727	31		696	1/3	242
Wheat	10.9	15	bu.	30.0	450	.90	405	162		243	1/3	135
Barley	10.1	14	bu.	40.0	560	.62	347	223		124	1/3	116
Orchard (home use)	.4	.5	acre			150.00	75		$22	53	1/4	18
Garden (home use)	.4	.5	acre			220.00	110		44	66	1/4	27
Raw land pasture		60	AUM	.15	9	2.00	18	18				
Pasture aftermath 4/		(104)	AUM	.5	52	2.00	104	104				
Farmstead and waste	5.7	8										
Total crops	100	138					$4,215	$1,586	$66	$2,563		$1,606
Dairy cows												
Butterfat		3	lbs.	240	720	$.36	$259	$8	$63	$188		
Cull beef			lbs.	168	504	.061	31			31		
Veal beef			lbs.	70	210	.11	23			23		
Heifers			lbs.	80	240	.10	24			24		
Beef cows												
Cull		16	lbs.	140	2,240	.10	224			224		
Market beef			lbs.	535	8,560	.10	856		20	836		
Hogs												
Cull sows		2	lbs.	104	208	.078	16			16		
Market hogs			lbs.	1,750	3,500	.10	350		20	330		
Chickens												
Meat		100	lbs.	6.8	680	.16	109		34	73		
Eggs			doz.	8.5	850	.24	204		32	172		
Total livestock							$2,096	$8	$169	$1,919		
Total crops and livestock							$6,311	$1,594	$235	$4,482		$1,606

Current Farm Expenses	Farm budget	Income to land
General expenses	$654	$425
Interest 3/	327	248
Taxes	12	12
Insurance	474	300
Depreciation and repairs	183	
Auto farm share	24	
Electricity	310	
Tractor expense		
Crop expenses		
Seed	90	
Harvesting	144	
Fertilizer	44	
Dusting and spraying	44	
Hired labor	28	
Livestock expenses		
Feed	25	
Supplies and veterinary	49	
Baby chicks	26	
Miscellaneous		
2% of above	47	
Total	$2,481	$985

Farm Investment

	Farm budget	Income to land
Land	$4,900	$4,900
Farm buildings	973	973
House	1,500	1,500
Fences	583	583
Domestic water system	540	540
Equipment	1,965	
Feed and supplies	248	
Livestock	2,377	
Total	$13,086	$8,496

Level of Living

Cash, family	$1,324
Home-used produce	235
Use of dwelling	226
Living allowance	$1,785
Capital accumulation	262
Level of living	$2,047

Farm Work

	Days
Crops	189
Livestock	162
Miscellaneous	22
Total	373
Work by operator	290
Family	75
Hired	8
Total	373

Financial Summary

	Farm budget	Income to land
Crop sales	$2,563	$1,606
Livestock	1,559	
Livestock products	360	
Farm privileges	461	
Total	$4,943	$1,606
Farm expenses	2,481	985
Net income	$2,462	$621
Family living allowance	1,785	
Payment capacity per farm	$677	$621
Payment capacity per net irrigable acre 1/	$5.21	$4.78
Irrigation operation and maintenance costs per net irrigable acre	3.29	3.29
Available for construction charges per net irrigable acre	$1.92	$1.49

Footnotes to Budget Summary

1/ Budget made for 138-acre farm. Net irrigable acreage, which excludes farmstead and waste areas, is 130 acres.
2/ Values at average prices for 1939-1944 period.
3/ Interest at 5 percent, of which 2 percent is used for capital accumulation and debt retirement.
4/ Duplicated acreage.

Table XXVIII summarizes the estimated payment and amortization capacity and probable annual installment that would be made on construction costs.

Table XXVIII
SUMMARY OF ESTIMATED PAYMENT AND
AMORTIZATION CAPACITY AND PROBABLE ANNUAL INSTALLMENT

Item	Fruit-crop farms	Dairy-field crop farms	General crop-livestock farms	Total for project
Net irrigable acreage	17,340	35,280	15,080	67,700
Payment capacity per net irrigable acre increased 50%	$20.50	$7.65	$7.81	
25% contingencies	-5.12	-1.91	-1.95	
O&M and replacement cost per net acre 1/	-4.23	-4.23	-4.23	
Amortization capacity per net acre	$11.15	$1.51	$1.63	
Probable annual installment per net irrigable acre				$1.50
Total probable annual installment on project construction costs				$102,000

1/ Estimated at 180 percent of 1940 costs.

Settlement Opportunities

The opportunity to develop and settle new farms would be very extensive on this project as none of the land has been developed or used for other than grazing purposes. The size of farm anticipated for this project is expected to average about 50 to 70 net irrigable acres. The project would thus permit the development of around 1,000 to 1,300 new farm units under conditions of mature development. This would increase by 80 to 100 percent the number of farms reported in San Juan County by the 1945 Census of Agriculture.

Development Period

A development period of about 10 years would be desirable on the South San Juan project before assessments for construction charges were made. Three or four years would be required to complete the necessary improvements, farm buildings, and other farm improvements. An additional 2 or 3 years would be needed to attain normal crop rotation and crop production. Since a portion of the farmers' income would be derived from orchards, which require from 7 to 10 years for development, 1 or 2 years of normal production should be allowed before full charges are made in order to provide the settlers with the opportunity of improving their financial status.

Repayment Organization

A suitable entity could no doubt be organized to represent the project water users in the necessary repayment contracts with the Federal Government and to operate and maintain the project.

CHAPTER VII

F I N A N C I A L A N A L Y S I S

The relative economic justification of the project development is measured by comparing the over-all benefits that would result from the development with the associated over-all costs of the project. For purposes of the comparison, benefits and costs have been computed as average annual equivalents over a 100-year common-time period. The useful economic life of the project has been estimated at 150 years, and operation, maintenance and replacement costs have been estimated to maintain all facilities in good operating condition throughout this period. Construction costs have been estimated at July 1951 prices. Project benefits and operation, maintenance, and replacement costs have been estimated at average 1939-1944 prices and have been adjusted to the newly adopted price level as explained in the previous chapter. All computations for the benefit-cost analysis are based on an interest rate of 2.5 percent.

For the purpose of this reconnaissance report the irrigation benefits for a project of 67,700 net acres have been computed in detail. Benefits for projects of other sizes, except Plan A, are assumed to average the same per acre as the project analyzed in detail. Benefits for Plan A, however, were computed separately.

Project Benefits

Tangible benefits that would result from the South San Juan project are associated primarily with river regulation for irrigation and incidental uses including sediment retention, flood control, fish and wildlife propagation and conservation, and recreation. While all of these benefits are measurable in monetary terms, they would be relatively small compared to the irrigation benefits. Therefore only the benefits that would be derived from irrigation have been evaluated for the purpose of the reconnaissance study.

Intangible benefits that would be attributable to the project are considered sufficient to offset intangible costs.

Irrigation benefits are divided into two classes, direct and indirect. Direct benefits are taken as the increase in net income to the farmer. The total annual direct irrigation benefits for the 67,700-acre project under mature development are estimated at $3,813,989 as shown in the following table.

Table XXIX
DIRECT IRRIGATION BENEFITS

Item	Fruit-crop farm	Dairy-field crop farm	General crop-livestock farm
Cash receipts	$3,186	$3,524	$4,482
Farm privileges	461	461	461
Debt retirement and capital accumulation	160	190	262
Total income	$3,807	$4,175	$5,205
Less farm expenses 1/	1,612	2,002	2,481
Direct benefits to project farmers	$2,195	$2,173	$2,724
Direct benefits to project farmers increased by 50%	$3,292	$3,259	$4,086
Total direct benefits per net irrigable acre	109.73	40.74	31.43
Total net irrigable acres each type farm	17,340	35,280	15,080
Total benefits each type farm	$1,902,718	$1,437,307	$473,964
Total project direct irrigation benefits		$3,813,989	
Total project direct irrigation benefits per acre		56.34	

1/ Expenses as used for benefit calculations are exclusive of allowance for family labor.

Indirect irrigation benefits are those that accrue from channeling of increased agricultural production through business and industrial firms. Net benefits accruing from the handling and processing of the products sold from the farm are Class 1 indirect benefits. Total Class 1 indirect benefits are estimated at $2,116,186 annually as shown in the table on the following page. Class 2 indirect net benefits accrue from purchase of goods and services and are estimated to be 15 percent of the value of the estimated direct benefits of the project. Class 2 benefits thus estimated would total $572,098 annually.

Colorado River Storage Project

The benefits of future water-consuming projects in the States of the upper division as defined by the Colorado River Compact are partially dependent upon water being made available through river regulation of the Colorado River Storage project. An appropriate share of the storage project cost, therefore, has been assigned to dependent projects for the benefit-cost analyses, but not for repayment. The assigned cost is estimated at $2.35 an acre-foot of stream depletion. The depletion for Plan D-2 of the Shiprock project, including a portion of the evaporation from Navajo Reservoir, is estimated at 174,900 acre-feet annually, equivalent to an annual cost of $411,000.

Table XXX
ESTIMATED CLASS 1 INDIRECT IRRIGATION BENEFITS

Item	Sales value	Percent factor	Indirect benefit
Fruit-crop farm			
Feed	$81	55	$45
Grain for milling	19	83	16
Fruits and vegetables sold fresh	2,699	65	1,754
Livestock	194	55	107
Poultry	89	52	46
Dairy products	104	71	74
Total farm (30 net irrigable acres)	$3,186		$2,042
Total farm increased 50%	4,779		$3,063
Total per net irrigable acre			$102.10
Total indirect benefits (17,340 irrigable acres)			$1,770,414
Total adjusted indirect benefits ($1,770,414 x .602) 1/			$1,065,789
Dairy field-crop farm			
Feed	$577	55	$317
Grain for milling	126	83	105
Fruits and vegetables sold fresh	815	65	530
Livestock	820	55	451
Poultry	247	52	128
Dairy products	939	71	667
Total farm (80 net irrigable acres)	$3,524		$2,198
Total farm increased 50%	$5,286		$3,297
Total per net irrigable acre			$41.21
Total indirect benefits (35,280 net irrigable acres)			$1,453,888
Total adjusted indirect benefits ($1,453,888 x .545) 1/			$792,369
General Crop-Livestock Farm			
Feed	$1,381	55	$760
Grain for milling	367	83	305
Fruits and vegetables sold fresh	815	65	530
Livestock	1,484	55	816
Poultry	247	52	128
Dairy products	188	71	133
Total farm (130 net irrigable acres)	$4,482		$2,672
Total farm increased 50%	6,723		4,008
Total per net irrigable acre			$30.83
Total indirect benefits (15,080 net irrigable acres)			$464,916
Total adjusted indirect benefits ($464,916 x .555) 1/			$258,028
Total adjusted Class 1 indirect benefits			$2,116,186

1/ Federal cost adjustment factor.

Irrigation Benefit-Cost Ratio

The annual benefits and annual equivalent costs of a 67,700-acre South San Juan project estimated for the purposes of this report are shown in the following tabulation.

Average Annual Equivalent Benefits

Direct irrigation benefits	$3,813,989
Indirect irrigation benefits Class 1	2,116,186
Indirect irrigation benefits Class 2	572,098
Total irrigation benefits	$6,502,273
Total average annual equivalent benefit adjusted for a 10-year development period (.885 x 6,502,273) attributable to South San Juan project	5,754,512
Total average annual equivalent benefit per net irrigable acre	85

Average Annual Equivalent Costs

	Total value	Average annual equivalent value
Construction costs	$136,013,000	
Interest (½ of 2⅝% of 136,013,000 for 5 years)	8,501,000	
Total construction cost	$144,514,000	
Less present worth of salvage value at end of 100 years (50/150 of $144,514,000 x .08465)	$4,078,000	
Net present worth of project investment	$140,436,000	
Present worth of project investment amortized over 100 years at 2⅝% (.02731 x $140,436,000)		$3,835,000
Operation, maintenance, and replacement costs		$252,000
Costs assigned from Colorado River Storage project		$411,000
Total average annual equivalent cost for project		$4,498,000
Total average annual equivalent cost per net irrigable acre		$66

For irrigation features the ratio of the average annual equivalent benefits to the average annual equivalent costs is 1.28 to 1 for Plan D-2.

Average annual equivalent costs and benefit cost ratios for other sizes of South San Juan projects considered are shown in Table I on page vi of the Synopsis.

Project Repayment

The cost of constructing the South San Juan project would be allocable to irrigation on a reimbursable basis. The annual operation, maintenance, and replacement costs would also be allocable to irrigation.

A summary of irrigation costs and annual payments for all plans is included in Table I on page vi.

CHAPTER VIII

P O T E N T I A L U P S T R E A M H Y D R O P O W E R

This chapter presents a brief description and reconnaissance appraisal of the potential hydropower development on the San Juan River and tributaries above the Navajo Reservoir site, excluding the tributary Pine River. Such power development may be considered an alternative to the possible power development of the San Juan-Chama project as the two possibilities are largely dependent on the same source of water. Any water diversion to the San Juan-Chama project in the amounts required to make that project economically justifiable would make unjustifiable any upstream power development within the San Juan Basin in the proportions described in this report. Diversions to the San Juan-Chama project from all San Juan River tributaries as far north as the West Fork would preclude all the potential power development except that on the Piedra River.

The reconnaissance appraisal of hydropower development is based largely on maximum potential development. It is possible that a somewhat more economical plan for power development on a smaller scale might be formulated with additional study.

Plan of Development

The plan of upstream power development as evolved from reconnaissance studies would involve the construction of five storage reservoirs, a system of diversion dams, canals and tunnels, five power plants, and an interconnecting transmission system to tie at Navajo Dam with the contemplated transmission system of the Colorado River Storage project. The general layout of the plan is depicted on the map on the following page. As shown on the map, the water conveyance system consists mostly of tunnels totaling 45 miles in length. The storage dams and transmission lines in the plan are listed in the tables on page 74.

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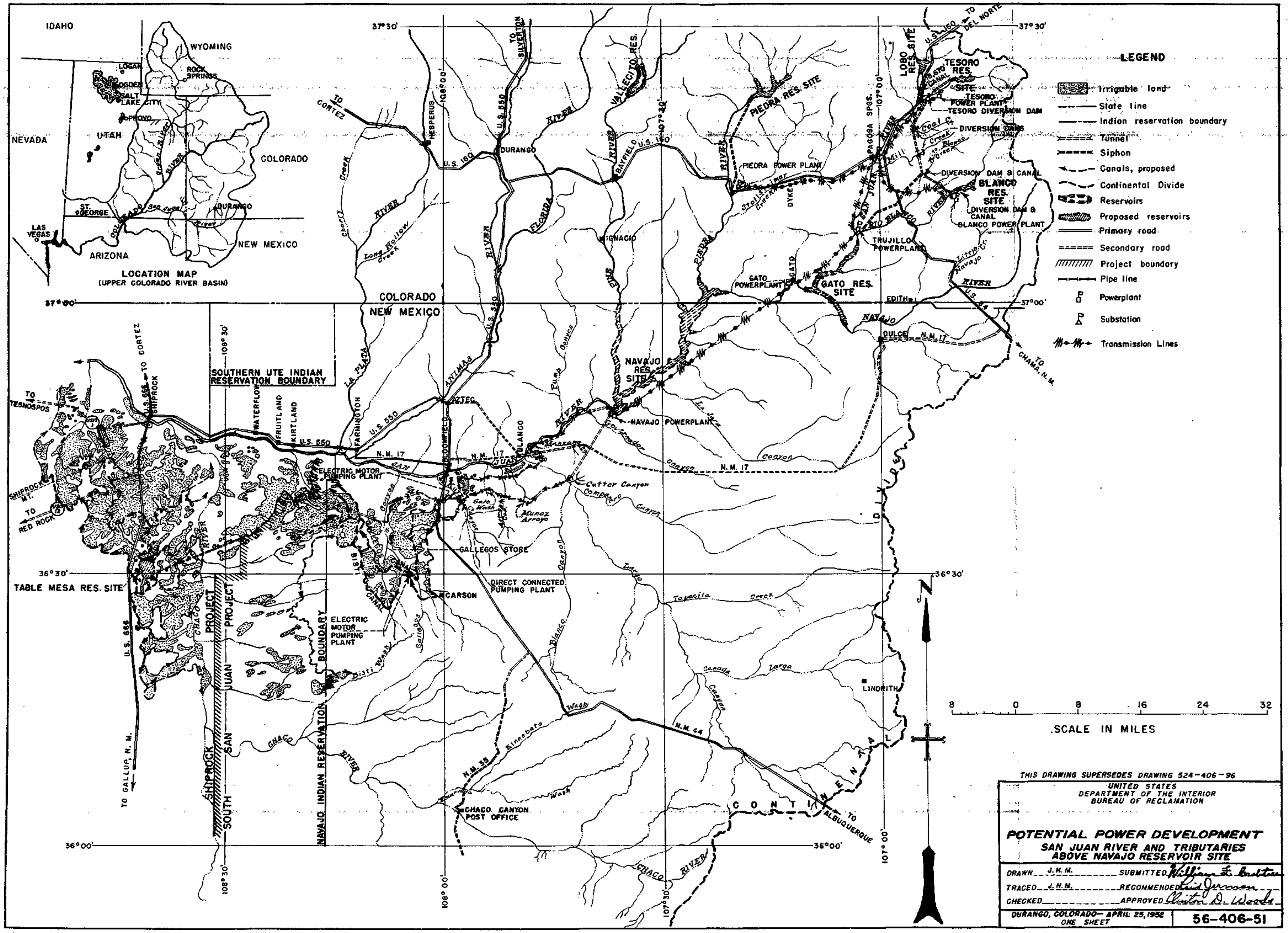
LOCATION MAP
(UPPER COLORADO RIVER BASIN)
IDAHO
WYOMING
NEVADA
UTAH
COLORADO
ARIZONA
NEW MEXICO
LEGEND
Irrigable land
State line
Indian reservation boundary
Tunnel
Siphon
Canals, proposed
Continental Divide
Reservoirs
Proposed reservoirs
Primary road
Secondary road
Project boundary
Pipe line
Powerplant
Substation
Transmission Lines
COLORADO
NEW MEXICO
SOUTHERN UTE INDIAN RESERVATION BOUNDARY
NAVAJO INDIAN RESERVATION BOUNDARY
SHIPROCK - SOUTH SAN JUAN PROJECT
TABLE MESA RES. SITE
NAVAJO RES. SITE
NAVAJO POWERPLANT
GATO RES. SITE
GATO POWERPLANT
BLANCO RES. SITE
BLANCO POWER PLANT
TESORO RES. SITE
TESORO POWER PLANT
TESORO DIVERSION DAM
LOBO RES. SITE
PIEDRA RES. SITE
PIEDRA POWER PLANT
VALLECITO RES.
TRUJILLO POWERPLANT
ELECTRIC MOTOR PUMPING PLANT
DIRECT CONNECTED PUMPING PLANT
GALLEGOS STORE
CARSON
CHACO CANYON POST OFFICE
LINDRITH
DURANGO
BAYFIELD
IGNACIO
AZTEC
FARMINGTON
BLOOMFIELD
DULCE
EDITH
CONTINENTAL DIVIDE
SCALE IN MILES
8 0 8 16 24 32
THIS DRAWING SUPERSEDES DRAWING 524-406-96
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
POTENTIAL POWER DEVELOPMENT
SAN JUAN RIVER AND TRIBUTARIES
ABOVE NAVAJO RESERVOIR SITE
DRAWN J.H.M.
TRACED J.H.M.
CHECKED
SUBMITTED
RECOMMENDED
APPROVED
DURANGO, COLORADO— APRIL 25, 1952
ONE SHEET
56-406-51

Table XXXI
STORAGE DAMS
HYDROPOWER DEVELOPMENT

Dam	River	Storage capacity (acre-feet)	Dam height (feet)	Crest elevation (feet)
Piedra	Piedra	273,500	400	7,680
Lobo	West Fork of San Juan River	90,000	180	7,906
Tesoro	East Fork of San Juan River	60,000	193	8,210
Blanco	Blanco	60,000	165	8,063
Gato	San Juan	558,000	320	6,600

Table XXXII
TRANSMISSION LINES
HYDROPOWER DEVELOPMENT

Line	Capacity (kv)	Length (miles)
Piedra to Pagosa Springs	115	25
East Fork to Pagosa Springs	115	13
Blanco to Pagosa Springs	115	10
Pagosa Springs to Trujillo	115	12
Trujillo to Gato	115	12
Gato to Navajo	115	30

Power Development

In the analysis of the potential power development, maximum utilization of the water was assumed. Studies were made on the basis of actual water supply records covering the period from 1931 through 1940. The critical dry period extending from July 1932 through April 1935 was used as the governing factor in routing water releases from the storage reservoirs in order to obtain an optimum production of electric energy from the project plants. The water releases were made on a monthly average availability basis and were so adjusted that all storage reservoirs would reach their dead storage level at approximately the same time and at the end of the critical low run-off period. Such a variation in releases from the various reservoirs would result in a maximum constant average energy output from the power system of 502.5 million kilowatt-hours annually throughout the critical dry period. This coordination of monthly reservoir releases was made as a basis for the design of the power features.

The plant capacities and their estimated average annual energy generation are summarized in the following table.

Table XXXIII
INSTALLED POWER PLANT CAPACITIES AND ENERGY GENERATION

Power plant	Installed capacity (Kilowatts)	Estimated average annual energy generation (Millions of kilowatt-hours)	
		Critical period	Average year
Trujillo	44,000	167.0	250.5
Piedra	40,000	185.6	179.0 1/
Gato	24,000	119.7	120.9
East Fork	7,500	18.2	28.0
Blanco	3,500	12.0	16.1
Total	119,000	502.5	594.5
Losses (8% of salable energy)		37.0	44.0
Salable energy available		465.5	550.5

1/ Average year less than critical year because of full utilization of hold-over storage during critical period.

The above estimates are based on over-all plant efficiencies of 80 percent, on the productive heads being equal to the average head on the plant by months, and on the corresponding estimated monthly water release through the plant.

By 1970 the annual load factor for the power market area was estimated to be approximately 55 percent. To supply an average annual firm load of 502.5 million kilowatt-hours at this load factor would require a peak capacity of 104,000 kilowatts. An allowance equal to the assumed capacity of the largest generating unit (15,000 kilowatts) was made for reserve capacity, making a total installed capacity of 119,000 kilowatts. On the above basis the system would supply its proportionate share of the peaking capacity required with a market area load factor of 55 percent. It is probable with a broad, integrated power system, however, that the peaking requirements would be supplied from some other source, such as the main-stem plants of the potential Colorado River Storage project. This would enable the comparatively small San Juan portion of the system to supply base load power to the area at a load factor much higher than 55 percent, but the value of the energy produced by the San Juan portion of the system would be somewhat lower than it would otherwise be.

Estimated Costs

Estimated construction and annual costs of the power development are summarized below.

Construction cost at July 1950 prices	$126,000,000
Annual costs	
Operation and maintenance	$430,000
Reserve for replacements	228,000
Amortization of construction costs over 50 years at 3 percent	4,899,000
Total annual costs	$5,557,000

The total annual costs would have to be paid with revenues received from the sale of the project energy. Although no estimate was made of the secondary energy that could be generated by the project plants, it was assumed that it could all be sold in this area at an average rate of 3.0 mills per kilowatt-hour. For this study, then, the revenue from the sale of secondary energy has been neglected, and the entire output from the project plants in an average hydro year (594.5 million kilowatt-hours) was assumed to be firm energy. After deductions were made for losses equal to 8 percent of the salable energy, an average annual firm energy output available for sale was obtained. Thus the salable firm electric energy of 550.5 million kilowatt-hours would annually cost an average of 10 mills per kilowatt-hour.

Value of Power

The value of power in the power market area was roughly computed by the Federal Power Commission's method from data contained in the Bureau's report entitled Power Market Survey--Colorado River Storage Project, dated February 1949. Fuel-electric plants at the principal load centers were considered as alternatives to the potential hydroelectric development. The cost of such alternative power at the high voltage side of the plants' substations, based on a 60-percent plant factor, was thus indicated to be around 7.5 to 8 mills per kilowatt-hour. The value of power in the market area as measured by the cost of this alternative power would therefore be less than the cost at present prices of producing power under the plan of upstream hydropower development, even excluding a major portion of the cost of transmitting the hydropower to load centers. On the basis of these estimates and comparison, development of the hydropower would be unjustifiable at the present time.

Power Market Area

Region 4 of the Bureau of Reclamation has studied the power market area in the States of the Upper Colorado River Basin that would be served with power from the Colorado River Storage project. The studies were based on information compiled by the Federal Power Commission and information obtained from other regions of the Bureau. Results of the studies are presented in the Bureau's report of February 1949, entitled Power Market Survey--Colorado River Storage Project.